Szczegółowa mapa geochemiczna Górnego Śląska

Detailed geochemical map of Upper Silesia

1:25 000

Arkusz
Sheet **PIEKARY ŚLĄSKIE**

Redaktorzy
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INTRODUCTION

Geochemical mapping at the scale of 1:25,000 for the map sheet Piekary Śląskie M-34-50-D-d is a continuation of detailed mapping work initiated in 1996–1999 by the pilot sheet Sławków M-34-63-B-b of the *Detailed Geochemical Map of Upper Silesia* (Lis, Pasieczna, 1999). By 2016, the Polish Geological Institute – National Research Institute (PIG-PIB) had developed 17 map sheets published in the form of separate atlases. All work was financed by the National Fund for Environmental Protection and Water Management after approval by the Ministry of the Environment (currently the Ministry of Climate and Environment).

The map sheet area is located in the northern part of the Upper Silesian Industrial District (USID, GOP in Polish), which is the most industrialized and urbanized region of Poland. Within its limits, there are districts of the towns of Piekary Śląskie, Bytom and Radzionków.

The main factors affecting the condition of the natural environment are as follows: historical and contemporary exploitation of hard coal deposits, historical mining and processing of Zn-Pb ores, zinc smelting, and contemporary lead recovery from acid-lead battery scrap at ZGH Orzeł Biały Company. Activities of these industries, most intensely developing in the 19th and 20th centuries, are associated with the appearance of anthropogenic anomalies of a number of elements in soils, stream and river sediments, and surface water (Lis, Pasieczna, 1995a, b; 1997). The most anthropogenically transformed area is the southern part of the map sheet, where numerous mining and metallurgical industries were located.

There are also valuable natural objects in the analyzed area. These include ponds in Radzionków and in the Grota Park in Sucha Góra (established in the area of the former Nadzieja Marii calamine mine), and the Żabie Doły nature and landscape complex at the southern border of the map sheet, created in 1997, and covering wasteland, water reservoirs and heaps. It has become a refuge for wetland birds and small mammals.

The results of geochemical research, presented in a cartographic form with an extensive commentary text and tabular summaries, show the status of quality of soils, sediments of inland water reservoirs and surface water, as well as a comparison to the natural regional background and applicable legal norms.

The collected information may be useful in giving opinions on local spatial development plans, conducting proceedings related to issuing decisions on environmental conditions and water law permits, assessing threats to the soil and water environment, and fulfilling the obligation imposed on the *starosts* by the Environmental Protection Law, i.e. conducting periodic tests of soil quality as part of state monitoring.

Digital version of the atlas is available at http://www.mapgeochem.pgi.gov.pl

The following persons participated in the implementation of the study:

- **A. Pasieczna** – research concept and project;
- **A. Konon** – supervision and coordination;
- **A. Biel, K. Górka, T. Kołecki, W. Markowski, A. Piotrowski, P. Woźniak** – sample collection;
- **K. Bala, T. Kołecki, A. Konon, W. Markowski, A. Pasieczna** – databases;
- **D. Karmasz, A. Maksymowicz, M. Stasiuk, A. Sztuczyńska –** management and coordination of analytical work;
- **Ł. Andrzejewski, M. Cichorski –** mechanical processing of samples for analysis;
- **M. Białecka, E. Kalwa –** chemical processing of samples for analysis;
- **J. Gąsior, B. Kamińska, M. Stasiuk –** organic carbon content determination using high-temperature combustion with IR detection;
- **M. Bellok, M. Białecka, E. Kalwa, A. Maksymowicz –** pH determination;
- **J. Duszyński, E. Górecka, D. Karmasz, D. Lech –** Hg content determination using the CV-AAS method;
- **W. Bureć-Drewniak, D. Karmasz, J. Kucharzyk, D. Lech, J. Retka –** determination of contents of major and trace elements using the ICP-OES and ICP-MS methods;
- **M. Cyglicki, A. Grabowska, A. Ilska, K. Szewczuk, A. Trojanowska** – grain-size analysis;
- **A. Konon, A. Pasieczna** – statistical calculations;
- **K. Bala, A. Konon, A. Pasieczna, A. Szczypczyk** – compilation of geochemical maps;
- **A. Pasieczna** – text preparation.

CHARACTERISTICS OF THE MAP AREA

Geographic and administrative location. The map sheet Piekary Śląskie M-34-50-D-d covers an area located in the Silesian Upland within a lower-order unit called the Bytom-Katowice Plateau (Kondracki, 2009).

The study area is located in the central part of Silesian Voivodeship: it is part of the Silesian urban-industrial agglomeration. Within its limits, there are districts of towns with poviat rights: Bytom (Sucha Góra, Stroszek, Śródmieście, the eastern ends of the Bobrek and Karb districts, and the northern part of the Szombierki and Rozbark districts) and Piekary Śląskie (districts: Kozłowa Góra, Centrum, Szarlej, Brzozowice-Kamień, Brzeziny, and parts of the Kamień and Dąbrówka Wielka districts). The northwestern part of the map sheet covers the area of the town of Radzionków, and the Radzionków commune (in the Tarnowskie Góry poviat), whereas the area at its eastern border is included in the Bobrowniki commune (in the Będzin poviat). At the southeastern limits of the map sheet, there are small areas of the town of Wojkowice in the Chorzów poviat and of the towns of Chorzów and Siemianowice Śląskie (Pls. 1–63).

Topography, geomorphology and hydrography. The map sheet area is located at an elevation of 270–330 m a.s.l. (in the Szarlejka Stream valley and in the Kozłowa Góra region, respectively); generally, it descends from north to south. It is characterized by a varied topography, especially strongly transformed in its southern part as a result of industrial activities.

The hydrographic network has undergone a strong transformation. Engineering of river channels resulted in the degradation of their valleys in the industrial and post-industrial areas. Most of the study area is located within the Brynica River drainage basin (part of the Vistula drainage basin). The southern part of the map sheet belongs to the Bytomka River drainage basin (part of the Odra drainage basin).

The eastern regions of the map sheet are drained directly by the Brynica River that is fed by the Świerklaniec Ditch in the north, the Szarlejka Stream and its tributaries in the central part, and the Orzeł Biały Ditch and Dąbrówka Wielka Ditch in the south.

Building and land use. Non-built-up and rural housing areas cover about 67% of the map sheet (Pl. 2). The non-built-up areas include predominantly wastelands scattered within the map sheet area, and arable fields that cluster in the north and east (Pl. 3). Significant part of the wasteland is represented by post-industrial and degraded areas, as well as those requiring revitalization. Large non-built-up areas also include forests and meadows in the northeastern margin of the map sheet, and forests and parks in the eastern buffer zone of Radzionków. Other non-built-up areas include roadside green belts, lawns and town parks, allotment gardens, and railway areas.

Residential, service (services and trade) and industrial areas are clustered in the southern part of the map sheet. Low-rise urban housing covers about 16% of the area, while industrial buildings occupy about 10% (infrastructure of hard coal mines, ZGH Orzeł Biały Company areas, metal plants, waste heaps, transport bases).

Economy. For many years, the most important industries in the map sheet area were the mining of zinc and lead ores, zinc smelting, and hard coal mining. Their most intense development took place in the 19th and 20th centuries. The beginnings of zinc and lead ore mining date back to the 12th century. Intense mining started in 1848 with the peak after World War II (Orzeł Biały...).

Shallow bodies of oxidized ores (calamines) were mined first, followed by sulfide ores that were mined starting from rich to poorer (Grzechnik, 1978). Unprofitable ores were left in the deposit or stored on the ground surface. After the development of technology and the improvement of the economic situation, secondary exploitation was undertaken. In the 13th and 14th centuries, ore mines were located in the vicinity of St. Małgorzata Hill (between today's streets of Małgorzatki and Łagiewnicka), as well as in the vicinity of Rycerska Street in Bytom. In the Sucha Góra district, galena was mined as early as in the 13th century, and later calamine was extracted in the Nadzieja Marii mine (area between the streets of 9 Maja, Galmanowa and Księdza Prymasa Stefana Wyszyńskiego), where the Grota Park is now located. In the 16th century, the mining was carried out in the Dąbrówka Wielka district, where a few tens of shafts were active, as well as in Radzionków and Szarlej (Majorczyk, 1985; 1986a, b). Most often, lead and silver were smelted on site from the mined ore.

The heyday of Zn-Pb ore mining after 1780 was associated with the use of steam engine to drain deposits and drill deep tunnels. Galena and calamine were mined at the beginning, limonite, associated mainly with weathered rocks filling karst sinkholes, was mined throughout the period of extraction. In 1788, the Dębówka mine was established, and the Jenny and Otto mines were opened in the 1890s. In the period 1810–1818, the Sigismund zinc smelter operated in Szarlej, equipped with 10 distillation furnaces, and the Concordia smelter was established near the calamine mines in 1813 (Majorczyk, 1986a, b).

Once the drainage was used in mines, the ores were extracted from greater and greater depths. However, the mining became costly and almost completely ceased in the 1750s.

The period of increased production of Zn-Pb ores and construction of zinc smelters restarted in the 19th century, when the appropriated technology was developed. Initially, the main raw material for zinc production was slag from lead smelting, subsequently calamine deposits, and finally Zn-Pb sulfide ores. In the years 1881–1978, near today's Nowy Dwór Street and the Bytom railway junction in Bytom, zinc and lead ores were mined by the Nowy Dwór mine (Nuehof, Neuhofgrube) (Kopalnia...). Due to depletion of the deposit, old mine heaps were exploited in 1960–1976. Currently, there are no traces of mine's buildings and shafts, and the A1 motorway runs through the area.

In the area of today's Piekary Śląskie, the Szarlej Biały zinc ore mine was opened in 1853 in the place of several previously existing mines. It operated under this name until 1934. Then, the Helena mine (later Waryński) was incorporated into it. The Szarlej Biały mine was constantly developing and it was one of the most modern ones in Upper Silesia at the beginning of the 20th century. In 1927–1928, a large flotation plant and a zinc smelter were built (Majorczyk, 1986b).

After World War II, Zn-Pb ore mining in the Bytom region was concentrated in four plants: ZGH Orzeł Biały in Brzeziny Śląskie (a district of Piekary Śląskie), J. Marchlewski mine in Bytom, Zakład Górniczo-Hutniczy Waryński in Piekary Śląskie, and Nowy Dwór mine in Bytom. In the late 1950s, administrative reorganization of these plants was made to form two mining and metallurgical complexes: Nowy Dwór was combined with Waryński, and ZGH Orzeł Biały with Marchlewski. In 1967, these plants were also combined to form the ZGH Orzeł Biały Mining and Metallurgical Plant, which exploited the deposits from a depth of 20–100 m (Zmiana...). As part of the Orzeł Biały mine, underground mining was carried out by the Dąbrówka mine in 1967–1989 (Krzanowska *et al*., 2004).

Currently, the ZGH Orzeł Biały Company (formerly Marchlewski) operates, comprising the Department of Battery Scrap Processing located in Bytom, and the Department of Metallurgy and the Lead Refinery in Piekary Śląskie in the areas of the former Orzeł Biały mine and zinc smelter. ZGH Orzeł Biały is the main producer of refined lead in Poland and the largest plant specializing in the recycling of used lead batteries. In 2011–2014, the largest investment program in the history of the plant was implemented, under which the modern Research and Development Centre and a technologically advanced line for processing battery scrap were built with the help of national and EU funds.

The following hard coal mines operated in the map sheet area: Radzionków, Julian, Andaluzja, Rozbark, Bytom, Szombierki and Bobrek. The Radzionków mine was active in the years 1871–1974 in the Buchacz district (Mrowiec, 1972; Krawczyk *et al*., 2002). The following mines operated in Piekary Śląskie: Andalusia in the Brzozowice-Kamień district (1903–2014) and Julian in the Centrum district (1954–1999) (Jaros, 1984). In Bytom, coal was mined in the Rozbark mine (1870–2004) (Witecka, 1985), Szombierki mine (1870–1996) (Jaros, 1984), and Bytom mine (1881– under decommissioning) (SRK, 2015). In the Bobrek mine, mining was carried out from 1907 (Węglokoks…). Currently, the KWK Bobrek-Piekary Ruch Piekary plant has been established through the merger of the Piekary and Bytom mines, where the mining is planned until around 2030 (Węglokoks…).

GEOLOGY AND MINERAL DEPOSITS

The map sheet area, located in the north of the Upper Silesian Coal Basin (USCB), is situated mostly within the structural unit called the Bytom Trough. It is part of a Paleozoic Variscan structure cut with numerous faults. Within the map sheet limits, there are Carboniferous, Permian, Triassic, Neogene and Quaternary deposits (Buła, Kotas, 1994).

The sub-Carboniferous basement is composed of the Malinowice Beds (Namurian A – Visean). These are terrigenous clastics with numerous levels of marine fossils, composed mainly of clay-silty rocks with interbeds of fine-grained sandstones.

The coal-bearing **Carboniferous** formations occur at a depth of approx. 200–1600 m. They form a complex of claystone-siltstone-sandstone rocks included in the Upper Carboniferous Paralic Series – Marginal Beds (Namurian A), the Upper Namurian Upper Silesian Sandstone Series (Namurian B and C), and the Lower Westphalian Mudstone Series (Westphalian B). These deposits are overlain by the Triassic, as well as by the Quaternary over large areas (Jureczka *et al*., 2005).

The Paralic Series deposits, which show sedimentary cyclicity, are composed of sandstones and clay-silty rocks with interbeds of thin coal seams, coal shales, and occasional sapropelic shales. These deposits were accumulated under terrestrial and coastal conditions, with periodic marine inundations, which is evidenced by the presence of marine fossils in the section, accompanied by numerous interbeds containing freshwater fossils. The maximum thickness of the Paralic Series in the axis of the Bytom Trough (Bytom-Rozbark region) is about 1300–1400 m, decreasing towards the north. Between Kozłowa Góra and the Wieczorka residential area in Piekary, these deposits form minor outcrops (Pl. 1).

The Upper Silesian Sandstone Series is represented by sandstones, conglomerates, mudstones and claystones containing hard coal seams. The section consists of two lithostratigraphic units – the Saddle Beds and Ruda Beds, overlying unconformably the Paralic Series (Kotas, Malczyk, 1972). These are limnic and deltaic formations. The topmost part of the Upper Silesian Sandstone Series is represented by the last level with freshwater fossils, accompanying the hard coal seams 407 and 408 – one of the most important correlation levels of the USCB (Dybova, Jachowicz, 1957). The section of this series includes approx. 60 hard coal seams (Jureczka, Kotas, 1995) attaining a thickness of approx. 4–8 m each. Currently, almost all coal seams have been depleted.

The Siltstone Series (100–150 m thick) is composed of siltstones, claystones and sandstones with numerous hard coal seams, up to 1.5 m thick. Its bottom part is represented by the Załęże Beds, corresponding to the Westphalian A in age, and the top part – Orzesze Beds, included in the lower part of the Westphalian B. The boundary between them is determined by a tuff marker horizon of seam 327 (Porzycki, 1972).

The overburden of Carboniferous deposits in a large part of the map sheet is represented by Lower and Middle **Triassic** deposits forming extensive, highly fragmented outcrops (Pl. 1). Their thickness, constrained by the tectonic setting and relief of the top Carboniferous surface, ranges from several tens of metres in the southern part of the research area to about 200 m in the eastern part (Buła, Kotas, 1994).

The Lower Triassic stratotype section (Świerklaniec Beds) is composed of sandstones, clays, claystones and siltstones. Their thickness ranges from several to over 40 m. In most of the map area, these beds are overlain by Middle Triassic carbonates, and minor outcrops are located in the Kozłowa Góra region and the Wieczorek residential area of Piekary Śląskie.

The complete Middle Triassic section occurs as a characteristic epicontinental facies with a thickness slightly exceeding 200 m, known as the Muschelkalk.

The Świerklaniec Beds are unconformably overlain by marine deposits that were formerly referred to as the Röt, composed of marly-dolomitic facies. These are dolomitic limestones, marly dolomites, dolomitic and sandy marls, and occasional cavernous limestones. The thickness of these deposits is variable and ranges from 30 to 50 m in the study area. Their extensive outcrops are found between Radzionków and the Centrum district of Piekary Śląskie.

The marly-dolomitic series is overlain by limestones assigned to the Błotnica Beds and the Gogolin Beds. The Błotnica Beds are represented by pelitic and fine-detrital limestones that, in the upper part of the section, contain numerous synsedimentary deformations in the form of folds and submarine landslides (so-called wavy limestones). In the lower part, the Gogolin Beds consist of a varied succession of limestones, marls, marly claystones and intraformational conglomerates. The total thickness of the Błotnica and the Gogolin Beds is in the range of 40–60 m.

The Gogolin Beds are overlain by a layer of ore-bearing dolomites, 20–40 m thick. These are epigenetic rocks that formed as a result of hydrothermal alteration of limestones, mainly of the Górażdże Beds and the Terebratula and Karchowice beds. The dolomites (and more rarely limestones) are crystallized to varying degrees. They are characterized by strong fracturing and the presence of irregular caverns, often filled with lead, zinc and iron minerals (galena, sphalerite, wurtzite, pyrite, marcasite). In the areas of outcrops of the Zn-Pb ore-bearing dolomites, metal sulfides oxidize and concentrate as calamines, often along with iron ores (limonites).

In the southern part of the map sheet, there are dolomites and limestones of the Jemielnica and Tarnowice beds, which attain a thickness of 30 m and approx. 20 m, respectively.

The **Neogene** deposits are composed of regoliths that accumulated mainly in karst sinkholes and chimneys developed at the top of Triassic carbonates, as well as of clays, silts, sands and marls representing sediments of a Miocene coastal zone. The karst sinkholes range from several to hundreds of metres in diameter. They are filled with loams, clays, sands and silts of variegated colours, as well as with limonite ores and calamines, which were the subject of intense exploitation in the 19th century in the area of Radzionków, Szarlej, Nowy Dwór, Brzeziny, the Szarlejka Stream valley, and the southeastern part of the map sheet.

Quaternary deposits occur either above the Middle Triassic formations or, in the southern part of the map sheet, above the Carboniferous rocks. Their extent and thickness increase towards the south.

The South Polish Glaciation deposits fill mainly the bottom of the fossil valley of the Bytomka River (in the southeast of the map sheet). These are glaciofluvial sands and gravels, ranging in thickness up to 25 m, as well as clays and ice-dammed lake muds, up to 10 m in thickness, most often covered with a till layer.

The deposits of Middle Polish glaciations are represented by clays and ice-dammed lake muds, up to 20 m thick, glaciofluvial sands and gravels, and tills that are not exposed on the surface. The glaciofluvial sands and gravels form covers of outwash plains in the western part of the map sheet and in the Brynica River valley.

The deposits of North Polish glaciations are composed of sands and gravels of overbank terraces of the Brynica River valley. They reach a thickness of 6–8 m.

The undivided Quaternary deposits consist of sands, tills and weathered (eluvial) muds, below 4 m in thickness, sands, muds and deluvial loams, as well as sands, gravels and deluvial-fluvial muds, with a thickness of 2–6 m, occurring in dry bottoms of valleys distributed across the entire map sheet area.

Holocene deposits occur only in the valleys of the Szarlejka Stream and Brynica River and minor watercourses. These are sands, gravels and muds of floodplain terraces, up to 8 m thick, and alluvial deposits of the valley bottoms (sandy muds with a large amount of humic substance).

In the southern part of the map sheet, there are clusters of heaps ranging in area from several to about 100 ha, which are remains left after long-time mining of hard coal, and iron, zinc and lead ores.

Mineral deposits. In the map sheet area, the following raw mineral deposits have been mined: hard coal, zinc and lead ores, iron ores, and rock raw materials – dolomites, clays and clay shales.

The first small **hard coal** mines were in operation already in the mid-19th century. Some of them were established in the place of mining plants that previously extracted calamine. In later years, these were among others: Radzionkaugrube (later Radzionków) mines – mining period 1863–1975, Heinitzgrube (Rozbark) – mining period 1870–1999, and Andalusiengrube (Andalusia) – mining period 1911–1999. Over the following years, the mines were subject to multiple combinations and they were changing their names (especially after World War II and in the 1990s). In the last 30 years, there have been significant changes related to the phasing out of hard coal mining and the closing down of several mines. Currently, mining activities are conducted by the KWK Bobrek-Piekary and the small mining plant EKO-PLUS.

In the central and southern parts of the map sheet, there are 19 hard coal deposits, falling within its limits to a varying degree. These are as follows: Powstańców Śląskich, Centrum-Szombierki, Rozbark, Bobrek-Miechowice, Andaluzja, Julian, Jowisz, Rozalia, Brzeziny, Bytom I, Bytom II, Bytom III, Piekary, Centrum, Bytom I-1, Bytom II-1, Barbara Chorzów 2, Powstańców Śląskich 1, and Centrum 1. Hard coal mining from the Bytom III deposit is significant and amounts to approx. 1 million t, from the Brzeziny deposit – approx. 0.9 million t, and from the Bytom I-1 deposit – about 0.15 million t (Szuflicki *et al*., 2020). Information on the parameters of the deposits and the quality parameters of the mineral resources is quoted after geological documentations of individual deposits and based on the system of management and protection of mineral resources (MIDAS).

As the hard coal resources became depleted and smaller deposits were documented within the boundaries of previously documented ones, their number and boundaries have been subject to frequent changes in recent years. Hard coal resources have been documented from a depth of 665 m (Powstańców Śląskich 1 deposit) to 1250 m (Barbara Chorzów 2 deposit) of categories A-C_2. The deposit bed consists of seams of the Orzesze Beds (group 300), Ruda Beds (400), Saddle Beds (500) and Paralic Beds (groups 800, 700 and 600 – Namurian A), ranging in thickness from 200 to 1000 m. In the study area, there are power coals (types 31+32, 33) and less frequent gas and coke coals (type 34). The thicknesses of single economic coal seams are varied and range from 1 to 10 m. The best quality coals are those from the Saddle Beds, containing the smallest amounts of ash and sulfur, and a relatively small amount of gangue overgrowths. They are also characterized by seams of considerable thicknesses.

The industrial resources in the study area are small (up to 16.3 million t) and documented only in four out of 19 deposits. The largest economic coal resources have been documented in the deposits of Centrum 1 (approx. 205.9 million t) and Centrum-Szombierki (approx. 170 million t).

In the 13th century, local **iron ore** deposits, mainly marcasites and limonites, were mineded (Majorczyk, 1986).

The **zinc and lead ore** deposits in the Triassic Bytom Trough are of historical importance (Molenda, 1960, 1972). The depleted deposits were hosted in Triassic ore-bearing dolomites and were among the world's largest and richest Zn-Pb ore deposits (Szuwarzyński, 1996; Paulo, Strzelska-Smakowska, 2000). The Zn-Pb ore deposits are no longer listed in the national balance of mineral resources (Szuflicki *et al*., 2020); however, some amounts of zinc, lead and accompanying elements remain at high concentrations in dolomites and in several dumps, although they are insufficient for industrial extraction. The resources of the only Zn-Pb ore deposit of Dąbrówka Wielka are 363,000 t and are non-economic. The zinc content is 4.2% and the lead content is 1.2% in the ore.

In the map sheet area, two deposits of **clay raw materials** for construction ceramics have been documented: the Bytom-Centrum deposit of Triassic clays and clay shales, and the Kozłowa Góra II deposit of Carboniferous clay shales. These are stratiform deposits of simple geological structure, which occupy a small area. Exploitation of the Bytom-Centrum deposit (average thickness 17.1 m, acreage about 0.78 ha), documented within the Triassic clays, was abandoned in the 1960s. The Kozłowa Góra II deposit (18.0–27.7 m in thickness) remains undeveloped.

In the southern part of the map sheet, within the Middle Triassic, the Rozbark deposit of **road and construction stones**, 5–39 m thick, is documented over an area of approx. 3.16 ha. The main mineable mineral is dolomite accompanied by Quaternary clays and sands. Even though the license has been issued, extraction of the deposit is not undertaken (Szuflicki *et al*., 2020).

HUMAN IMPACT

Most of environmental problems in the study area are a consequence of industrial activity and urbanization leading to changes in the landscape and hydrographic network, and to soil, sediment and water pollution. Vast areas in the southern and southwestern parts of the map sheet, where the mining of Zn-Pb ores and hard coal was concentrated, were subjected to local subsidence by several meters due to ductile deformations of the area. Near-surface extraction of metal ores and hard coal caused discontinuous deformations in the form of depressions, sinkholes and crevices. These deformations sometimes become active as a result of mining carried out in the underlying coal seams.

Atmospheric air. According to the air quality assessment, the map sheet area is included in class C, where the concentrations of pollutants in the air exceed the permissible levels. Particularly threatened by air pollution are clusters of furnace-heated small houses, forming areas of the so-called low emission of PM10, PM2.5 dusts and benzo(a)pyrene (Stan…, 2017, 2020). These components also get into the air as a result of the activity of heating stations (MPEC, Julian, Osiedlowa and Orzeł Biały in Piekary) and local and industrial boiler houses, as well as from communication sources. The most important sources of air dust pollution in Piekary Śląskie are the MPEC heating plants (19 Gen. Ziętka Street, Andaluzja II, Julian, Olimpia and Transmasz) (Aktualizacja..., 2011). Gaseous pollutants are emitted by the above-mentioned boiler houses and by the Department of Metallurgy, ZGH Orzeł Biały.

According to the annual air quality assessment carried out by the Provincial Inspectorate of Environmental Protection (WIOŚ), the major gas pollutant is carbon dioxide in the study area, which accounts for 98.1% of the total gas emissions in the Silesian Voivodeship. Methane, carbon monoxide and sulfur dioxide also play a significant role as pollutants (Stan…, 2017, 2020). Most nitrogen dioxide emissions come from different types of transport.

Emissions of organic compounds (including aromatic hydrocarbons and solvents, formaldehyde, phenol) and heavy metals come from industrial plants of various sectors. Emission of odours is detected mainly around sewage treatment plants, and municipal and industrial waste landfills.

The study results on the amount of fall of particulate matter, and contents of arsenic, cadmium, lead, zinc and thallium in it, do not exceed standard levels.

Surface water and groundwater. Large amounts of underground mine water are introduced into surface water (Kropka, Respondek, 2000). For many years, waters containing significant amounts of zinc, cadmium and lead ions have been discharged, resulting in the increased concentrations of these metals in river sediments. On the other hand, underground waters in hard coal mines are in many cases excessively contaminated with chloride and sulfate ions (Aktualizacja…, 2011, 2012). In recent years, comprehensive programs of water and sewage management have been implemented, which should result in a reduction in the pollution load to surface water.

Pollutants affecting the quality of surface waters also penetrate into groundwater in the Quaternary, Triassic and Carboniferous formations.

The Quaternary aquifer system has been degraded as a result of drainage activities of hard coal mines, historic mining of Zn-Pb ores, and infiltration of rainwater collecting atmospheric and surface pollutants. The Triassic aquifer system is uncovered or partially overlain by Quaternary formations, and recharged by rainwater infiltration directly in areas of outcrops and through permeable Quaternary deposits (Razowska-Jaworek, Brodziński, 2016). The recharge also occurs by infiltration of waters from the Brynica and Szarlejka rivers. The water table of the Carboniferous aquifer system has been degraded and lowered due to mining drainage.

The main Triassic groundwater reservoirs in the western part of the map sheet are the Bytom Groundwater Basin (GZWP No. 329) and the Gliwice Groundwater Basin (GZWP No. 330), whose boundary zone runs near Radzionków. The waters of the Gliwice Groundwater Basin have been polluted with trichlorethane and tetrachloroethane by the Chemical Company Tarnowskie Góry (Szadkowska, Gwóźdź, 2015).

Soils. In areas of waste heaps of hard coal and Zn-Pb ore mining, zinc smelting, and limestone mining, as well as of municipal solid waste landfills, soils have undergone strong anthropogenic alterations and their profile is very often not fully developed. Their natural components are mixed with foreign materials, often reworked and dried many times. Due to the presence of numerous industrial and post-industrial facilities, as well as intense urbanization, agricultural soils occur in very small areas of the eastern and central parts of the map sheet, and in allotment gardens.

Research on the chemical condition of soils was carried out as part of regional monitoring. It showed pollution of the soils (Program ...) due to historical exploitation and smelting of Zn-Pb ores, iron smelting and waste dispersion, the discharges of mine waters and sewage treatment waters, as well as dust emissions from industrial plants and transportation means. The use of mining waste in the reclamation of post-industrial areas and road and water construction sometimes contributes to the spread of pollutants penetrating into the soil.

Landfills. In the southern part of the map sheet area, large amounts of post-mining waste (gangue from Zn-Pb ore and hard coal mining, and tailings from the processing of ores, coal sludge and other sludge) and waste from the industry (zinc smelting slag) are stored. Post-mining waste from coal mines is characterized by a low content of substances aggressive to the natural environment. Therefore, they are used for engineering, levelling, backfilling and the production of building materials.

The post-mining and metallurgical heaps located west of Brzeziny and Brzozowice reach heights of up to 30 m (Aktualizacja…, 2011). There are also subsidence troughs, up to several meters deep, and sinkholes in this area. Over the past few years, old heaps have been dismantled and the waste has been processed into building aggregates in the areas of Zn-Pb ore mining and zinc smelting. At the same time, these places have been filled with wastes brought from outside (many of them represents residues from the sorting of municipal sludge) without the required permits (Biuletyn…, 2014). In the area of one of the sealed workings, copper foundry sludge is stored, and in the area of the former Huta Waryński zinc smelter, there is a lead-bearing sludge storage yard (Aktualizacja…, 2011). Some of the heaps have been dismantled or reclaimed, but the operating plants constantly enforce the necessity to manage the waste from thermal processes, construction industry, and sewage treatment processes. Chemical erosion and drainage from landfills plays a significant role in environmental degradation causing acidification to facilitate migration of metals (Bauerek *et al*., 2017). The material gathered on waste heaps is characterized by accumulation of such elements as As, Cd, Pb, Tl and Zn, contained both in Zn-Pb ore minerals and in secondary mineral phases (Cabała, 1996, 2009; Cabała, Teper, 2007). During a long storage period, there is a release and migration of these elements in soluble compounds that are a threat to the natural environment.

In Szarlej south of the Szarlejka River and west of road 911, an unlined municipal landfill operated from the 1950s to 2006 (Aktualizacja…, 2011). After reclamation (including the putting of a sealing layer on the top, covering the slopes with a soil layer, biogas intake, and water drainage), a section of the A1 motorway was built in the vicinity.

Discharges of sewage and underground mine water. Sewage and underground mine waters are discharged to the Brynica and Bytomka rivers through a system of ditches and tributaries. Mine waters discharged to these rivers contain concentrations of chlorides, sulfates and suspensions, which exceed the permissible levels for sewage discharged into waters. Significant sources of pollution in the Brynica River are wastewater from the Północ sewage treatment plant (Wieczorka residential area) and the Brzózka treatment plant (Brzozowice-Kamień district), and waters from the Szarlejka Stream, Ditch from Orzeł Biały, and Ditch from Dąbrówka Wielka. Sanitary sewage from the western part of Piekary Śląskie is discharged into the Bytomka River.

MATERIALS AND METHODS

The research carried out in 2017–2021 comprised the study of published and archived materials, designation of soil sampling sites on topographic maps at the scale of 1 : 10,000, soil, sediment and surface water sampling, measurements of geographic coordinates at sampling sites, measurements of pH and specific electrolytic conductivity of surface water in the field, chemical analysis of samples, development of field and laboratory databases, statistical calculations of the results of chemical analyses, construction of the topographic base map, construction of the geological map and geochemical maps, and interpretation of research results. The workflow sequence is illustrated in the attached diagram (Fig. 1).

FIELD WORKS

Soil samples were collected on a regular grid 250×250 m (16 samples/km^2). The locations of sampling sites are marked in maps showing both the built-up areas and land use (Pls. 2–3). In total, 1325 samples were taken from a depth of 0.0–0.3 m and 1207 samples from a depth of 0.8–1.0 m. In the case of a shallower depth to the bedrock, a 20 cm-thick sample was collected from just above the bedrock. Soil samples (approx. 500 g), collected with a hand auger, 60 mm in diameter, were placed in canvas bags labeled with appropriate numbers, and pre-dried on wooden pallets in a field storage facility.

Sediment and surface water samples (301 and 297 samples, respectively) were collected from rivers, streams, ditches, canals, lakes, settling tanks, and ponds. The distance between the sampling sites on watercourses was approx. 250 m. The sampling points of surface water and sediments are presented in plates showing chemical elements content in these environmental elements, starting from plates 7 and 9, respectively. Sediment samples weighing approx. 500 g (and of the finest possible fraction) were taken from the banks of water bodies using the aluminum scoop and placed in 500 ml plastic containers, marked with appropriate numbers.

Surface water samples were collected from the same sites where sediment samples were taken. Electrolytic conductivity of water (EC) and its pH were measured in the field. For EC measurements, a conductometer with automatic temperature compensation was used, assuming the reference temperature of 25°C. Water samples were filtered in the field using 0.45 µm Milipore filters, and after filling 30 ml bottles, acidified with nitric acid. The bottles were labeled with appropriate numbers.

The sampling sites of all samples were marked on topographic maps at the scale of 1 : 10,000 and labeled with appropriate numbers.

The locations of sampling sites were determined by GPS, using a device that enables not only to measure geographic coordinates but also to record additional information (pH and EC values of water, data on the housing area, land use, and lithology of samples). The measurement of coordinates was recorded with an accuracy of ±2–10 m. Before going into the field, the network of coordinates of the sampling sites was entered into the GPS device memory. Subsequent sampling sites were searched in the field using the satellite navigation method. For greater security, all field data were also recorded on specially prepared cards (Fig. 2).

LABORATORY WORKS

The preparation of samples for testing, determination of physicochemical parameters, and chemical analyses were performed at the Polish Geological Institute's chemical laboratory.

Sample preparation. After delivery to the laboratory, the soil samples were dried at room temperature and sieved through 2 mm-mesh nylon sieves. After sieving and quartering, each soil sample from the depth of 0.0–0.3 m was divided into three sub-samples: one for chemical analysis, the second for granulometric analysis, and the third for archival purposes, while each soil sample from the depth of 0.8–1.0 m was divided into two sub-samples: one for chemical analysis and the other for archival purposes (Fig. 1). Soil samples designated for chemical analyses were ground in agate ball mills to the <0.06 mm fraction.

The sediment samples were dried at room temperature and then sieved through 0.2 mm-mesh nylon sieves. After quartering, the <0.2 mm fraction was divided into two sub-samples: one for chemical analysis and the other for archival purposes (Fig. 1).

The archival samples have been stored at the Polish Geological Institute – National Research Institute in Warsaw.

Chemical analyses. Digestion of the soil and sediment samples was performed in aqua regia (1g of sample to a final volume of 50 ml) for 1 hour at 95°C in a thermostated aluminum block.

Determinations of the Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Ni, P, Pb, S, Sr, Ti, V and Zn contents in soils and sediments were made using *Inductively Coupled Plasma Atomic Emission Spectrometry* (ICP-OES). Analyses of the Hg content in soil and sediment samples were carried out using *Cold Vapor Atomic Absorption Spectrometry* (CV-AAS). The soil pH was determined by the potentiometric method in the H_2O suspension, and the determination of organic carbon content (TOC) in soil – by the high-temperature combustion method with IR detection.

Determination of the B, Ba, Ca, Cr, Fe, K, Mg, Mn, Na, P, SiO_2, SO_4, Sr, Ti and Zn contents in surface water was carried out using the ICP-OES method, while ICP-MS *Inductively Coupled Plasma-Mass Spectrometry* was used to find out the contents of Ag, Al, As, Be, Cd, Co, Cu, Li, Mo, Ni, Pb, Sb, Se, Tl, U and V.

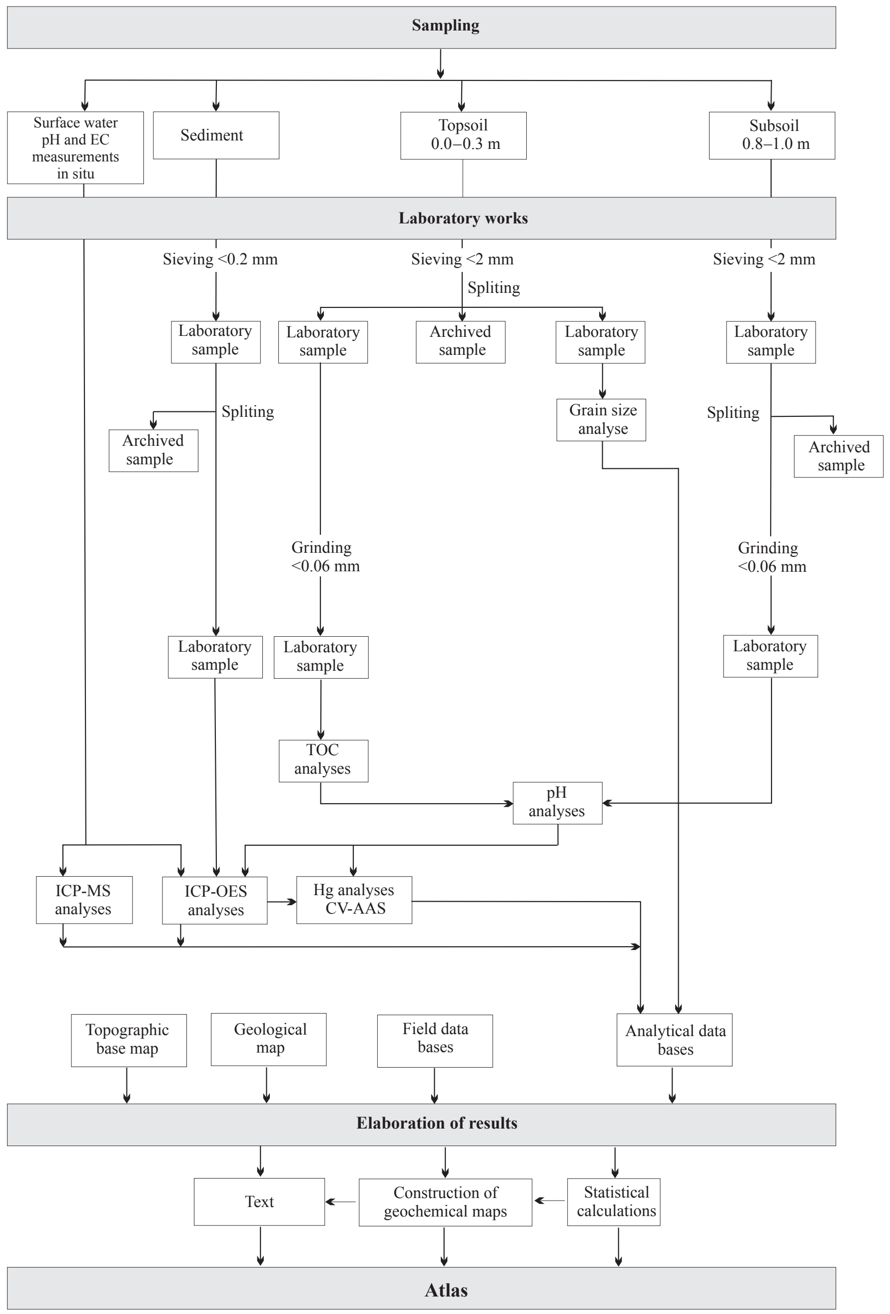

Fig. 1. Scheme of the work performed

The summary of analytical methods and detection limits of the elements is presented in Table 1.

The quality control of the determinations was carried out by analyzing duplicate samples (5% of the total number of samples), reference materials with certified content of the tested elements (2% of the total number of samples), and internal control samples confirming the correct performance of instrumental measurements (5% of the total number of samples). The purity of the reagents and vessels was controlled using "reagent blank samples" and "procedure blank samples".

The expanded uncertainty of the results (at the assumed probability level 95%, and the coverage factor k = 2) for the water, soil and sediment samples does not exceed 25%, except for the expanded uncertainty for the mercury content in the soil and sediment samples, and the organic carbon content in the soil samples, which is 30%.

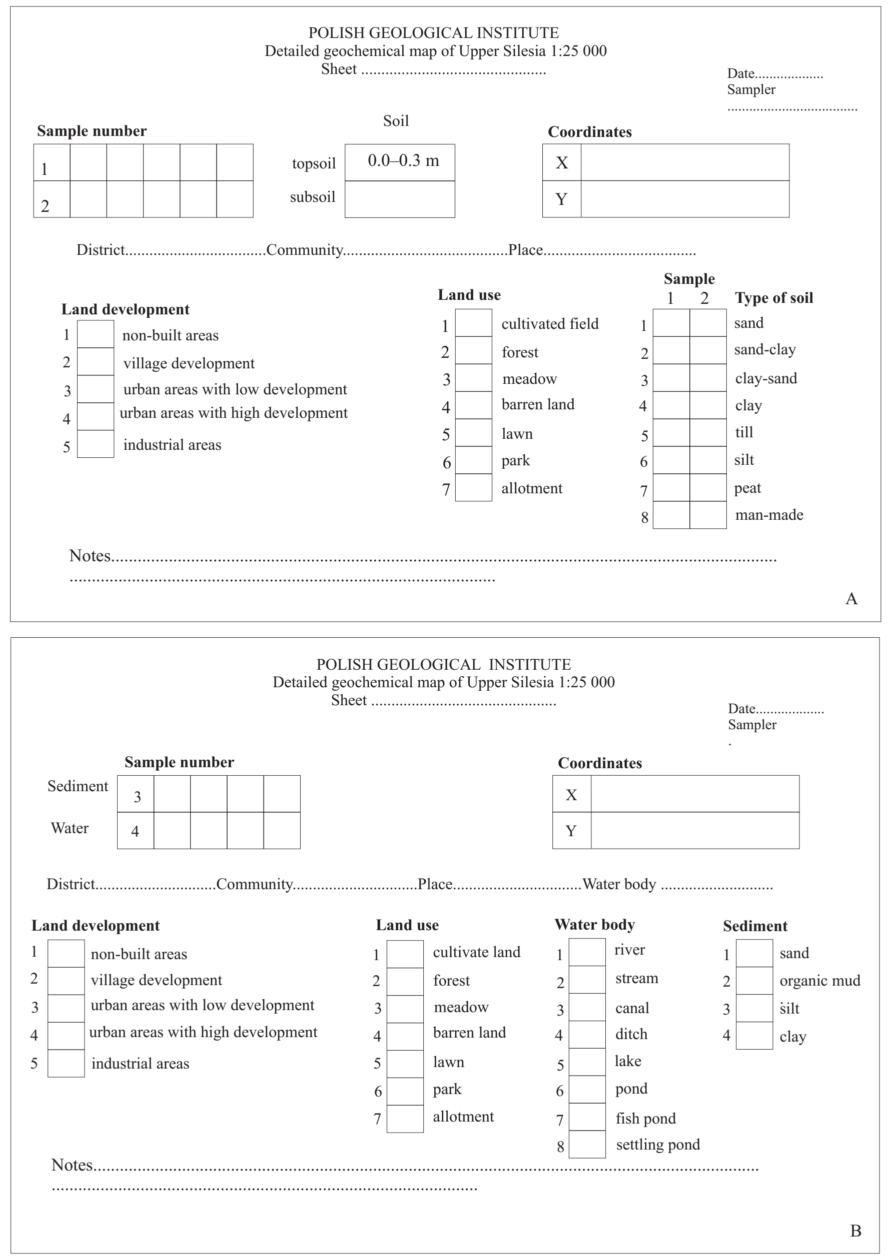

Fig. 2. Sampling cards of soils (A) as well as sediments and surface water (B)

Granulometric analyses of soils from the depth of 0.0–0.3 m were performed at the at the PIG's laboratory in Warsaw. The grain composition was analyzed with the sieve method in accordance with the instruction for the development of geochemical maps and the guidelines of the PN-R-04033 and BN-78/9180-11 standards.

After the organic matter had been oxidized (with hydrogen peroxide), the samples were sieved through a column of sieves of the following mesh sizes: 1 mm; 0.1 mm; 0.02 mm, and the obtained fractions of 2–1 mm, 1.0–0.1 mm and <0.02 mm were weighed.

Results of the grain-size analyses (converted into percentages) are presented on the maps of grain-size classes: 1.0–0.1 mm sand fraction, 0.1–0.02 mm silt fraction, and <0.02 mm clay fraction (Pls. 4–6).

DATABASES AND GEOCHEMICAL MAPS CONSTRUCTION

Topographic base map. The most recent 1 : 50,000 scale topographic map in the *1992* coordinate system, map sheet Bytom M-34-50-D (VMap L2 vector data), was used for the construction of the 1 : 25,000 geochemical maps. The topographic map contains the following vector information layers:
- topography;
- hydrography (subdivided into rivers, streams, ditches and stagnant water reservoirs);
- road communication network (by class);
- railway network;
- housing areas (subdivided into rural, urban and industrial housing);
- forests;
- industrial areas (industrial facilities, mine workings, heaps and settling tanks).

Geological map. To illustrate the geological structure of the study area, the 1 : 50,000 *Detailed Geological Map of Poland* was used, Bytom M-34-50-D sheet (Biernat, 1954; updated by Wilanowski, Lewandowski, 2016). The vector images of the map sheet that were developed as a result of digitization were combined with the topographic base map to construct a geological map at the scale of 1 : 25,000 (Pl. 1).

Databases. Separate databases (spreadsheets) have been created for:
- soils from the depth of 0.0–0.3 m (topsoil);
- soils from the depth of 0.8–1.0 m (subsoil);
- sediments;
- surface water.

The soil databases contain the following information: sample numbers, results of coordinate measurements at sampling sites, record of field observations (housing area type, land use, soil type, sampling site location: poviat, commune, locality), date and name of the sampling person, and results of chemical analyses.

The databases of sediments and surface water comprise the following information: sample numbers, results of coordinate measurements at sampling sites, record of field observations (housing area type, land use, water body type, sediment type, administrative location of sampling site: poviat, commune, locality), date and name of the sampling person and the results of chemical analyses.

The sheet data are placed in separate tables (for soils, sediments and surface water) of the professional geodatabase of the Central Geological Database (CBDG) functioning in the *Oracle* software. These tables were used to compile single-element geochemical maps in *ArcGIS 10.6*. Descriptive data (metadata), results of chemical analyses of samples, and geometric data that make up the graphic part of the study are stored in the geodatabase.

Statistical calculations. The results stored in the databases were used to extract subsets for statistical calculations according to various environmental criteria, for example, the contents of elements in soils of industrial areas, forest soils, and urban soils, and in sediments and waters of individual streams and reservoirs, as well as for the construction of geochemical maps. The calculations of statistical parameters were performed (using the *Statistica* software) for both the entire datasets and subsets for soils, sediments and surface water. Once the content of elements was below the determination limit of the method, the content equal to half of the detection limit of the given analytical method was assumed for statistical calculations. The arithmetic mean, geometric mean, median, and minimum and maximum values were calculated. These data for individual elements and indicators are summarized in Tables 2–5 and are presented on geochemical maps (Pls. 7–62).

When interpreting the results, the calculated median values were used as a measure of the geochemical background of individual elements. The median is a statistical parameter that better characterizes the content compared to the arithmetic mean, as it is less affected by extreme values. Other statistical parameters (variance, standard deviation) are not suitable for characterizing a population of undefined distribution.

Construction of maps. The following maps were developed for the Piekary Śląskie sheet (Pls. 2–63):
- built-up area;
- land use;
- contents of organic carbon and sand, silt and clay fractions in soils from 0.0–0.3 m depth (topsoil);
- pH in soils from 0.0–0.3 depth (topsoil) and 0.8–1.0 m depth (subsoil);
- contents of Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, Mg, Mn, Ni, P, Pb, S, Sr, Ti, V and Zn in soils from the depths of 0.0–0.3 m and 0.8–1.0 m and in sediments;
- pH and EC and contents of Ag, Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, SO_4, Sb, Se, SiO_2, Sr, Ti, Tl, U, V and Zn in surface water;
- classification of cadmium-polluted soils from 0.0–0.3 m depth, and the indication of their proper use.

The geochemical maps were compiled using ESRI's *ArcGIS 10.6* software suitable for mapping and spatial data development. The program allows creating new maps or modifying the existing ones, analyzing and visualizing spatial data, and managing them in geodatabases.

The built-up area, land use types and the distribution of elemental contents in sediments and surface water are presented in the form of point maps.

To demonstrate the distribution of grain classes in soils, their pH, and content of chemical elements, the isoline map construction was chosen due to its transparency and readability. The isoline geochemical maps were generated using the deterministic *Inverse Distance Weighted* (IDW) method. The method that allows obtaining a result for a given grid by averaging the values from the nearest points, and the closer points have a greater effect on the interpolated value. This effect is expressed as the reciprocal of the distance of a given point, raised to the exponent set by the performer. The advantage of the method is the determination of the distance from which points are taken into account in the interpolation process.

Maps of the distribution of grain classes, soil's pH, and elemental contents in soils have been constructed based on the set of chemical analyses for the Bytom, Piekary Śląskie, Tarnowskie Góry and Świerklaniec sheets at the scale of 1 : 25,000. One spatial analysis of the sheets was performed for each map to prevent discrepancies at their boundaries. The resulting single-element maps were combined with the topographic base within the boundaries of a given sheet.

The grain classes of soils were selected taking into account the values of calculated statistical parameters of their content in the area of the above-mentioned four sheets. The soil pH was presented according to the scale adopted in soil science (acidic, neutral and alkaline soils). The spatial distribution of selected soil elements is presented with the use of geometric progression to determine the distribution classes.

The geochemical maps of sediments of water bodies and surface water were separately prepared for the Piekary Śląskie sheet. They are constructed in the form of pie-chart maps, assigning the respective pie-chart diameters to individual content classes, usually arranged in a geometric progression.

When preparing the exemplary classification map of topsoils (Pl. 63), which indicates the proper way of their use due to pollution with cadmium, the results of geochemical investigations were compared to the values of permissible con-

Tabela 1
Table 1

Metody analityczne i granice wykrywalności

Analytical methods and detection limits

Pierwiastek/ związek Element/ compound	Metoda analityczna Analytical method	Jednostka Unit	Granica wykrywalności Detection limit	Metoda analityczna Analytical method	Jednostka Unit	Granica wykrywalności Detection limit
	Gleby, osady Soils, sediments			Wody powierzchniowe Surface water		
Ag	ICP-OES	mg/kg	1	ICP-MS	µg/dm^3	0,05
Al	ICP-OES	%	0,01	ICP-MS	µg/dm^3	0,5
As	ICP-OES	mg/kg	3	ICP-MS	µg/dm^3	2
B				ICP-OES	mg/dm^3	0,01
Ba	ICP-OES	mg/kg	1	ICP-OES	mg/dm^3	0,001
Be				ICP-MS	µg/dm^3	0,05
C_{org} (TOC)	*	%	0,02			
Ca	ICP-OES	%	0,01	ICP-OES	mg/dm^3	0,1
Cd	ICP-OES	mg/kg	0,5	ICP-MS	µg/dm^3	0,05
Co	ICP-OES	mg/kg	1	ICP-MS	µg/dm^3	0,05
Cr	ICP-OES	mg/kg	1	ICP-OES	mg/dm^3	0,003
Cu	ICP-OES	mg/kg	1	ICP-MS	µg/dm^3	0,05
Fe	ICP-OES	%	0,01	ICP-OES	mg/dm^3	0,01
Hg	CV-AAS	mg/kg	0,02			
K				ICP-OES	mg/dm^3	0,5
Li				ICP-MS	µg/dm^3	0,3
Mg	ICP-OES	%	0,01	ICP-OES	mg/dm^3	0,1
Mn	ICP-OES	mg/kg	2	ICP-OES	mg/dm^3	0,001
Mo				ICP-MS	µg/dm^3	0,05
Na				ICP-OES	mg/dm^3	0,5
Ni	ICP-OES	mg/kg	1	ICP-MS	µg/dm^3	0,5
P	ICP-OES	%	0,002	ICP-OES	mg/dm^3	0,05
Pb	ICP-OES	mg/kg	2	ICP-MS	µg/dm^3	0,05
S	ICP-OES	%	0,003			
Sb				ICP-MS	µg/dm^3	0,05
Se				ICP-MS	µg/dm^3	2
SiO_2				ICP-OES	mg/dm^3	0,1
SO_4				ICP-OES	mg/dm^3	1
Sr	ICP-OES	mg/kg	1	ICP-OES	mg/dm^3	0,003
Ti	ICP-OES	mg/kg	5	ICP-OES	mg/dm^3	0,002
Tl				ICP-MS	µg/dm^3	0,05
U				ICP-MS	µg/dm^3	0,05
V	ICP-OES	mg/kg	1	ICP-MS	µg/dm^3	1
Zn	ICP-OES	mg/kg	1	ICP-OES	mg/dm^3	0,003

ICP-OES – emisyjna spektrometria atomowa ze wzbudzeniem w plazmie indukcyjnie sprzężonej
Inductively Coupled Plasma Atomic Emission Spectrometry
ICP-MS – spektrometria mas z jonizacją w plazmie indukcyjnie sprzężonej
Inductively Coupled Plasma-Mass Spectrometry
CV-AAS – absorpcyjna spektrometria atomowa z generowaniem zimnych par rtęci
Cold Vapour Atomic Absorption Spectrometry
* – wysokotemperaturowe spalanie z detekcją IR
high temperature combustion with IR detection

Parametry statystyczne zawartości pierwiastków chemicznych i odczynu gleb (0,0–0,3 m)

Statistical parameters of chemical elements contents and acidity of topsoils (0.0–0.3 m)

Tabela 2
Table

Gleby Soils	Parametry Parameters	Ag mg/kg	Al %	As mg/kg	Ba mg/kg	C_{org} %	Ca %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe %	Hg mg/kg	Mg %	Mn mg/kg	Ni mg/kg	P %	Pb mg/kg	S %	Sr mg/kg	Ti mg/kg	V mg/kg	Zn mg/kg	pH
Granica wykrywalności Detection limit		1	0,01	3	1	0,02	0,01	0,5	1	1	1	0,01	0,02	0,01	2	1	0,002	2	0,003	1	5	1	1	
Gleby ogółem Soils as a whole n = 1325	a	<1	0,06	<3	<1	0,03	<0,01	<0,5	<1	<1	2	0,02	<0,02	<0,01	3	<1	<0,002	6	<0,003	1	6	1	10	4,14
	b	91	3,09	11 735	1036	49,66	26,36	1906,9	50	447	5777	35,57	5,49	8,16	16 751	389	1,080	54 940	11,800	536	1424	720	93 378	11,05
	c	2	0,79	104	187	4,07	1,70	22,4	6	19	61	2,17	0,14	0,58	864	18	0,055	1007	0,204	44	130	23	3086	7,37
	d	<1	0,73	23	152	2,91	0,73	8,6	5	16	28	1,64	0,09	0,29	589	14	0,044	334	0,054	30	107	20	1108	7,32
	e	<1	0,75	18	154	2,75	0,76	8,2	6	15	25	1,59	0,09	0,25	581	14	0,047	304	0,040	30	101	21	1031	7,49
Tereny bez zabudowy Non-built-up areas n = 832	a	<1	0,06	<3	<1	0,05	<0,01	<0,5	<1	<1	2	0,02	<0,02	<0,01	3	1	<0,002	6	<0,003	1	6	1	10	4,14
	b	91	3,09	11 735	936	34,53	26,36	1906,9	41	447	5777	24,37	2,27	8,16	16 751	389	0,570	54 940	11,800	373	1424	142	93 378	11,05
	c	2	0,81	133	172	3,76	1,67	25,3	7	17	66	2,22	0,12	0,60	865	18	0,049	1166	0,257	37	117	23	3336	7,18
	d	<1	0,74	22	140	2,61	0,56	8,4	5	14	25	1,59	0,08	0,25	549	14	0,040	322	0,050	24	95	20	985	7,12
	e	<1	0,78	16	147	2,45	0,44	8,1	6	15	21	1,51	0,08	0,20	544	14	0,044	279	0,033	23	92	21	904	7,32
Tereny z zabudową wiejską Village areas n = 51	a	<1	0,18	4	67	1,04	0,08	1,3	1	3	6	0,29	<0,02	0,03	83	3	0,017	69	0,016	6	33	5	156	6,04
	b	5	1,78	147	1036	19,10	8,04	37,3	14	29	135	3,41	0,39	4,79	2062	38	0,156	1116	0,193	333	562	41	4262	9,19
	c	<1	0,69	20	184	3,02	1,10	9,4	5	14	29	1,41	0,08	0,43	512	13	0,051	299	0,043	39	117	19	998	7,56
	d	<1	0,64	14	151	2,50	0,64	7,1	5	12	22	1,23	0,06	0,24	430	12	0,045	237	0,035	25	96	17	749	7,54
	e	<1	0,69	13	142	2,25	0,77	7,2	5	13	20	1,27	0,06	0,22	447	12	0,046	237	0,036	20	92	18	850	7,58
Tereny z zabudową miejską niską Low-block urban areas n = 213	a	<1	0,23	<3	24	0,03	0,13	<0,5	2	3	6	0,41	<0,02	0,04	108	3	0,009	11	<0,003	7	36	5	22	5,72
	b	16	1,57	1693	1010	15,00	11,82	277,0	20	272	398	13,34	0,79	5,95	16 130	74	0,520	7536	2,390	338	1423	136	35 972	9,53
	c	1	0,77	56	230	4,17	1,90	17,1	6	23	45	2,00	0,13	0,55	943	18	0,069	633	0,096	60	153	24	2718	7,70
	d	<1	0,73	27	190	3,43	1,27	9,8	6	18	33	1,72	0,09	0,36	719	16	0,059	387	0,059	46	130	22	1543	7,67
	e	<1	0,73	24	205	3,44	1,43	9,2	6	17	33	1,67	0,09	0,34	716	15	0,057	363	0,055	49	127	21	1551	7,72
Tereny z zabudową miejską wysoką Tower-block urban areas n = 108	a	<1	0,14	<3	31	0,61	0,10	0,6	2	6	9	0,52	<0,02	0,08	104	6	0,012	49	0,015	5	46	3	168	6,07
	b	26	1,42	794	802	15,17	6,35	204,0	13	170	224	5,98	1,94	3,40	3208	45	0,260	10 070	2,520	186	472	70	21 388	9,39
	c	1	0,69	41	196	3,38	1,36	13,4	5	22	40	1,73	0,16	0,41	759	15	0,072	554	0,093	43	139	21	1822	7,76
	d	<1	0,66	21	168	2,87	1,02	6,7	5	18	31	1,54	0,10	0,29	618	13	0,058	291	0,053	37	129	19	1105	7,74
	e	<1	0,68	18	169	3,02	1,02	5,8	4	16	28	1,45	0,09	0,26	574	13	0,053	268	0,044	39	130	19	985	7,73
Tereny przemysłowe Industrial areas n = 121	a	<1	0,09	<3	15	0,72	0,06	<0,5	<1	2	4	0,16	<0,02	0,02	30	2	0,003	14	0,011	4	22	4	55	6,58
	b	43	2,54	1663	792	49,66	11,50	300,7	50	202	2467	35,57	5,49	5,42	6664	97	1,080	45 808	2,290	536	668	720	36 451	9,58
	c	2	0,80	80	204	7,12	2,14	25,9	7	25	84	2,79	0,31	0,68	961	22	0,055	1273	0,196	65	174	31	4034	7,68
	d	<1	0,74	28	166	5,05	1,35	10,8	7	20	44	2,16	0,13	0,44	742	19	0,041	439	0,093	49	144	24	1652	7,66
	e	<1	0,75	24	170	5,10	1,61	11,4	7	20	38	2,01	0,13	0,42	714	18	0,042	399	0,085	49	130	24	1599	7,68
Pola uprawne Cultivated fields n = 121	a	<1	0,19	<3	38	0,33	0,04	<0,5	<1	3	5	0,28	<0,02	0,03	57	2	0,014	12	0,005	5	25	5	45	4,95
	b	15	1,71	111	546	18,18	7,06	75,6	23	38	116	6,05	0,46	3,16	4325	53	0,570	1714	0,280	124	369	45	10 516	8,11
	c	<1	0,82	19	156	2,21	0,62	9,7	6	14	19	1,43	0,09	0,26	630	13	0,057	293	0,029	21	93	21	1128	7,14
	d	<1	0,78	15	145	1,97	0,35	7,3	5	13	17	1,30	0,07	0,18	535	11	0,052	235	0,025	18	87	20	771	7,12
	e	<1	0,81	14	145	1,96	0,30	7,2	5	13	18	1,31	0,07	0,16	522	12	0,052	235	0,025	17	92	20	766	7,20
Lasy Forests n = 129	a	<1	0,06	<3	18	0,39	<0,01	<0,5	<1	<1	2	0,02	<0,02	<0,01	3	<1	<0,002	11	0,004	1	6	1	10	4,14
	b	12	2,56	493	881	29,10	26,36	160,8	23	447	124	21,39	1,43	6,97	16 751	176	0,250	7826	0,830	338	560	84	24 817	9,62
	c	<1	0,75	27	191	4,29	1,20	13,2	6	18	24	1,99	0,12	0,31	1032	15	0,039	513	0,059	37	107	22	1858	6,39
	d	<1	0,66	14	146	3,05	0,22	5,3	4	12	17	1,15	0,08	0,12	351	9	0,029	249	0,033	17	82	17	516	6,29
	e	<1	0,71	13	159	3,01	0,21	6,3	5	13	17	1,31	0,08	0,12	455	11	0,033	250	0,032	17	84	19	599	6,43
Łąki Meadows n = 35	a	<1	0,28	4	67	1,02	0,07	1,3	1	4	6	0,25	0,02	0,02	38	2	0,013	61	0,013	6	16	6	117	5,48
	b	2	1,72	124	430	21,15	5,44	38,7	16	36	167	5,45	0,34	2,03	3100	29	0,218	1256	0,265	57	156	62	5020	8,63
	c	<1	0,78	20	176	3,13	0,87	7,7	6	14	21	1,62	0,09	0,33	618	12	0,063	261	0,050	20	72	22	994	6,84
	d	<1	0,71	14	158	2,56	0,38	5,5	5	12	16	1,29	0,07	0,16	428	10	0,052	192	0,038	17	65	19	598	6,79
	e	<1	0,73	11	172	2,46	0,30	5,0	5	13	15	1,41	0,06	0,14	477	10	0,049	170	0,032	14	66	19	508	6,79
Nieużytki, ugory Barren lands n = 519	a	<1	0,08	<3	<1	0,05	0,03	<0,5	<1	2	2	0,16	<0,02	0,02	28	2	0,003	6	<0,003	3	17	2	23	5,00
	b	91	3,09	11 735	1010	49,66	19,66	1906,9	50	202	5777	35,57	5,49	8,16	16 130	389	1,080	54 940	11,800	536	1424	720	93 378	11,05
	c	4	0,81	212	180	5,17	2,38	36,9	8	21	106	2,81	0,18	0,83	972	23	0,051	1845	0,419	52	143	26	5075	7,50
	d	<1	0,74	30	139	3,30	1,06	10,4	6	17	37	2,01	0,10	0,40	654	18	0,040	422	0,088	36	113	22	1417	7,46
	e	<1	0,77	20	147	3,13	1,14	10,0	6	17	31	1,79	0,10	0,34	606	17	0,042	353	0,064	37	101	22	1179	7,57

Tabela 2 cd.
Table 2 cont.

Gleby Soils	Parametry Parameters	Ag mg/kg	Al %	As mg/kg	Ba mg/kg	C_{org} %	Ca %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe %	Hg mg/kg	Mg %	Mn mg/kg	Ni mg/kg	P %	Pb mg/kg	S %	Sr mg/kg	Ti mg/kg	V mg/kg	Zn mg/kg	pH
	a	<1	0,40	5	79	1,64	0,10	1,5	1	5	7	0,44	<0,02	0,03	24	3	0,016	72	0,017	7	27	8	194	5,71
Ogródki działkowe	b	19	2,45	1209	1036	19,10	4,71	64,1	14	48	583	6,44	0,40	2,26	3606	72	0,280	2077	0,280	373	562	51	13 071	9,19
Allotments	c	2	0,97	70	330	5,64	1,45	14,4	8	21	67	2,47	0,15	0,49	904	22	0,074	632	0,071	76	166	27	2306	7,60
n = 44	d	<1	0,91	32	276	4,74	1,05	11,0	7	19	45	2,17	0,12	0,34	716	19	0,064	465	0,060	53	140	25	1751	7,58
	e	<1	0,86	28	292	4,93	1,17	11,6	7	19	43	2,09	0,14	0,34	745	20	0,063	445	0,053	51	129	24	1918	7,68
	a	<1	0,38	6	61	0,69	0,22	1,7	3	8	8	0,77	<0,02	0,06	244	6	0,017	57	0,010	9	65	11	269	6,31
Parki	b	7	1,81	705	906	9,38	19,00	145,3	12	43	97	4,17	0,57	2,08	1635	38	0,100	5535	1,830	206	520	59	25 343	8,05
Parks	c	1	0,79	76	236	3,62	2,03	22,4	6	17	34	1,83	0,16	0,42	670	17	0,048	738	0,149	45	134	22	3359	7,42
n = 22	d	<1	0,74	33	180	2,83	0,99	12,1	5	15	27	1,66	0,11	0,28	599	15	0,044	422	0,052	34	116	21	1800	7,41
	e	<1	0,75	28	178	3,07	0,85	10,1	6	16	28	1,65	0,11	0,26	598	17	0,046	447	0,049	30	109	22	1623	7,48
	a	<1	0,14	<3	23	0,03	0,10	<0,5	1	3	6	0,34	<0,02	0,04	104	3	0,008	11	<0,003	5	38	3	22	5,72
Trawniki	b	26	1,55	925	660	15,17	16,63	277,0	20	272	398	8,40	1,94	7,76	10 577	74	0,520	10 070	2,520	257	1423	136	35 972	9,53
Lawns	c	1	0,72	44	199	3,60	1,78	15,5	6	22	40	1,83	0,13	0,57	842	16	0,063	568	0,092	50	148	22	2234	7,77
n = 322	d	<1	0,68	23	168	3,02	1,19	8,5	5	18	31	1,60	0,09	0,36	666	14	0,052	340	0,055	39	128	20	1313	7,74
	e	<1	0,70	21	173	3,09	1,31	7,7	5	16	29	1,57	0,09	0,32	642	14	0,052	316	0,051	42	124	20	1222	7,77
	a	<1	0,06	<3	18	0,07	<0,01	<0,5	<1	<1	2	0,02	<0,02	<0,01	3	<1	<0,002	11	0,004	1	16	1	10	4,23
Gleby piaszczyste	b	14	1,47	2454	595	12,34	26,36	245,5	14	45	294	15,40	1,07	6,38	11 949	43	0,520	7856	8,790	154	387	83	55 460	8,95
Sandy soils	c	<1	0,69	41	162	2,68	0,88	14,8	5	12	25	1,46	0,10	0,29	653	12	0,050	501	0,091	25	89	18	1818	7,00
n = 334	d	<1	0,64	16	138	2,20	0,33	7,6	4	11	18	1,14	0,07	0,15	436	10	0,042	267	0,031	18	81	16	803	6,96
	e	<1	0,68	15	140	2,20	0,30	7,7	5	12	17	1,24	0,07	0,13	484	10	0,046	257	0,028	17	83	17	824	7,06
	a	<1	0,15	<3	21	0,30	0,02	<0,5	<1	4	4	0,25	<0,02	0,02	17	2	0,007	22	0,004	3	10	6	44	4,20
Gleby gliniaste	b	17	1,94	11 735	587	7,82	19,00	388,8	33	74	1169	24,37	0,46	7,59	4321	389	0,570	54 940	8,410	105	307	62	38 010	8,87
Clay soils	c	<1	0,86	80	155	2,45	1,10	15,7	6	16	27	1,80	0,10	0,46	709	16	0,051	889	0,097	22	89	23	1763	7,02
n = 302	d	<1	0,82	17	142	2,16	0,41	7,5	5	14	19	1,47	0,08	0,23	522	13	0,044	265	0,031	18	83	21	754	6,97
	e	<1	0,84	15	147	2,23	0,33	6,9	6	14	18	1,44	0,08	0,18	525	13	0,047	241	0,028	18	88	22	777	7,18
	a	<1	0,44	7	88	2,47	0,02	1,2	<1	7	7	0,33	0,07	0,04	27	3	0,018	61	0,033	4	6	11	71	4,14
Gleby torfiaste	b	<1	1,71	48	443	34,53	1,34	19,3	16	29	54	5,45	0,30	0,29	1089	30	0,218	749	0,388	68	92	53	1080	6,44
Peaty soils	c	<1	1,07	25	307	13,07	0,50	8,0	7	17	22	2,23	0,18	0,12	361	15	0,097	317	0,167	26	42	31	489	5,45
n = 13	d	<1	0,97	21	288	9,13	0,32	6,0	5	15	19	1,68	0,16	0,10	205	13	0,083	256	0,122	21	37	28	381	5,41
	e	<1	0,85	23	319	10,12	0,41	6,3	7	13	24	2,16	0,15	0,11	269	13	0,091	245	0,095	19	40	26	382	5,48
	a	<1	0,08	<3	<1	0,03	0,03	<0,5	<1	2	3	0,16	<0,02	0,02	28	2	0,003	6	<0,003	3	17	2	22	5,01
Gleby antropogeniczne	b	91	3,09	7105	1036	49,66	19,66	1906,9	50	447	5777	35,57	5,49	8,16	16 751	264	1,080	46 667	11,800	536	1424	720	93 378	11,05
Man-made soils	c	3	0,80	148	211	5,31	2,41	29,5	7	24	94	2,68	0,18	0,78	1047	22	0,058	1323	0,309	64	169	26	4355	7,75
n = 676	d	<1	0,74	31	162	3,74	1,44	9,7	6	19	41	2,05	0,10	0,45	737	18	0,046	416	0,089	48	140	23	1576	7,72
	e	<1	0,75	24	172	3,76	1,56	9,5	6	18	36	1,93	0,10	0,41	694	18	0,047	363	0,072	49	136	23	1527	7,75
Tło geochemiczne; geochemical background																								
Gleby Europy [1] Soils of Europe n = 837	e	0,27	5,82	6	65	1,73	0,92	0,15	7	22	12	1,96	0,04	0,46	524	14	0,055	15	0,023	89	3420	33	48	7,7
Gleby Polski [2] Soils of Poland n = 10 840	e	<1		<5	32		0,18	<0,5	2	4	5	0,51	<0,05	0,06	217	4	0,034	13	0,012	8	26	7	35	6,1
Gleby regionu śląsko-krakowskiego [3] Soils of Cracow-Silesia Region n = 1564	e	<1		<5	54		0,22	1,3	3	5	7	0,63	0,08	0,07	257	5	0,030	44	0,015	10	28	9	104	6,7
Dopuszczalne zawartości pierwiastków powodujących ryzyko [4]; permissible levels of elements causing the risk																								
I grupa; group I				25	400			2	50	200	200		5			150		200					500	
II grupa; group II				10–50	200–600			2–5	20–50	150–500	100–300		2–5			100–300		100–500					300–1000	
III grupa; group III				50	1000			10	100	500	300		10			300		500					1000	
IV grupa; group IV				100	1500			15	200	1000	600		30			500		600					2000	

a – minimum; minimum; b – maksimum; maximum; c – średnia arytmetyczna; arithmetic mean; d – średnia geometryczna; geometric mean; e – mediana; median; n – liczba próbek; number of samples; [1] Salminen, 2005; [2] Lis, Pasieczna, 1995a; [3] Lis, Pasieczna, 1995b; [4] Rozporządzenie Ministra Środowiska, 2016

Parametry statystyczne zawartości pierwiastków chemicznych i odczynu gleb (0,8–1,0 m)

Statistical parameters of chemical elements contents and acidity of subsoils (0.8–1.0 m)

Tabela 3
Table

Gleby Soils	Parametry Parameters	Ag mg/kg	Al %	As mg/kg	Ba mg/kg	Ca %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe %	Hg mg/kg	Mg %	Mn mg/kg	Ni mg/kg	P %	Pb mg/kg	S %	Sr mg/kg	Ti mg/kg	V mg/kg	Zn mg/kg	pH
Granica wykrywalności Detection limit		1	0,01	3	1	0,01	0,5	1	1	1	0,01	0,02	0,01	2	1	0,002	2	0,003	1	5	1	1	
Gleby ogółem Soils as a whole n = 1207	a	<1	0,07	<3	<1	<0,01	<0,5	<1	<1	1	0,03	<0,02	<0,01	4	<1	<0,002	2	<0,003	1	8	<1	10	4,77
	b	97	3,22	7330	3508	22,83	697,3	96	307	4900	28,34	11,41	11,87	34 587	173	0,500	50 610	12,310	764	1494	132	94 904	9,73
	c	2	0,79	84	126	2,36	15,3	7	17	43	2,15	0,09	0,91	923	18	0,033	722	0,206	38	118	21	2644	7,67
	d	<1	0,68	12	77	0,51	2,8	5	13	16	1,37	0,04	0,27	415	12	0,023	124	0,022	19	95	17	469	7,64
	e	<1	0,73	11	76	0,46	2,8	5	14	16	1,46	0,04	0,23	489	13	0,026	123	0,018	19	93	19	455	7,76
Tereny bez zabudowy Non-built-up areas n = 774	a	<1	0,07	<3	<1	<0,01	<0,5	<1	<1	1	0,04	<0,02	<0,01	4	<1	<0,002	2	<0,003	1	8	<1	10	4,77
	b	97	2,99	7330	3508	22,83	697,3	96	307	4900	28,34	2,29	11,11	34 587	173	0,500	50 610	12,310	535	1494	125	94 904	9,73
	c	2	0,80	106	108	2,36	16,1	7	17	49	2,27	0,07	0,96	975	19	0,030	816	0,253	31	110	21	2722	7,53
	d	<1	0,67	11	64	0,38	2,1	5	13	14	1,33	0,03	0,25	363	12	0,020	97	0,018	14	87	16	350	7,49
	e	<1	0,73	9	59	0,25	1,6	5	14	14	1,45	<0,02	0,21	417	13	0,021	78	0,012	12	86	19	272	7,63
Tereny z zabudową wiejską Village areas n = 49	a	<1	0,08	<3	12	0,02	<0,5	<1	1	2	0,03	<0,02	<0,01	7	<1	0,003	5	<0,003	1	27	1	16	5,82
	b	<1	1,28	41	518	18,15	14,1	13	74	40	3,26	0,37	9,64	1521	31	0,110	558	0,081	210	632	41	2548	8,92
	c	<1	0,60	9	93	2,55	3,0	5	12	12	1,10	0,04	1,12	360	11	0,025	107	0,016	28	96	16	422	7,86
	d	<1	0,53	6	60	0,39	1,4	3	9	9	0,79	0,02	0,21	220	8	0,019	54	0,012	13	78	12	207	7,84
	e	<1	0,60	7	62	0,24	1,4	4	11	10	1,10	0,02	0,14	306	9	0,023	60	0,004	9	75	16	244	7,90
Tereny z zabudową miejską niską Low-block urban areas n = 198	a	<1	0,15	<3	16	0,03	<0,5	<1	3	2	0,15	<0,02	0,03	35	2	0,004	3	<0,003	3	20	4	20	6,67
	b	13	1,85	1146	731	17,28	183,8	23	46	1049	17,79	3,37	8,56	15 689	70	0,160	7902	4,480	306	640	69	39 277	9,31
	c	<1	0,78	39	149	2,19	13,9	6	16	30	2,04	0,10	0,75	925	16	0,042	484	0,079	46	122	21	2581	7,91
	d	<1	0,72	16	103	0,78	5,0	5	14	18	1,52	0,05	0,31	585	13	0,034	205	0,025	28	107	19	876	7,89
	e	<1	0,73	16	99	0,86	5,6	5	14	19	1,60	0,06	0,27	615	14	0,034	230	0,026	30	103	20	980	7,94
Tereny z zabudową miejską wysoką Tower-block urban areas n = 94	a	<1	0,25	<3	14	0,07	<0,5	1	2	3	0,33	<0,02	0,02	94	2	0,006	5	<0,003	3	33	3	30	6,27
	b	31	1,51	636	1308	17,14	248,1	15	130	150	6,46	0,75	9,84	3216	42	0,190	16 170	5,570	378	449	51	26 425	9,30
	c	1	0,75	30	194	1,87	11,9	5	17	28	1,57	0,12	0,58	675	14	0,044	534	0,113	54	144	21	1757	8,01
	d	<1	0,71	17	144	1,10	5,1	5	15	22	1,40	0,08	0,31	548	13	0,037	215	0,040	37	131	19	845	8,00
	e	<1	0,73	16	148	1,12	5,3	5	13	21	1,37	0,08	0,27	536	12	0,037	222	0,039	42	130	18	904	8,05
Tereny przemysłowe Industrial areas n = 92	a	<1	0,26	<3	8	0,04	<0,5	<1	4	2	0,24	<0,02	0,04	25	3	0,004	9	<0,003	3	24	5	28	5,57
	b	31	3,22	1279	931	20,64	225,8	15	265	577	10,91	11,41	11,87	8227	74	0,230	13 070	3,800	764	919	132	34 005	9,50
	c	2	0,85	91	176	3,06	22,4	7	22	53	2,53	0,25	1,12	1035	20	0,041	963	0,275	69	169	25	4210	7,91
	d	<1	0,75	23	122	1,28	7,3	6	17	28	1,82	0,08	0,47	647	16	0,030	289	0,071	43	128	21	1217	7,89
	e	<1	0,71	18	133	1,58	8,3	6	16	29	1,88	0,08	0,44	675	18	0,032	276	0,070	59	120	21	1336	7,93
Pola uprawne Cultivated fields n = 249	a	<1	0,07	<3	14	0,01	<0,5	<1	<1	2	0,04	<0,02	<0,01	9	<1	0,003	2	<0,003	1	18	<1	10	4,96
	b	3	2,24	470	1732	22,83	115,4	96	71	53	20,93	0,50	11,11	34 587	100	0,130	3500	0,120	276	1494	97	20 922	9,02
	c	<1	0,84	16	76	2,24	5,0	6	15	13	1,74	0,04	1,08	749	17	0,025	168	0,011	20	100	21	802	7,60
	d	<1	0,71	7	51	0,28	1,1	4	12	9	1,13	0,03	0,22	298	11	0,018	56	0,006	10	83	16	199	7,58
	e	<1	0,75	7	46	0,15	0,8	4	13	10	1,17	0,03	0,16	327	11	0,018	45	0,006	9	82	17	139	7,57
Lasy Forests n = 122	a	<1	0,09	<3	10	<0,01	<0,5	<1	2	1	0,05	<0,02	<0,01	4	<1	<0,002	3	<0,003	1	18	1	10	4,86
	b	97	2,99	366	683	18,49	419,8	31	129	435	17,31	0,59	7,07	19 541	79	0,230	30 300	1,390	498	785	125	18 426	9,70
	c	2	0,72	20	86	0,99	9,9	5	15	18	1,94	0,06	0,33	1187	14	0,024	567	0,037	24	108	18	1450	7,03
	d	<1	0,58	6	49	0,10	1,2	3	10	8	0,88	0,03	0,11	209	8	0,013	54	0,010	8	87	12	175	6,96
	e	<1	0,63	4	36	0,06	<0,5	4	10	7	0,92	0,02	0,09	196	7	0,012	32	0,007	6	85	13	92	7,13
Łąki Meadows n = 34	a	<1	0,13	<3	15	0,02	<0,5	<1	1	1	0,08	<0,02	0,01	11	<1	0,003	4	<0,003	2	19	2	17	5,53
	b	3	1,94	162	260	6,32	48,0	17	54	31	9,89	0,14	2,79	3088	118	0,150	3764	0,150	37	303	63	50 909	8,16
	c	<1	0,74	13	82	0,60	4,5	6	14	10	1,57	0,03	0,28	563	15	0,032	222	0,019	11	79	18	2049	7,08
	d	<1	0,58	5	62	0,16	0,9	4	10	7	0,87	0,02	0,11	208	7	0,022	46	0,011	7	63	13	170	7,04
	e	<1	0,55	4	58	0,12	<0,5	4	10	6	0,87	<0,02	0,09	211	7	0,023	36	0,009	7	71	11	114	7,12

Tabela 3 cd.
Table 3 cont.

Gleby Soils	Parametry Parameters	Ag mg/kg	Al %	As mg/kg	Ba mg/kg	Ca %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe %	Hg mg/kg	Mg %	Mn mg/kg	Ni mg/kg	P %	Pb mg/kg	S %	Sr mg/kg	Ti mg/kg	V mg/kg	Zn mg/kg	pH
Nieużytki, ugory Barren lands n = 444	a	<1	0,08	<3	<1	0,01	<0,5	<1	1	1	0,03	<0,02	<0,01	7	<1	<0,002	4	<0,003	1	7	1	21	4,77
	b	82	3,22	7330	1308	20,64	697,3	72	307	4900	28,34	11,41	11,87	15 689	173	0,500	50 610	12,310	764	919	132	94 904	9,65
	c	3	0,80	179	134	3,04	25,3	8	19	80	2,74	0,12	1,16	1025	21	0,035	1293	0,469	46	126	23	4413	7,70
	d	<1	0,69	19	83	0,82	4,2	6	15	23	1,75	0,05	0,38	522	15	0,025	188	0,047	25	95	19	711	7,66
	e	<1	0,75	13	85	0,88	3,8	6	16	22	1,81	0,06	0,33	563	17	0,026	176	0,038	32	93	21	575	7,77
Ogródki działkowe Allotments n = 43	a	<1	0,33	<3	20	0,06	<0,5	1	5	3	0,40	<0,02	0,06	54	4	0,006	9	<0,003	4	41	7	37	6,92
	b	8	2,79	290	1099	12,25	175,2	20	183	258	17,79	0,60	6,55	11 310	60	0,340	7976	0,430	535	399	69	29 002	9,73
	c	1	1,01	32	184	1,52	15,5	7	21	32	2,74	0,09	0,59	1206	19	0,045	744	0,046	50	127	25	2814	7,81
	d	<1	0,89	15	116	0,55	4,7	6	16	20	1,84	0,05	0,26	668	15	0,034	217	0,021	26	108	21	790	7,80
	e	<1	0,87	15	94	0,40	4,6	6	14	18	1,81	0,05	0,23	655	16	0,033	188	0,020	21	105	22	737	7,81
Parki Parks n = 22	a	<1	0,24	4	16	0,03	<0,5	<1	6	3	0,54	<0,02	0,01	32	3	0,006	17	<0,003	4	42	8	41	6,20
	b	2	2,32	366	369	14,38	177,3	16	42	50	8,93	0,27	8,27	2620	57	0,070	4642	0,150	137	258	58	26 868	8,51
	c	<1	0,94	36	103	2,37	17,6	6	17	20	1,90	0,07	0,64	682	18	0,033	422	0,031	38	117	22	2577	7,68
	d	<1	0,81	17	80	0,59	4,8	5	14	14	1,46	0,04	0,22	451	13	0,028	151	0,016	22	104	19	804	7,67
	e	<1	0,80	14	95	0,50	5,5	5	13	15	1,31	0,04	0,20	556	12	0,028	150	0,016	18	99	18	785	7,76
Trawniki Lawns n = 293	a	<1	0,22	<3	12	0,03	<0,5	<1	2	2	0,15	<0,02	0,02	25	2	0,003	3	<0,003	2	20	3	16	5,72
	b	41	1,70	2196	3508	18,15	248,1	94	130	1121	11,92	3,37	9,84	25 120	163	0,280	16 170	5,570	378	640	66	39 277	9,47
	c	1	0,73	42	171	2,31	12,4	6	17	29	1,68	0,10	0,80	824	15	0,041	471	0,101	49	131	20	2074	8,00
	d	<1	0,68	15	113	0,91	4,9	5	13	19	1,35	0,05	0,33	521	12	0,032	187	0,031	30	114	18	778	7,99
	e	<1	0,71	16	122	1,07	5,3	5	13	19	1,40	0,06	0,28	558	12	0,034	205	0,032	34	111	19	905	8,03
Gleby piaszczyste Sandy soils n = 328	a	<1	0,07	<3	8	<0,01	<0,5	<1	<1	1	0,03	<0,02	<0,01	4	<1	<0,002	2	<0,003	1	15	<1	10	4,96
	b	7	2,32	1385	345	20,64	161,6	18	42	123	10,66	0,22	11,76	4499	57	0,160	3750	5,960	103	632	52	34 130	9,31
	c	<1	0,49	14	45	0,51	3,2	3	8	8	0,83	0,02	0,25	270	6	0,016	124	0,039	8	81	10	540	7,38
	d	<1	0,43	4	34	0,08	0,7	2	6	5	0,55	<0,02	0,07	129	5	0,011	34	0,005	5	71	8	101	7,35
	e	<1	0,43	3	30	0,07	<0,5	2	6	5	0,55	<0,02	0,07	132	4	0,011	25	0,005	5	74	9	72	7,47
Gleby gliniaste Clay soils n = 440	a	<1	0,11	<3	2	0,01	<0,5	<1	4	2	0,14	<0,02	0,02	29	2	0,003	4	<0,003	2	11	3	21	4,77
	b	7	2,88	7330	1732	22,83	419,8	96	71	435	21,91	0,59	11,87	34 587	118	0,150	30 300	9,530	276	1494	125	50 909	9,02
	c	<1	0,98	51	100	3,05	11,7	8	19	21	2,40	0,06	1,38	1075	21	0,032	550	0,082	27	97	26	1823	7,62
	d	<1	0,88	12	73	0,63	2,6	6	16	15	1,76	0,04	0,39	528	16	0,026	112	0,014	17	83	22	454	7,58
	e	<1	0,90	11	72	0,34	2,4	6	15	15	1,70	0,04	0,27	528	16	0,027	100	0,014	15	85	23	417	7,75
Gleby antropogeniczne Man-made soils n = 434	a	<1	0,09	<3	<1	0,05	<0,5	<1	3	5	0,22	<0,02	0,04	57	3	0,003	6	<0,003	4	14	4	35	5,57
	b	82	3,22	4286	3508	19,37	697,3	93,7	307	4900	28,34	11,41	9,13	25 120	173	0,500	50 610	12,310	764	919	132	94 904	9,73
	c	3	0,82	170	212	3,06	28,4	7,8	22	92	2,90	0,17	0,96	1270	23	0,048	1357	0,456	71	168	25	5094	7,97
	d	1	0,75	31	147	1,70	8,9	6,5	18	37	2,14	0,09	0,51	795	19	0,037	373	0,094	52	137	23	1564	7,95
	e	<1	0,76	22	161	1,90	8,5	6,4	17	33	1,91	0,09	0,42	730	19	0,038	317	0,071	54	133	23	1451	8,02

a – minimum; b – maksimum; c – średnia arytmetyczna; d – średnia geometryczna; e – mediana; n – liczba próbek;
minimum; maximum; arithmetic mean; geometric mean; median; number of samples

Parametry statystyczne zawartości pierwiastków chemicznych w osadach

Statistical parameters of chemical elements contents in sediments

Tabela Table **4**

Osady Sediments	Parametry Parameters	Ag mg/kg	Al %	As mg/kg	Ba mg/kg	Ca %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe %	Hg mg/kg	Mg %	Mn mg/kg	Ni mg/kg	P %	Pb mg/kg	S %	Sr mg/kg	Ti mg/kg	V mg/kg	Zn mg/kg
Granica wykrywalności Detection limit		1	0,01	3	1	0,01	0,5	1	1	1	0,01	0,02	0,01	2	1	0,002	2	0,003	1	5	1	1
Osady (wszystkie próbki) Sediments (all samples) n = 301	a	<1	0,02	<3	1	0,03	<0,5	<1	<1	<1	0,05	<0,02	0,01	20	<1	<0,002	6	0,009	1	<5	<1	24
	b	138	2,35	2974	967	33,66	9695,0	131	471	8056	37,61	9,15	7,13	23 810	1307	0,902	27 190	13,780	1925	493	62	69 330
	c	2	0,73	109	161	3,26	63,8	9	25	137	2,78	0,31	0,63	1407	31	0,115	1163	0,588	97	98	20	4938
	d	1	0,61	30	123	1,40	12,7	7	19	45	2,11	0,15	0,34	692	20	0,074	430	0,264	46	83	18	1714
	e	<1	0,65	26	127	1,23	11,7	7	19	40	2,09	0,14	0,34	631	20	0,075	394	0,246	39	88	19	1469
Strumienie i rowy bez nazwy Streams and ditches (without a name) n = 98	a	<1	0,05	<3	1	0,03	1,0	<1	2	2	0,28	<0,02	0,01	35	3	0,003	27	0,019	2	<5	2	123
	b	138	2,35	2974	575	16,30	9695,0	49	88	1539	37,61	1,11	7,13	23 810	475	0,530	27 190	13,780	434	458	57	69 330
	c	3	0,75	140	182	1,89	125,0	8	22	68	2,85	0,19	0,29	1403	30	0,113	1353	0,529	40	86	20	3870
	d	<1	0,63	32	138	0,90	14,1	6	19	38	2,09	0,12	0,31	633	21	0,082	408	0,175	29	71	18	1493
	e	<1	0,65	23	162	0,79	11,4	7	19	33	1,99	0,12	0,29	618	20	0,083	317	0,146	30	73	20	1165
Jeziora Lakes n = 34	a	<1	0,02	<3	7	0,14	<0,5	<1	<1	<1	0,05	<0,02	0,07	20	<1	<0,002	6	0,009	1	6	<1	24
	b	12	1,27	1057	336	14,29	232,3	50	37	7922	19,86	0,71	6,78	22 760	162	0,240	8446	3,640	360	460	62	33 730
	c	2	0,55	106	106	2,61	30,7	11	15	313	2,49	0,15	0,67	1795	29	0,058	1116	0,441	49	101	18	4778
	d	<1	0,47	28	87	0,04	10,0	7	13	41	1,55	0,10	0,30	578	16	0,040	410	0,171	28	81	15	1351
	e	<1	0,56	24	97	0,97	10,6	6	14	42	1,47	0,12	0,22	488	12	0,042	425	0,131	30	92	16	1392
Stawy Ponds n = 65	a	<1	0,07	<3	9	0,05	<0,5	2	3	3	0,30	<0,02	0,03	35	3	0,004	8	0,022	3	15	4	28
	b	27	1,43	2236	610	19,93	427,2	22	59	8056	11,65	9,15	6,89	8729	126	0,210	20 600	7,360	486	493	49	59 190
	c	2	0,66	135	127	3,70	45,5	8	19	227	3,11	0,30	0,80	1349	26	0,056	1512	0,736	84	111	21	6969
	d	<1	0,58	32	96	1,72	13,9	7	16	43	2,36	0,10	0,35	748	21	0,046	504	0,360	47	93	18	2099
	e	<1	0,70	28	105	1,67	12,3	8	16	34	2,27	0,11	0,30	797	22	0,049	476	0,385	45	94	21	2164
Osadniki Sediment strainers (clarifiers) n = 15	a	<1	0,06	5	22	0,33	0,6	<1	2	18	0,20	0,04	0,15	228	3	0,011	32	0,039	22	19	5	103
	b	14	1,37	2750	486	33,66	272,2	33	45	1148	10,06	0,39	6,63	3709	48	0,090	9610	4,320	1416	131	36	57 000
	c	3	0,62	232	140	9,41	37,9	11	20	124	2,36	0,16	0,98	1029	24	0,040	1553	0,766	344	94	20	7603
	d	1	0,49	28	101	5,37	8,4	8	17	51	1,74	0,12	0,53	656	21	0,034	401	0,424	204	83	18	1603
	e	<1	0,51	17	112	6,25	4,4	8	16	42	1,61	0,10	0,50	594	23	0,033	216	0,406	304	115	19	782
Brynica Brynica River n = 31	a	<1	0,42	4	42	0,15	2,4	3	5	12	0,48	0,07	0,05	103	6	0,042	48	0,069	8	37	7	259
	b	8	2,28	53	463	4,40	129,1	22	32	126	5,57	0,66	0,78	2749	38	0,690	751	2,850	111	130	41	33 190
	c	1	1,27	32	229	1,59	24,7	9	21	51	2,78	0,30	0,38	1074	19	0,289	327	0,596	50	75	21	6021
	d	<1	1,13	28	188	1,10	13,8	8	19	39	2,44	0,25	0,27	838	18	0,231	255	0,363	38	70	20	1940
	e	<1	1,32	31	249	1,01	13,1	7	21	37	2,65	0,25	0,29	736	18	0,237	315	0,278	38	68	21	1535
Zlewnia Brynicy Brynica River catchment n = 110	a	<1	0,02	<3	7	0,03	<0,5	<1	<1	<1	0,05	<0,02	0,01	20	<1	<0,002	6	0,009	1	<5	<1	24
	b	8	2,35	76	575	4,99	129,1	46	51	265	5,57	0,96	1,91	7991	74	0,690	1271	2,850	111	283	41	33 190
	c	<1	0,93	25	202	1,06	16,3	8	21	42	2,14	0,19	0,34	889	20	0,154	318	0,309	34	78	20	2464
	d	<1	0,77	20	161	0,69	9,9	7	18	30	1,82	0,12	0,25	535	17	0,100	233	0,166	26	66	18	1045
	e	<1	0,83	21	173	0,67	10,2	7	20	30	1,91	0,13	0,27	598	18	0,093	270	0,152	28	70	20	1021
Bytomka Bytomka River n = 17	a	<1	0,26	16	63	0,87	4,2	4	10	33	1,04	0,08	0,26	181	12	0,036	130	0,157	39	81	9	578
	b	6	0,95	44	302	18,03	13,6	29	471	285	8,86	8,03	0,89	12 760	41	0,140	1053	1,080	770	235	33	3041
	c	2	0,60	31	135	7,30	7,8	15	103	122	3,52	1,35	0,58	3178	29	0,086	554	0,545	317	130	20	1902
	d	1	0,55	29	125	5,27	7,4	13	47	103	3,13	0,60	0,55	1516	27	0,081	465	0,485	232	126	18	1753
	e	1	0,57	28	118	5,24	7,4	16	33	135	3,14	0,47	0,60	1342	31	0,087	518	0,511	231	134	23	1973
Zlewnia Bytomki Bytomka River catchment n = 77	a	<1	0,05	4	1	0,24	0,6	<1	4	7	0,72	<0,02	0,09	122	3	0,003	32	0,037	12	15	2	103
	b	138	1,43	2974	564	18,03	404,8	50	471	1539	37,61	9,15	7,13	23 810	475	0,240	20 600	13,780	770	458	62	48 860
	c	5	0,56	267	113	5,45	46,4	13	38	162	4,13	0,58	1,07	2669	39	0,070	2205	1,045	155	112	19	7416
	d	2	0,48	48	85	3,18	13,6	9	21	68	2,88	0,18	0,55	1173	25	0,053	606	0,467	88	94	17	2268
	e	1	0,53	28	101	3,69	9,4	9	18	52	2,77	0,16	0,50	1082	25	0,059	497	0,478	65	97	18	1973
Szarlejka Szarlejka River n = 21	a	<1	0,09	4	25	0,43	2,3	<1	5	11	0,39	0,04	0,14	98	4	0,013	128	0,107	16	42	3	381
	b	8	1,04	52	191	3,89	29,2	10	50	174	4,27	1,61	0,97	2920	45	0,460	6775	2,310	206	219	28	5073
	c	2	0,54	31	107	2,41	15,1	6	29	90	2,11	0,52	0,64	593	22	0,149	991	0,810	97	122	18	2755
	d	2	0,47	27	99	2,09	12,5	5	26	74	1,91	0,35	0,58	484	19	0,105	706	0,570	80	116	16	2295
	e	2	0,44	29	99	2,82	16,9	6	26	76	2,26	0,38	0,64	510	18	0,101	736	0,546	86	116	18	2888

Tabela 4 cd.
Table 4 cont.

Osady Sediments	Parametry Parameters	Ag mg/kg	Al %	As mg/kg	Ba mg/kg	Ca %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe %	Hg mg/kg	Mg %	Mn mg/kg	Ni mg/kg	P %	Pb mg/kg	S %	Sr mg/kg	Ti mg/kg	V mg/kg	Zn mg/kg
Zlewnia Szarlejki Szarlejka River catchment n = 77	a	<1	0,09	4	20	0,12	0,9	<1	5	6	0,39	<0,02	0,03	98	4	0,010	33	0,025	3	15	3	113
	b	12	1,27	282	967	26,44	427,2	22	71	8056	9,68	1,61	4,24	8729	79	0,460	6775	2,380	1925	493	57	59 190
	c	2	0,64	44	162	3,97	32,5	7	22	181	2,78	0,26	0,59	1218	23	0,093	993	0,569	150	122	22	4957
	d	1	0,58	29	125	1,86	14,4	6	19	49	2,20	0,16	0,37	720	20	0,065	612	0,332	65	106	19	2401
	e	1	0,67	29	118	2,41	14,8	7	19	43	2,26	0,14	0,41	635	21	0,063	711	0,396	64	103	20	2844
Zlewnia Rowu z Dąbrówki Wielkiej Dąbrówka Wielka Ditch catchment n = 15	a	<1	0,06	12	14	0,23	7,6	<1	2	12	0,20	0,08	0,14	235	3	0,015	207	0,016	12	19	5	614
	b	12	1,01	421	245	33,66	9695,0	131	72	403	4,68	1,11	1,53	3832	1307	0,430	27 190	3,680	741	171	28	69 330
	c	4	0,70	153	123	7,03	730,2	15	26	126	2,17	0,33	0,56	793	131	0,130	3430	0,740	121	94	19	11 999
	d	2	0,61	82	98	2,40	45,6	6	20	75	1,77	0,25	0,37	576	34	0,083	1585	0,254	58	82	18	3909
	e	2	0,69	117	126	2,92	23,1	6	18	81	1,88	0,24	0,25	593	20	0,068	1394	0,284	34	98	19	2991
Zlewnia Rowu z Orła Białego Orzeł Biały Ditch catchment n = 21	a	<1	0,13	<3	20	0,15	1,1	3	7	11	0,54	0,04	0,09	74	7	0,009	26	0,042	9	26	4	116
	b	10	1,12	1740	486	15,69	149,7	16	45	7922	7,53	0,57	6,89	3822	48	0,360	5637	2,500	498	173	36	29 290
	c	2	0,70	201	154	2,93	29,6	6	18	470	1,97	0,21	0,92	809	20	0,072	1225	0,465	63	89	19	5861
	d	1	0,61	43	117	1,00	15,9	5	16	75	1,57	0,16	0,34	390	17	0,050	734	0,235	34	84	16	2410
	e	<1	0,73	32	124	0,85	12,5	5	15	65	1,51	0,18	0,22	293	17	0,060	826	0,229	23	84	20	1830
Zlewnia Rowu Świerklanieckiego Rów Świerklaniecki Ditch catchment n = 11	a	<1	0,24	6	87	0,21	2,5	3	7	9	0,74	0,02	0,10	165	7	0,033	38	0,040	12	42	6	330
	b	<1	1,00	35	282	2,32	17,7	11	30	66	3,89	0,11	0,73	2739	28	0,902	358	1,081	54	147	29	1520
	c	<1	0,49	19	152	1,11	7,9	6	16	24	2,05	0,05	0,28	884	16	0,247	147	0,317	27	86	15	822
	d	<1	0,45	16	142	0,94	6,6	5	14	21	1,82	0,05	0,22	676	14	0,139	127	0,170	25	79	14	735
	e	<1	0,46	18	149	1,16	5,3	6	11	19	2,04	0,05	0,19	672	15	0,124	146	0,123	25	71	15	824
Tło geochemiczne; geochemical background																						
Osady strumieniowe Europy[1)] Stream sediments of Europe n = 794	e		10,4	6	87,5	2,44	0,29	8	22	15	1,97	0,04	0,72	453	17	0,056	14	0,050	124	3800	29	60
Osady Polski[2)] Sediments of Poland n = 12 778	e	<1		<5	54	0,86	<0,5	3	5	7	0,80	0,05	0,11	274	6	0,059	13	0,040	20	30	7	62
Osady regionu śląsko-krakowskiego[3)] Sediments of Cracow-Silesia Region n = 1459	e	1		6	98	0,71	2,5	4	9	15	1,07	0,06	0,13	292	11	0,066	59	0,052	24	42	12	259

a – minimum; minimum b – maksimum; maximum c – średnia arytmetyczna; arithmetic mean d – średnia geometryczna; geometric mean e – mediana; median n – liczba próbek; number of samples [1)] Salminen, 2005; [2)] Lis, Pasieczna, 1995a; [3)] Lis, Pasieczna, 1995b;

Parametry statystyczne przewodności elektrolitycznej właściwej, odczynu i zawartości pierwiastków chemicznych w wodach powierzchniowych

Statistical parameters of electrolytic conductivity, acidity and chemical elements contents in surface water

Tabela 5
Table

Wody powierzchniowe Surface water	Parametry Paramters	EC mS/cm	pH	Ag µg/dm³	Al µg/dm³	As µg/dm³	B mg/dm³	Ba mg/dm³	Be µg/dm³	Ca mg/dm³	Cd µg/dm³	Co µg/dm³	Cr mg/dm³	Cu µg/dm³	Fe mg/dm³	K mg/dm³	Li µg/dm³	Mg mg/dm³	Mn mg/dm³	Mo µg/dm³	Na mg/dm³	Ni µg/dm³	P mg/dm³	Pb µg/dm³	SO_4 mg/dm³	Sb µg/dm³	Se µg/dm³	SiO_2 mg/dm³	Sr mg/dm³	Ti mg/dm³	Tl µg/dm³	U µg/dm³	V µg/dm³	Zn mg/dm³
Granica wykrywalności Detection limit				0,05	0,5	2	0,01	0,001	0,05	0,1	0,05	0,05	0,003	0,05	0,01	0,5	0,3	0,1	0,001	0,05	0,5	0,5	0,05	0,05	1	0,05	2	0,1	0,003	0,002	0,05	0,05	1	0,003
Wody powierzchniowe (wszystkie próbki) Surface water (all samples) n = 297	a	0,10	4,5	<0,05	5,1	<2	0,03	0,008	<0,05	15,4	<0,05	<0,05	<0,003	0,22	<0,01	1,4	0,6	0,9	0,002	<0,05	0,7	<0,5	<0,05	<0,05	10	<0,05	<2	0,1	0,035	<0,002	<0,05	<0,05	<1	<0,003
	b	9,32	9,7	0,32	1851,3	164	2,96	0,335	0,62	589,4	1084,70	179,39	0,252	140,53	89,92	559,2	647,9	426,8	8,935	25,50	2616,8	2972,9	2,64	541,03	2602	88,81	35	33,5	6,518	0,004	150,31	9,97	7	38,588
	c	1,30	8,1	<0,05	60,0	4	0,59	0,072	<0,05	139,3	6,64	2,33	0,003	3,79	0,52	23,8	63,7	57,3	0,363	1,63	182,8	27,9	0,13	4,85	434	1,50	3	9,9	0,660	<0,002	0,06	1,12	<1	1,007
	d	0,76	8,1	<0,05	18,5	2	0,36	0,059	<0,05	105,5	0,17	0,17	<0,003	2,20	0,04	12,9	17,7	33,5	0,104	0,81	47,2	2,1	0,05	0,47	209	0,55	<2	7,0	0,397	<0,002	<0,05	0,61	<1	0,045
	e	0,69	8,1	<0,05	13,3	2	0,17	0,072	<0,05	93,3	0,09	0,12	<0,003	2,07	0,03	12,9	14,8	27,0	0,101	0,73	39,5	1,7	<0,05	0,33	173	0,45	<2	10,4	0,323	<0,002	<0,05	0,81	<1	0,034
Strumienie i rowy bez nazwy Streams and ditches (without a name) n = 93	a	0,12	6,2	<0,05	6,5	<2	0,04	0,016	<0,05	21,3	<0,05	<0,05	<0,003	0,47	<0,01	1,4	0,6	5,7	0,002	<0,05	3,5	<0,5	<0,05	<0,05	14	<0,05	<2	1,5	0,094	<0,002	<0,05	<0,05	<1	<0,003
	b	4,31	8,7	0,32	1851,3	164	2,96	0,146	0,62	589,4	1084,70	179,39	0,006	140,53	89,92	373,3	403,7	288,2	8,935	8,92	885,6	2972,9	0,85	541,03	2450	88,81	16	33,5	2,535	0,003	100,53	9,97	7	38,588
	c	0,94	7,8	<0,05	133,1	5	0,23	0,079	0,06	148,3	19,24	6,16	<0,003	5,60	1,35	22,1	38,7	53,8	0,531	1,15	63,8	75,2	0,09	10,01	399	2,42	2	12,9	0,422	<0,002	2,92	1,44	<1	1,934
	d	0,67	7,8	<0,05	22,7	2	0,15	0,070	<0,05	111,8	0,87	0,24	<0,003	2,97	0,07	10,0	10,7	32,3	0,135	0,58	28,7	3,4	0,05	0,71	208	0,57	<2	11,8	0,313	<0,002	0,18	0,76	<1	0,189
	e	0,65	7,9	<0,05	13,5	1	0,12	0,083	<0,05	95,4	0,68	0,14	<0,003	2,23	0,05	8,7	8,7	25,5	0134	0,56	28,6	2,5	<0,05	0,50	159	0,45	<2	11,4	0,264	<0,002	0,12	1,09	<1	0,099
Jeziora Lakes n = 31	a	0,11	4,5	<0,05	6,4	<2	0,03	0,011	<0,05	23,4	<0,05	<0,05	<0,003	0,22	<0,01	5,3	1,4	3,6	0,002	<0,05	5,7	<0,5	<0,05	<0,05	20	0,12	<2	1,0	0,099	<0,002	<0,05	<0,05	<1	<0,003
	b	4,72	9,0	0,05	523,8	11	2,55	0,149	0,46	457,6	57,85	17,58	0,004	23,93	3,76	90,9	344,4	426,8	3,644	7,26	1372,1	108,7	1,89	152,40	2284	5,41	11	19,2	2,099	0,002	64,14	9,81	2	25,89
	c	0,76	8,1	<0,05	27,8	3	0,22	0,054	<0,05	138,0	3,44	1,35	<0,003	3,55	0,35	18,2	34,5	64,6	0,524	1,59	79,2	8,0	0,12	7,70	483	0,93	<2	7,8	0,430	<0,002	2,67	0,88	<1	2,064
	d	0,50	8,1	<0,05	11,6	3	0,13	0,046	<0,05	96,9	0,17	0,12	<0,003	1,79	0,04	13,2	12,0	32,2	0,104	0,81	26,1	1,1	0,05	0,81	196	0,66	<2	5,4	0,328	<0,002	0,09	0,33	<1	0,046
	e	0,44	8,2	<0,05	9,4	3	0,12	0,055	<0,05	76,4	0,10	<0,05	<0,003	1,76	0,04	12,1	8,1	27,0	0,092	1,19	20,3	1,0	<0,05	0,50	184	0,71	<2	7,2	0,304	<0,002	0,06	0,57	<1	0,039
Stawy Ponds n = 63	a	0,10	7,1	<0,05	5,1	<2	0,03	0,018	<0,05	15,4	<0,05	<0,05	<0,003	0,29	<0,01	1,4	0,9	3,2	0,004	<0,05	0,7	<0,5	<0,05	<0,05	10	0,05	<2	0,1	0,035	<0,002	<0,05	<0,05	<1	<0,003
	b	9,32	8,6	0,05	183,4	13	2,67	0,165	0,06	480,1	10,65	7,38	0,005	26,40	3,11	95,4	440,8	257,3	4,583	9,30	2616,8	355,9	0,47	24,09	2483	9,27	25	33,5	5,732	0,003	150,31	8,43	3	6,897
	c	1,53	7,9	<0,05	17,5	3	0,36	0,067	<0,05	142,1	0,59	0,65	<0,003	3,53	0,18	24,2	65,0	66,9	0,475	1,20	148,3	11,2	0,06	1,72	508	1,65	2	7,7	0,621	<0,002	2,75	1,26	<1	0,500
	d	0,95	7,9	<0,05	11,9	2	0,22	0,058	<0,05	103,0	0,10	0,13	<0,003	2,40	0,03	14,6	23,8	38,0	0,147	0,63	37,9	1,7	<0,05	0,53	227	0,70	<2	4,2	0,406	<0,002	0,06	0,53	<1	0,030
	e	0,94	8,0	<0,05	10,0	2	0,24	0,059	<0,05	95,1	0,06	0,05	<0,003	2,67	0,03	14,4	34,4	34,7	0,153	0,94	44,6	1,4	<0,05	0,41	187	0,69	<2	5,4	0,420	<0,002	<0,05	0,63	<1	0,023
Osadniki Sediment strainers (clarifiers) n = 14	a	0,72	7,9	<0,05	5,9	<2	0,16	0,009	<0,05	38,4	<0,05	<0,05	<0,003	1,62	<0,01	21,0	27,7	7,4	0,002	0,40	76,3	0,8	<0,05	<0,05	221	0,10	<2	1,2	0,449	<0,002	<0,05	0,50	<1	<0,003
	b	4,35	8,9	0,06	18,1	13	2,44	0,146	<0,05	464,1	11,59	3,26	0,010	9,16	0,09	559,2	647,9	181,1	0,599	25,50	1212,5	51,3	0,10	5,17	2602	2,78	18	24,1	3,445	<0,002	5,03	2,51	3	2,669
	c	2,46	8,4	<0,05	9,9	5	1,18	0,051	<0,05	243,2	0,93	0,48	<0,003	4,48	0,02	81,0	226,7	111,5	0,097	4,88	574,3	7,2	<0,05	1,04	998	0,72	5	12,6	2,071	<0,002	0,57	1,25	<1	0,417
	d	2,24	8,4	<0,05	9,4	4	0,96	0,033	<0,05	201,0	0,07	0,13	<0,003	3,99	0,01	42,0	184,6	94,9	0,034	2,94	421,6	3,1	<0,05	0,22	852	0,41	4	10,8	1,725	<0,002	0,13	1,11	<1	0,035
	e	2,55	8,4	<0,05	9,4	4	0,09	0,026	<0,05	248,2	<0,05	0,09	<0,003	3,69	<0,01	28,5	218,5	110,2	0,046	3,55	570,0	2,4	<0,05	0,14	924	0,31	5	12,8	2,209	<0,002	0,10	0,98	<1	0,039
Brynica Brynica River n = 35	a	0,21	5,5	<0,05	18,8	<2	0,03	0,037	<0,05	53,2	<0,05	0,05	<0,003	0,59	<0,01	4,0	2,9	11,,5	0,016	0,44	11,6	0,6	<0,5	0,08	48	0,17	<2	1,2	0,126	<0,002	<0,05	0,48	<1	<0,003
	b	1,48	8,9	<0,05	158,8	5	0,39	0,097	0,07	245,0	4,95	0,47	<0,003	3,53	0,05	28,3	70,0	106,5	0,233	2,46	389,0	12,0	<0,5	0,44	739	0,95	6	12,6	1,195	<0,002	4,37	1,47	2	4,231
	c	0,49	8,5	<0,05	50,4	<2	0,10	0,087	<0,05	78,7	0,34	0,15	<0,003	1,08	0,03	8,5	13,9	25,5	0,084	0,71	73,4	2,2	<0,5	0,17	143	0,33	2	4,2	0,322	<0,002	0,41	0,66	<1	0,455
	d	0,38	8,5	<0,05	42,0	<2	0,07	0,085	<0,05	70,8	0,05	0,13	<0,003	0,97	0,03	6,9	7,6	19,7	0,067	0,63	34,9	1,3	<0,5	0,16	93	0,31	<2	3,0	0,235	<0,002	0,05	0,63	<1	0,013
	e	0,24	8,7	<0,05	38,1	<2	0,04	0,094	<0,05	54,6	<0,05	0,11	<0,003	0,81	0,03	4,3	3,6	12,8	0,054	0,50	13,9	0,8	<0,5	0,14	54	0,28	<2	2,1	0,135	<0,002	<0,05	0,59	<1	0,005
Zlewnia Brynicy Brynica River catchment n = 114	a	0,12	5,5	<0,05	5,6	<2	0,03	0,016	<0,05	15,4	<0,05	<0,05	<0,003	0,47	<0,01	1,4	0,6	5,1	0,002	<0,5	3,5	<0,5	<0,05	<0,05	13	0,09	<2	0,1	0,035	<0,002	<0,05	<0,05	<1	<0,003
	b	1,48	9,0	0,08	1851,3	6	0,39	0,152	0,62	245,0	34,87	16,96	<0,003	51,14	5,54	28,3	70,0	106,5	2,042	5,17	389,0	25,5	0,85	38,52	739	2,04	6	29,6	1,195	0,003	4,37	3,09	3	4,231
	c	0,50	8,0	<0,05	113,7	<2	0,10	0,091	0,05	79,5	1,89	1,27	<0,003	2,38	0,27	8,4	9,5	22,7	0,188	0,69	37,6	3,4	0,08	1,45	132	0,43	<2	8,1	0,251	<0,002	0,21	0,86	<1	0,372
	d	0,41	8,0	<0,05	30,4	<2	0,09	0,088	<0,05	71,6	0,21	0,15	<0,003	1,57	0,04	6,8	5,9	19,3	0,069	0,46	20,5	1,8	<0,05	0,37	103	0,37	<2	5,4	0,212	<0,002	0,07	0,53	<1	0,036
	e	0,42	8,0	<0,05	23,8	<2	0,09	0,094	<0,05	65,9	0,22	0,10	<0,003	1,76	0,03	6,4	4,5	19,4	0,056	0,49	15,8	1,4	<0,05	0,26	109	0,34	<2	8,4	0,204	<0,002	0,06	0,61	<1	0,039
Bytomka Bytomka River n = 18	a	2,83	8,0	<0,05	6,8	4	0,83	0,020	<0,05	180,2	<0,05	<0,05	<0,003	3,31	0,01	22,2	175,7	103,8	0,062	1,00	646,8	1,3	<0,05	<0,05	860	0,14	6	10,9	2,042	<0,002	<0,05	0,99	<1	<0,003
	b	7,51	8,6	<0,05	60,8	6	2,70	0,028	<0,05	285,5	0,18	0,77	0,252	4,86	0,06	58,3	415,0	143,3	0,201	5,77	1532,6	3,2	0,19	0,79	1313	0,62	12	14,7	3,354	<0,002	0,18	1,72	1	0,081
	c	5,00	8,3	<0,05	19,1	5	1,49	0,025	<0,05	237,9	0,06	0,29	0,031	4,00	0,03	36,6	254,3	118,6	0,095	4,08	1007,6	2,1	0,07	0,15	1027	0,37	8	13,4	2,678	<0,002	0,09	1,27	<1	0,023
	d	4,85	8,3	<0,05	16,6	5	1,39	0,025	<0,05	236,5	<0,05	0,19	0,004	3,97	0,02	34,9	246,3	118,1	0,089	3,62	972,9	2,0	<0,05	0,10	1018	0,34	8	13,4	2,659	<0,002	0,07	1,26	<1	0,014
	e	4,92	8,2	<0,05	17,7	5	1,27	0,025	<0,05	237,4	<0,05	0,27	<0,003	3,89	0,02	32,0	232,4	116,4	0,086	4,77	930,7	2,1	<0,05	0,12	984	0,37	8	13,7	2,727	<0,002	0,11	1,20	<1	0,014
Zlewnia Bytomki Bytomka River catchment n = 77	a	0,23	4,5	<0,05	5,1	<2	0,04	0,009	<0,05	38,4	<0,05	<0,05	<0,003	0,33	<0,01	4,5	1,5	7,4	0,001	0,06	6,3	<0,5	<0,05	<0,05	39	0,10	<2	0,8	0,131	<0,002	<0,05	<0,05	<1	<0,003
	b	7,51	9,0	0,32	523,8	164	2,96	0,104	0,46	486,7	182,05	154,34	0,252	32,58	89,92	373,3	415,0	426,8	8,935	8,92	2616,8	2972,9	1,89	541,03	2450	88,81	25	33,5	5,732	0,003	100,53	9,97	7	38,588
	c	2,56	8,1	<0,05	19,6	8	0,81	0,040	<0,05	227,5	4,58	3,02	0,009	4,43	1,44	43,5	148,4	115,4	0,558	2,55	451,6	49,2	0,10	10,46	888	2,44	5	12,8	1,444	<0,002	3,36	1,49	<1	1,722
	d	1,76	8,1	<0,05	12,0	4	0,46	0,034	<0,05	190,3	0,12	0,20	<0,003	3,37	0,04	27,3	75,1	85,2	0,156	1,51	164,2	2,62	0,05	0,30	594	0,63	3	9,9	0,990	<0,002	0,11	0,92	<1	0,040
	e	1,89	8,2	<0,05	10,2	5	0,49	0,028	<0,05	238,1	0,06	0,24	<0,003	3,75	0,03	27,0	128,6	113,5	0,137	1,38	207,9	2,00	<0,05	0,17	963	0,46	3	13,1	0,920	<0,002	0,09	1,17	<1	0,027
Rów z Dąbrówki Wielkiej Rów z Dąbrówki Wielkiej (ditch) n = 6	a	0,31	7,6	<0,05	9,0	2	0,03	0,023	<0,05	33,78	0,09	<0,05	<0,003	1,99	<0,01	4,6	3,9	0,9	0,019	0,59	6,8	0,7	<0,05	0,86	79	1,56	<2	2,8	0,152	<0,002	0,08	<0,05	<1	0,023
	b	0,79	9,7	<0,05	251,9	9	0,08	0,071	<0,05	117,83	3,09	0,32	<0,003	16,04	0,31	79,0	151,3	26,2	0,300	19,90	60,0	5,2	0,09	63,68	286	7,45	35	23,2	0,419	0,004	2,13	0,76	2	0,214
	c	0,46	8,2	<0,05	59,8	6	0,06	0,051	<0,05	77,79	1,33	0,15	<0,003	7,91	0,11	23,1	43,5	14,9	0,082	6,12	19,0	2,3	<0,05	16,22	174	3,98	10	10,6	0,281	<0,002	0,52	0,30	<1	0,114
	d	0,43	8,2	<0,05	25,9	6	0,05	0,047	<0,05	72,70	0,77	0,12	<0,003	6,57	0,05	14,3	17,3	9,6	0,050	2,54	13,4	1,8	<0,05	7,19	162	3,26	4	8,0	0,268	<0,002	0,25	0,15	<1	0,089
	e	0,39	8,0	<0,05	18,1	7	0,06	0,055	<0,05	76,07	0,95	0,15	<0,003	7,66	0,04	14,1	20,4	15,8	0,045	3,20	10,8	1,8	<0,05	6,90	172	3,24	4	9,5	0,281	<0,002	0,21	0,27	<1	0,097

Tabela 5 cd.
Table 5 cont.

Wody powierzchniowe Surface water	Parametry Paramters	EC mS/cm	pH	Ag µg/dm^3	Al µg/dm^3	As µg/dm^3	B mg/dm^3	Ba mg/dm^3	Be µg/dm^3	Ca mg/dm^3	Cd µg/dm^3	Co µg/dm^3	Cr mg/dm^3	Cu µg/dm^3	Fe mg/dm^3	K mg/dm^3	Li µg/dm^3	Mg mg/dm^3	Mn mg/dm^3	Mo µg/dm^3	Na mg/dm^3	Ni µg/dm^3	P mg/dm^3	Pb µg/dm^3	SO_4 mg/dm^3	Sb µg/dm^3	Se µg/dm^3	SiO_2 mg/dm^3	Sr mg/dm^3	Ti mg/dm^3	Tl µg/dm^3	U µg/dm^3	V µg/dm^3	Zn mg/dm^3
Zlewnia Rowu	a	0,11	6,5	<0,05	6,7	<2	0,03	0,019	<0,05	23,38	<0,05	<0,05	<0,003	0,22	<0,01	4,6	1,4	0,9	0,019	0,10	6,1	<0,5	<0,05	0,23	20	0,26	<2	1,1	0,099	<0,002	<0,05	<0,05	<1	0,003
z Dąbrówki Wielkiej	b	3,42	9,7	<0,05	1230,9	21	1,29	0,071	0,23	480,11	1084,70	179,39	0,006	140,53	2,75	559,2	647,9	218,3	7,233	25,50	397,5	2296,7	0,09	205,71	2602	47,75	35	29,1	1,581	0,004	50,40	2,07	2	38,511
Rów z Dąbrówki Wielkiej	c	1,07	7,9	<0,05	110,8	7	0,30	0,040	<0,05	192,19	85,89	17,86	<0,003	15,26	0,34	60,7	142,8	60,9	0,910	5,37	80,8	250,5	<0,05	21,71	753	6,87	7	11,2	0,548	<0,002	5,33	0,56	<1	4,147
(ditch) catchment	d	0,67	7,9	<0,05	18,9	5	0,12	0,037	<0,05	118,78	1,88	0,34	<0,003	5,16	0,07	21,5	32,4	24,0	0,116	1,89	31,2	5,5	<0,05	3,76	294	3,12	3	8,3	0,386	<0,002	0,54	0,25	<1	0,236
n = 15	e	0,61	7,9	<0,05	9,5	7	0,08	0,035	<0,05	95,61	1,44	0,13	<0,003	7,49	0,09	17,7	35,4	25,8	0,066	2,76	25,2	2,6	<0,05	3,49	184	3,78	2	7,7	0,323	<0,002	0,41	0,39	<1	0,191
	a	0,38	8,3	<0,05	14,6	<2	0,06	0,008	<0,05	47,07	<0,05	0,05	<0,003	0,88	<0,01	7,7	5,6	10,9	0,017	0,42	26,2	1,7	0,06	0,17	26	0,50	<2	5,7	0,206	<0,002	<0,05	0,19	<1	0,006
Szarlejka	b	3,73	8,9	<0,05	104,0	7	0,94	0,243	0,06	236,57	0,23	1,90	<0,003	4,68	0,99	47,26	246,5	88,8	0,731	5,09	1075,5	6,0	2,64	3,97	457	6,06	10	16,2	3,214	<0,002	0,08	2,08	2	0,047
Szarlejka Stream	c	1,13	8,4	<0,05	28,4	<2	0,28	0,070	<0,05	106,58	<0,05	0,72	<0,003	1,55	0,11	27,07	55,5	37,5	0,211	1,66	258,4	4,7	0,88	0,77	232	1,26	3	13,8	0,792	<0,002	<0,05	0,62	<1	0,019
n = 20	d	0,86	8,4	<0,05	25,1	<2	0,21	0,042	<0,05	98,18	<0,05	0,56	<0,003	1,38	0,06	24,87	29,4	32,6	0,177	1,14	148,7	4,6	0,52	0,54	201	0,83	<2	13,3	0,501	<0,002	<0,05	0,43	<1	0,017
	e	0,66	8,4	<0,05	23,9	<2	0,16	0,034	<0,05	85,15	<0,05	0,84	<0,003	1,09	0,07	26,40	19,0	26,9	0,204	0,71	118,9	5,3	0,56	0,50	177	0,58	<2	15,3	0,372	<0,002	<0,05	0,26	<1	0,016
	a	0,10	7,3	<0,05	6,7	<2	0,05	0,007	<0,05	17,00	<0,05	<0,05	<0,003	0,29	<0,01	1,4	0,6	3,2	0,004	<0,05	0,7	<0,5	<0,05	<0,05	10	0,08	<2	0,5	0,062	<0,002	<0,05	<0,05	<1	<0,03
Zlewnia Szarlejki	b	9,32	8,9	0,06	183,4	11	1,84	0,335	0,06	589,39	28,73	2,87	<0,003	10,09	0,99	70,3	471,0	257,3	3,437	6,41	2200,9	37,5	2,64	5,31	1891	6,06	10	29,3	6,518	0,003	0,80	9,81	4	5,326
Szarlejka Stream catchment	c	1,29	8,2	<0,05	20,6	3	0,27	0,088	<0,05	122,75	0,96	0,42	<0,003	2,31	0,09	18,5	45,6	44,3	0,271	1,43	181,8	3,2	0,31	1,10	316	1,03	<2	9,6	0,730	<0,002	0,09	1,12	<1	0,299
n = 62	d	0,80	8,2	<0,05	15,4	2	0,18	0,064	<0,05	92,86	0,08	0,15	<0,003	1,68	0,03	13,6	18,0	29,0	0,101	0,81	54,8	1,6	0,07	0,63	166	0,63	<2	7,0	0,425	<0,002	<0,05	0,48	<1	0,228
	e	0,68	8,3	<0,05	13,3	2	0,16	0,062	<0,05	84,72	<0,05	0,13	<0,003	1,59	0,04	14,4	19,0	27,0	0,170	0,79	63,8	1,6	<0,05	0,49	177	0,60	<2	10,1	0,357	<0,002	<0,05	0,59	<1	0,020
Zlewnia Rowu	a	0,13	7,4	<0,05	7,0	<2	0,05	0,017	<0,05	19,41	<0,05	<0,05	<0,003	1,62	<0,01	7,8	2,9	4,20	0,013	0,23	2,5	0,8	<0,05	0,14	74	<0,05	<2	0,4	0,112	<0,002	<0,05	<0,05	<1	0,009
z Orła Białego	b	4,17	8,5	0,05	69,1	6	2,44	0,157	<0,05	390,00	10,65	6,99	0,010	26,40	0,63	165,2	230,9	232,7	4,583	9,30	462,9	31,1	0,10	24,09	2483	8,04	7	18,6	1,088	<0,002	150,31	4,52	3	8,730
Orzeł Biały Ditch catchment	c	1,53	8,0	<0,05	13,6	2	0,49	0,062	<0,05	176,71	3,05	1,02	<0,003	7,01	0,07	34,9	74,1	88,8	0,627	1,72	130,3	8,0	<0,05	2,86	732	2,06	2	9,0	0,607	<0,002	10,43	1,37	<1	2,376
n = 18	d	1,02	8,0	<0,05	11,3	<2	0,27	0,049	<0,05	142,28	0,60	0,23	<0,003	4,93	0,03	22,4	40,4	55,0	0,244	1,10	48,5	3,9	<0,05	0,84	472	0,81	<2	6,6	0,506	<0,002	0,46	0,82	<1	0,405
	e	1,00	8,0	<0,05	11,0	2	0,21	0,052	<0,05	147,82	0,40	0,26	<0,003	4,66	0,03	16,4	39,3	90,7	0,280	1,00	54,1	3,3	<0,05	0,70	606	1,39	<2	9,5	0,492	<0,002	0,23	1,32	<1	0,352
	a	0,16	8,2	<0,05	19,4	<2	0,03	0,053	<0,05	45,59	<0,05	0,05	<0,003	0,61	0,02	3,8	2,5	10,59	0,004	0,14	11,40	0,6	<0,05	0,16	45	0,24	<2	0,4	0,107	<0,002	<0,05	0,07	<1	<0,003
Zbiornik Kozłowa Góra	b	0,19	9,0	<0,05	36,1	<2	0,03	0,098	<0,05	53,14	0,52	0,67	0,010	1,92	1,09	6,1	3,3	11,89	0,256	0,54	12,16	3,0	<0,05	2,17	50	0,31	<2	8,4	0,127	<0,002	0,12	0,60	<1	0,103
Kozłowa Góra Reservoir	c	0,18	8,5	<0,05	25,6	<2	0,03	0,090	<0,05	51,52	0,10	0,15	<0,003	0,90	0,19	4,2	2,8	11,48	0,043	0,44	11,77	1,1	<0,05	0,49	48	0,27	<2	2,7	0,123	<0,002	<0,05	0,51	<1	0,017
n = 7	d	0,18	8,5	<0,05	25,0	<2	0,03	0,088	<0,05	51,46	<0,05	0,08	<0,003	0,84	0,06	4,2	2,8	11,47	0,013	0,41	11,76	1,0	<0,05	0,29	48	0,27	<2	1,8	0,122	<0,002	<0,05	0,43	<1	0,004
	e	0,18	8,5	<0,05	23,9	<2	0,03	0,096	<0,05	52,87	<0,05	0,06	<0,003	0,75	0,03	3,9	2,6	11,60	0,009	0,48	11,68	0,9	<0,05	0,21	49	0,27	<2	2,3	0,125	<0,002	<0,05	0,56	<1	0,004
Wartości wskaźników jakości wód powierzchniowych i pitnych; surface water and drinking water quality guidelines																																		
I klasa [1] Class I		≤0,36	7,5–8,2	≤5	≤400	≤50	≤2	≤0,5	≤0,8	≤68,3	0,5	≤50	≤0,05	≤50	0,1			≤5		≤40		10	≤0,18	10	≤31,6	≤2	≤20			≤0,05	≤2		≤50	≤1
II klasa [1] Class II		≤0,45	7,3–8,2							≤76,2	1				0,3			≤7,8				20	≤0,22	10	≤37,7									
Naturalne wody mineralne [2] Natural Mineral Water						10		1			3		0,05						500			20		10		5	10							
Wody pitne [3] Drinking Water		2,5	≥6,5–9,5≤		200	10	1				5		0,05						50		200	20		10	250	5	10							

a – minimum; b – maksimum; c – średnia arytmetyczna; d – średnia geometryczna; e – mediana; n – liczba próbek
minimum maximum arithmetic mean geometric mean median number of samples

[1] Wartości wskaźników jakości wód powierzchniowych w Polsce; surface water quality guidelines in Poland (Rozporządzenie..., 2016)

[2] Naturalne wody mineralne; Natural Mineral Water (EU Directive 2009/54/EC Natural Mineral Water)

[3] Wody pitne; Drinking Water (EU Directive 1998/83/EC Drinking Water)

centrations specified in the Regulation of the Minister of the Environment (Rozporządzenie..., 2016). The soil areas distinguished were classified into use groups I, II, III and IV.

For the purpose of publication, the geochemical maps were combined in pairs, i.e. the geochemical map of topsoils and the geochemical map of sediments are placed on one table, and the geochemical map of subsoils and the geochemical map of surface water is presented on the adjacent one. This method of presentation allows direct comparison of geochemical images of different environments. For convenient use, the maps (with a linear scale) were printed in a slightly smaller format (A3). This procedure did not miss any detail of the map content.

RESULTS

SOILS

The most important sources of anthropogenic pollution of soils include the deposition of particulate matter and gases from industrial plants, various means of transport, corrosion of building materials, heating of housing estates, and using plant protection products (Wong *et al*., 2006; Albanese, Breward, 2011). Particularly significant changes in soil chemistry are caused by the mining of metal ores and by metallurgy. The greatest threats are posed by the impact of waste from these activities (Fuge *et al*., 1993; Adamo *et al*., 2002; Swennen *et al*., 2002; Cappuyns *et al*., 2005; Navarro *et al*., 2006; Acosta *et al*., 2011). The study area within the map sheet is a typical example of soil pollution as a result of Zn-Pb ore mining and processing (Pasieczna, 2018).

The parent rocks of soils within the map sheet area are lithologically diverse Carboniferous, Triassic, Neogene and Quaternary deposits (Pl. 1), from which various types of soils formed. Rendzinas developed on Triassic limestones and dolomites (dominant in the northern part of the map sheet). Their characteristic feature is high calcium content. Podzolic soils developed from Carboniferous sandstones and Quaternary glaciofluvial silts. The most fertile podzolic soils composed of silts occur in the Dąbrówka Wielka region (Aktualizacja..., 2011). Quaternary glacial tills (predominant in the south) are the parent rocks of cambisols and gleyed soils. Fluvisols and peats developed in the Brynica River and Szarlejka Stream valleys.

Large areas are occupied by anthropogenic soils of considerable thickness, occurring mainly in areas of industrial facilities, in places of waste storage and reclaimed heaps, in built-up areas, near communication routes, in mining areas, as well as in river channels of transformed watercourses or in post-mining areas overgrown with a natural plant succession. These soils often form on a parent rock extracted from greater depths, which shows completely different properties than the rock on which the original soil cover developed.

Grain-size composition. Grain-size composition is the granulation of the mineral part of soil's solid phase and is expressed by the particle size and the percentage share of each fraction (Bednarek *et al*., 2004). Under natural conditions, soil grain-size composition changes very little and is one of the most important features affecting its physical, chemical and biological properties (Mocek *et al*., 2000; Ryżak *et al*., 2009).

In the study, the subdivision of soil particles into granulometric groups has been adopted from the standard BN-78/9180-11, valid until 2008, because it is a continuation of the project carried out for several years now in accordance with the instructions for the geochemical map at the scale of 1 : 25,000. The results of grain-size analyses are presented for the following grain groups: 1.0–0.1 mm sand fraction, 0.1–0.02 mm silt fraction, <0.02 mm clay fraction (Pls. 4–6). Changing the ranges of grain-size groups in accordance with the current guidelines of the Polish Soil Science Society (Klasyfikacja..., 2008) would make it impossible to compare the grain-size composition with the data from the previously developed sheets.

The sand fraction (1.0–0.1 mm), consisting of rounded grains of quartz, feldspar and other silicates, predominates in the grain-size composition of the studied soils. Its content ranges from 2% to 95% (median 48%). The soils rich in the sand fraction (>80%) cover the Brynica River valley and the Radzionków region (Pl. 4). Anthropogenic soils of the southern edges of the map sheet contain of over 40% of the silt fraction (Pl. 5). In the topsoil layer of many regions, the clay fraction content exceeds 20% (Pl. 6), which indicates they are highly fertile. This fraction, consisting mainly of clay minerals and secondary oxide minerals, has a crucial effect on the physical and chemical properties of soils (their possibility of retaining both nutrient and toxic elements for plants, and their lower mobility under hypergenic conditions compared to sandy soils).

Acidity. Both the topsoil (0.0–0.3 m) and the subsoil (0.8–1.0 m) are dominated by neutral and alkaline soils. In the subsoil, there was also a significant proportion of strongly alkaline soils (pH>8), occurring in the southeastern part of the map sheet area. The percentage of soils with a pH value >7.4 in the topsoil is about 61%, and in the subsoil it is 76%. The high pH value is mostly of natural origin. The parent rocks of the soils are represented mainly by Triassic carbonates and the waste dispersed on the surface due to the historical mining of Zn-Pb ores, rich mainly in calcium (Pls. 20 and 21) and magnesium that affect the pH value.

Additional factors that make the soil alkaline are the large proportion of debris in anthropogenic embankments in the city, the use of calcium-rich building materials (mortars, plasters), the periodic dusting of mining and metallurgical waste heaps, and the scattering of Triassic limestones and dolomites extracted in small open-pit mines for local needs.

The acidic reaction (pH <6.3) is found in small areas of soils developed from peat deposits and glaciofluvial sands occurring in the upper sector of the Brynica River valley.

Geochemistry. The soils of the map sheet area are polluted mostly with metals. The main polluting factor is the shallow occurrence of Zn-Pb ores and hard coals, the mining of which results in the accumulation of a huge mass of waste on numerous heaps. The dispersion of material from heaps, and metalliferous dust from the former zinc and iron foundries, as well as surface runoff, led to significant changes in the chemical composition of the soils in relation to the parent rocks. That is why the basic geochemical features of original rocks are very poorly readable, and the content of cadmium, lead and zinc in these rocks sometimes remains in the range close to the economic concentrations in their ore deposits.

In the topsoil, the distribution of elements (aluminum, barium, calcium, cobalt, magnesium, manganese, nickel, phosphorus, strontium, titanium and vanadium), which are sourced mainly from parent rocks, was changed by anthropogenic factors. Comparison of the median values shows that their contents significantly exceed the geochemical background value of the Silesian-Cracow region (Table 2). About two-fold enrichment compared to the regional background is found for cobalt, manganese, sulfur and vanadium, and three-fold enrichment is observed for barium, calcium, chromium, magnesium, strontium and titanium. The highest concentrations are found in the case of cadmium and lead – six times greater compared to the geochemical background in the region, and zinc – 10 times greater.

In both depth ranges, the soils are rich in aluminum (0.40–3.09% in topsoil and 0.40–3.22% in subsoil). The aluminum content is related to the abundance of soils in the silt and clay fractions, in which fine-grained feldspars, mica and clay minerals are accumulated.

The clearly larger areas of barium-rich topsoil (>240 mg/kg) allow concluding that barium accumulation is associated with the dispersion of fine particles from industrial plants and the drainage of post-mining waste heaps. The prevalence of anthropogenic sources of barium is demonstrated by the median value twice as high as its content in topsoil. Both the topsoil and subsoil are rich in barium (120–480 mg/kg). Barium comes from coal combustion dust (Różkowska, Ptak, 1995a, b), waste heaps, and discharges of mine waters and residual heavy liquids from coal enrichment (Górnictwo...).

The total organic carbon (TOC) content varies in the topsoil from 0.03 to 49.66%. In the soils of meadows and arable fields of the eastern and northern parts of the map sheet, the content of organic carbon (<1.50%) is clearly unfavourable. The median contents of TOC in the soils of agricultural fields, forests, and industrial areas are 1.96%, 3.01% and 5.10%, respectively (Table 2). Anthropogenic soils in the vicinity of heaps and areas of hard coal mines, and natural peat soils of the Brynica River valley contain > 6% of this component.

Both the topsoil and subsoil, rich in calcium (>2%), magnesium (>0.50%), manganese (>800 mg/kg) and strontium (>80 mg/kg), and locally also in iron, developed on carbonates (predominantly limestones) that occur in the bedrock. Concentrations of calcium and magnesium have a positive effect on the properties of soils by increasing the pH and favouring the binding of heavy metals. These soils occupy larger areas in the deeper layer, which proves the natural origin of these elements. The spatial distribution of the soils coincides with the outcrops of Triassic limestones and dolomites. These areas include Bobrowniki, Brzozowice, Andaluzja residential area, Brzeziny and Jutrzyny in the southeast of the map sheet, Piekary-Centrum, Buchacz and Nowy Dwór in the central part, and Radzionków-Kozłowa Góra in the north. The soils of the northern part of the Brynica River valley, which developed from Quaternary glaciofluvial sands and gravels, contain the lowest amount of these elements.

The natural source of phosphorus in soils are phosphorus minerals from parent rocks. This element, as one of the basic nutrients for plants, also has a negative impact on the environment (Sapek, 2007, 2008). In the study area, the phosphorus content is higher in the topsoil compared with subsoil (the median values are 0.047% and 0.026%, respectively). In the topsoil, the greatest amount of phosphorus is found in the soils of arable lands and allotment gardens, which is probably associated with its excessive accumulation as a result of using phosphorus fertilizers and introducing it along with waste and sewage.

Strong anthropogenic anomalies of silver, arsenic, cadmium, copper, sulfur, lead and zinc were found in the soils of areas of historical mining of Zn-Pb ores, at sites of numerous old scrubbers and post-flotation waste landfills, in the areas of historical zinc smelters and their waste dumps, in the vicinity of the currently operating ZGH Orzeł Biały plant (producing lead from lead-acid battery scrap), and landfills from its activity.

The soil pollution with these elements near waste dumps in the west of the map sheet (in the Buchacz-Dąbrowa Miejska-Nowy Dwór and Radzionków area, and in forests along the northwestern edge of the map sheet) is related mainly to the historical extraction of galena and calamines. In the eastern part (from Brzozowice across Brzeziny and Jutrzyny to the Arki Bożka housing estate and Żabie Doły), environmental pollution is a result of the historical mining of Zn-Pb ores, storage of waste from flotation, and modern activity of the Orzeł Biały ZGH plant that stores waste nearby (including hazardous waste containing heavy metals) (Poradnik…, 2010).

The silver (>4 mg/kg) and arsenic (>160 mg/kg) anomalies are characterized by higher intensity in the topsoil and a similar range in both soil depth zones. Within the silver anomaly in the west of the map sheet, the maximum Ag concentration was 32 mg/kg, and in the area of heaps in the east, the concentration was 50–97 mg/kg. In the extremely arsenic-polluted soils, the maximum As concentration of 11,735 mg/kg was recorded in topsoil of a green space (formerly a heap?) in Bytom. In the Żabie Doły region, the concentration often attains 1,500–5,000 mg/kg, and in the Buchacz-Nowy Dwór region, a maximum of 1,395 mg/kg of arsenic was found.

In the areas of silver and arsenic anomalies in the eastern part of the map sheet, a surprisingly high copper concentration (>160 mg/kg) was recorded compared to the median copper concentration in soils of the Silesian-Cracow region (7 mg/kg), which indicates its anthropogenic origin. At some sites in topsoil of landfill areas west of Brzeziny and in the valley of the Orzeł Biały Ditch, the copper concentration exceeds 1,200 mg/kg, reaching a maximum of 5,777 mg/kg. The source of copper may have been the production of alloys, which developed particularly intensely in the 15th century using copper ores from the Banska Bystřica region in Slovakia and small deposits in the Tatra Mountains (Garbacz-Klempka *et al*., 2012, 2017). Currently, copper from foundries is sent to landfills in the form of sludge, and is also dispersed in dust emitted from the ZGH Orzeł Biały and accumulated in the waste of the plant (Poradnik…, 2010). In the western part of the map sheet, the soil enrichment in copper only sporadically exceeds 160 mg/kg. The significant mobility f copper under hypergenic conditions results in its penetration deep into soil profiles, sediments and waters.

In the southeastern and northwestern parts of the map sheet area, soils highly contaminated by cadmium, lead and zinc were found. Of particular concern is the pollution of soils by these elements in agricultural lands and allotment gardens distributed at various locations. The surfaces of polluted soils are more extensive in the topsoil compared to subsoil, indicating the anthropogenic factor as the main cause of the pollution.

In the areas of highest pollution by cadmium, lead and zinc, the Zn-Pb and iron ores have been mined since the Middle Ages. In the 19th century, new mines were established, including the largest ones of Szarlej, Cecylia and Brzozowice, which, along with the Nowa Helena mine, were called Waryński after the Second World War. In the period 1967–1989, underground mining was carried out by the Dąbrówka mine, which was part of ZGH Orzeł Biały (Krzanowska *et al*., 2004). After the flotation process, Zn-Pb ores were processed in the Brzeziny and Piekary Śląskie plants, as well as in the zinc foundry (formerly Lazyhütte) in Radzionków (Zakłady...).

At present, the source of soil pollution is the dispersion of waste and leachate from landfills where waste is stored, which comes from the lead production from lead-acid battery scrap at ZGH Orzeł Biały. During the refining of raw lead, it is cleaned of impurities (including metals, which are also contained in dust discharged by gas installations in the plant) (Poradnik…, 2010). Ebonite waste from the processing of battery scrap, gypsum from processes of electrolyte neutralization, and metallurgy slag (hazardous waste) from lead smelting are stored in the plant landfills.

The soils contaminated with cadmium (>8 mg/kg), lead (>250 mg/kg) and zinc (>1000 mg/kg) cover the area extending from Bobrowniki through Brzozowice, Brzeziny and Jutrzyny to the Arki Bożka housing area in the east, the Rojca-Buchacz-Dąbrowa Miejska-Nowy Dwór region in the west of the map sheet, and part of Radzionków and the forests along the northwest edge of the map sheet.

Soils that contain cadmium concentrations within the limits of regional geochemical background (1–2 mg/kg) in topsoil occur only locally in the upper part of the Brynica River valley. In subsoil, they are found in scattered small areas in various parts of the map sheet. Within the anomaly area (mainly around landfills), the cadmium concentration often exceeds 100 mg/kg. Almost 30% of topsoil in the map sheet area show a cadmium concentration of >15 mg/kg. These soils should be excluded from use. The maximum cadmium concentration (1,148.1–1,906.9 mg/kg) was found in soils of Brzozowice (wasteland between Konarskiego Street and the sewage treatment plant). They also contain lead 34,740–35,270 mg/kg and zinc 54,076–76,464 mg/kg. In the area of heaps (wasteland) in Brzeziny Śląskie, the cadmium concentration is 346.5–356 mg/kg, the lead concentration is 11,828–13,626 mg/kg, and the zinc concentration is 55,307–68,536 mg/kg. In the western part of the map sheet area, a high cadmium concentration was found in alluvial soils of the Szarlejka valley at Hajdy Street (278.8 mg/kg), in the vicinity of Góra Powstańców Śląskich hill in Radzionków (102.7 mg/kg), and in the forests at the northwest end of the map sheet (145.2 mg/kg).

Soils containing lead and zinc concentrations within the limits of regional geochemical background (<50 mg/kg and <100 mg/kg, respectively) occur in topsoil only in the Gajówka region and east of Kozłowa Góra. In subsoil, such concentrations are recorded over a slightly larger area in the upper part of the Brynica River valley. There are significant areas covered with soils containing >250 mg/kg lead and >1000 mg/kg zinc; some of them are arable lands. In the centre of the anomaly, >5,000 mg/kg of lead and >25,000 mg/kg of zinc were recorded.

The areas of cadmium, lead and zinc anomalies show increased contents of iron, cobalt, chromium, iron and nickel. In soils from both depth ranges, the iron content is usually within the range of 1–2%, and in the areas of the heaps, the content of 4–8% was recorded, presumably associated with the presence of its sulphides in the form of admixtures in Zn-Pb ores, as well as in coal mining tailings. In turn, iron sulphides may contain cobalt, chromium and nickel in the form of substitutions, which explains the occurrence of their increased content within iron anomalies.

In the southern part of the map sheet, both the topsoil and subsoil layers locally contain mercury (>0.20 mg/kg). The maximum mercury concentrations of 5.49 mg/kg and 11.41 mg/kg were recorded in topsoil and subsoil near the Silesia Fuel Terminal and the railway track in the Buchacz residential area in Radzionków, respectively. The presence of mercury in soils near railway track is presumably due to the use of mercury compounds in wood preservatives (to preserve railway sleepers). Soil pollution in the eastern part of the map sheet is probably related to its presence in iron sulfides, which are an admixture in Zn-Pb ores. Its increased contents in other regions may be the result of dispersion of mercury bound in mineral matter of coal during its combustion (Bojakowska, Sokołowska, 2001; Aleksa *et al*., 2007; Kabata-Pendias, Mukherjee, 2007; Hławiczka, 2008). In many cases, mercury comes from scrap of fluorescent lamps, Zn-HgO batteries, detonators, and devices formerly used in measurement and control equipment in many industries and in electrical equipment of chloride-sodium plants (Szpadt, 1994; Paulo, Strzelska-Smakowska, 2000).

Pollution by sulfur (>0.160%) is found in both topsoil and subsoil, and the areas of its anomalies are similar in terms of size. In the topsoil layer, the highest sulfur content (a maximum of 11.800%) was recorded in soils of green spaces near the Arki Bożka residential area. Approximately 2.5% of soils are characterized by the sulfur content of >2%. The spatial distribution of this element indicates the material of heaps left after Zn-Pb ore mining and zinc smelting as its source.

Widespread occurrence of arsenic, cadmium, lead and zinc compounds in soils from which they can penetrate into waters is the cause of many human diseases in various countries across the world (Kabata-Pendias, Mukherjee, 2007; Kabata-Pendias, Szteke, 2015; Migaszewski, Gałuszka, 2016). Due to the ease of accumulation and the harmful effects of excess arsenic, cadmium, lead and zinc on plants and soil microorganisms, the percentage of the sheet area polluted with these metals to different extents has been estimated (Table 6). The harmful concentration of arsenic (>100 mg/kg) is found in 9.96% of the topsoils, and 8.78% of the subsoils. The soils are very strongly polluted with cadmium, lead and zinc; 28.37% of the topsoil contains >15 mg/kg of cadmium, 23.69% of it contains >600 mg/kg of lead, and 29.58% of it contains >2000 mg/kg of zinc. At the depth of 0.8–1.0 m, the proportion of soils polluted with these metals decreases and amounts to 17.48% for cadmium, 17.23% for lead, and 21.54% for zinc.

The topsoil has been assessed in terms of the degree of pollution by metals, classifying it into the use groups of I–III and IV based on permissible contents (Rozporządzenie..., 2016). Considering the contents of arsenic, barium, chromium, zinc, cadmium, cobalt, copper, nickel, lead and mercury, from 48.53 to 100% of the analyzed soils have been classified into groups I–III (meeting the conditions of multifunctional use – residential areas, arable lands and forests). Group IV (soils that can only be used as industrial areas) is represented by 0.08%–21.89% of soils. From 1.43% to 29.58% are soils with metals and arsenic contents exceeding the standards (Table 7). In many cases, the current land use is inappropriate and requires monitoring and reclamation. The concentrations of cadmium, zinc and lead in soils of some agricultural lands are so high that these areas should not be used even for industrial purpose. An example of soil classification (in a cartographic form) according to the permissible cadmium content, indicating the proper use (in accordance with Rozporządzenie..., 2016), is presented on the map of the distribution of the content of this element (Pl. 63). Almost 1/3 of the map sheet area is covered by soils with a cadmium concentration of >15 mg/kg, which can be considered toxic.

SEDIMENTS

Bottom sediments of rivers, streams and stagnant water bodies accumulate from mineral and organic suspensions originating from erosion and precipitation of components in the waters. Their chemical composition depends on lithology, as well as on the mode of management and use of the drainage basin (Hoth *et al*., 2005; Blodau, 2006; Hrdinka, 2007; Zgłobicki, 2008; Hinwood *et al*., 2012; Cánovas *et al*., 2015).

In industrial, urbanized and agricultural areas, potentially harmful elements and organic compounds of leachates from waste dumps, industrial and municipal sewage discharged into surface water, and from surface runoff penetrate into the sediments (Ciszewski, 1997, 2002, 2005; Matschullat *et al*., 1997; Miller, 1997; Swennen, Van der Sluys, 2002; Bojakowska *et al*., 2006; Harnischmacher, 2007; Kozieł, Zgłobicki, 2010; Lagauzère *et al*., 2011; Govil *et al*., 2012; Cempiel *et al*., 2014).

Pollutants that accumulate in sediments can attain concentrations that are toxic to aquatic organisms and pose a risk to humans and animals consuming fish or molluscs feeding at sites of their occurrence. Harmful components of sediments can be re-released into water as a result of biological, chemical and physical processes (Friese, 2002; Harnischmacher, 2007), and their migration to floodplain terraces also causes an increase in the concentration of heavy metals in soils of river valleys (Ibragimow *et al*., 2010).

Within the map sheet area, the investigations covered sediments of the Brynica River, Bytomka River and Szarlejka Stream, Dąbrówka Wielka Ditch and Orzeł Biały Ditch, their tributaries, and numerous stagnant water bodies that developed as a result of underground mining. The areas of the catchments of the watercourses are schematically shown in Fig. 3.

Brynica River and its catchment. Within the map sheet limits, the Brynica River completely lost its natural features as a result of economic activity. Its tributaries, with engineered, embanked and sealed channels, are common collectors of sewage from mines, industrial plants, cities and housing estates (Program...). At the northern boundary of the study area is the Kozłowa Góra drinking water reservoir,built in 1933–1939 by damming the Brynica River channel, into which the Świerklaniec Ditch waters flow downriver of the reservoir. From the Kozłowa Góra Resoervoir to the sewage treatment plant in the Wieczorek residential area in Piekary Śląskie, the Brynica River meanders strongly, flowing in a natural riverbed. In the further course, its riverbed is channelized and lined with concrete. The riverbed was sealed to prevent water from escaping into the Triassic, strongly karstified bedrock (Czaja, 1999).

In alluvial sediments of the Brynica River and the entire drainage basin, the median value of lithogenic elements – barium, calcium, cobalt, magnesium, nickel, sulfur, strontium, titanium and vanadium – is slightly higher than the geochemical background values for the sediments of the Silesian-Cracow region (Table 4).

Compared to all alluvial sediments in the map sheet area, the Brynica River sediments distinguish themselves by a high contents of phosphorus (often >0.320%) and sulfur (>0.600%). The source of these elements is probably surface runoff from soils of the valley filled with peat deposits that can easily accumulate them within. Downstream of the sewage treatment plant at the Osiedle Wieczorek residential area, an additional source of phosphorus are sewage discharges.

Along the Wesoła-Namiarki section, the sediments of the river draining Holocene alluvial muds, which are rich in clay minerals, abound in aluminum (1.60–2.25%).

Tabela 6
Table

Udział obszarów zajmowanych przez gleby o różnych zawartościach arsenu, kadmu, cynku i ołowiu na głębokości 0,0–0,3 m i 0,8–1,0 m

The share of areas occupied by soils with different arsenic, cadmium, lead and zinc content in topsoil (0.0–0.3 m) and subsoil (0.8–1.0 m)

Pierwiastek Element	Zawartość Content mg/kg	Powierzchniowa warstwa gleb Topsoil 0,0–0,3 m		Podglebie Subsoil 0,8–1,0 m	
		Obszar/Area		Obszar/Area	
		km²	%	km²	%
As	<10	19,42	23,54	38,75	46,97
	10–25	32,31	39,16	21,59	26,18
	25–50	15,19	18,41	9,91	12,01
	50–100	7,34	8,90	4,98	6,04
	>100	8,21	9,96	7,24	8,78
Cd	<2	7,28	8,83	35,81	43,41
	2–5	19,23	23,32	14,21	17,23
	5–10	20,36	24,67	11,61	14,08
	10–15	12,20	14,79	6,42	7,78
	>15	23,41	28,37	14,42	17,48
Pb	<100	10,02	12,15	37,45	45,40
	100–200	17,24	20,90	12,91	15,65
	200–500	30,88	37,43	15,51	18,80
	500–600	4,79	5,81	2,39	2,89
	>600	19,55	23,69	14,21	17,23
Zn	<300	11,33	13,73	34,85	42,25
	300–500	9,96	12,07	7,51	9,11
	500–1000	18,74	22,71	11,14	13,50
	1000–2000	18,05	21,88	11,20	13,58
	>2000	24,40	29,58	17,77	21,54

Throughout the Brynica River drainage basin, the contents of arsenic (<3–50 mg/kg), calcium (0.50–2.50%), iron (1.60–3.20%) and magnesium (0.20–0.80%) most often remain within the limits of natural geochemical background.

Pollution of the Brynica River sediments with potentially toxic metals (cadmium, copper, lead and zinc) is recorded downstream of the Szarlejka Stream mouth, and especially downstream of the Orzeł Biały Ditch, whose sediments contain very high levels of these elements. Sediments of the upper part of the Brynica River drainage basin (from the Kozłowa Góra Reservoir to the Biały Orzeł Ditch) and downriver show the following concentrations of metals, respectively: silver <1–2 mg/kg and 2–8 mg/kg, cadmium 10–30 mg/kg and 60–130 mg/kg, lead 50–300 mg/kg and 570–750 mg/kg, and zinc 500–2,500 mg/kg and 17,720–33,190 mg/kg. The pollution source is the drainage of waste heaps from mining and processing of Zn-Pb ores and long-term zinc smelting, as well as from surface runoff from soils extremely polluted with these metals.

The mercury concentration in sediments of the Brynica River tributaries is commonly in the range of <0.02–0.20 mg/kg. Much higher levels of 0.20–0.78 mg/kg are found in the Brynica River.

The distribution of barium concentration shows enrichment in the upper part of the Brynica drainage basin (100–500 mg/kg). Downstream of the Orzeł Biały Ditch the concentration is 50–120 mg/kg, being probably the result of precipitation of its compounds due to mixing of waters of different pH and redox potential values.

Tabela 7
Table

Klasyfikacja gleb z głębokości 0,0-0,3 m ze względu na dopuszczalną zawartość pierwiastków potencjalnie toksycznych

Topsoil (0.0–0.3 m) classification according to the permissible content of potentially toxic elements

Pierwiastek Element	Wartości dopuszczalne stężeń w glebie (Rozporządzenie Ministra Środowiska z dnia 1 września 2016 r.) Permissible limit values in soil (Decree of the Polish Ministry of the Environment of 1th September 2016)			Liczba próbek /udział procentowy próbek w zależności od stopnia zanieczyszczenia Number of samples/percentage of samples according to the pollution degree		
	Grupa I–III Group I–III	Grupa IV Group IV	A	Grupa I–III Group I–III	Grupa IV Group IV	A
As	<50	50–100	>100	1075 81,13%	118 8,91%	132 9,96%
Ba	<1000	1000–1500	>1500	1323 99,85%	2 0,15%	–
Cr	<500	500–1000	>1000	1325 100%	–	–
Zn	<1000	1000–2000	>2000	643 48,53%	290 21,89%	392 29,58%
Cd	<10	10–15	>15	753 56,33%	196 14,79%	376 28,38%
Co	<100	100–200	>200	1325 100%	–	–
Cu	<300	300–600	>600	1293 97,58%	13 0,98%	19 1,43%
Ni	<300	300–500	>500	1324 99,93%	1 0,08%	–
Pb	<500	500–600	>600	934 70,49%	77 5,81%	314 23,70%
Hg	<10	10–30	>30	1325 100%	–	–

Grupy I–III Group I–III – obszary zabudowy mieszkaniowej, użytków rolnych i lasów; agricultural, forest and residential areas

Grupa IV Group IV – obszary przemysłowe; industrial areas

A – obszary o zawartości ponadnormatywnej; areas with oversized content

Bytomka River and its catchment. The upper reach of the Bytomka River, called Bytomska Woda, starts its course near the Bytom-Karb railway station and is recharged mainly with underground water from mines (Cempiel *et al.*, 2014). The river flows across urban areas, and in places in a deep valley with water bodies and wetland meadows. Within the area of the upper part of the Bytomka River catchment (beyond the western boundary of the map sheet), the industrialized and urbanized part of Bytom is situated. It is also the area where shafts and settling ponds of the inactive Szombierki and Rozbark coal mines, the active Bobrek mine, and the Bytom railway station are located. Some of the pollution in the Bytomka Stream sediments may come from these sources. Earlier studies showed significant pollution of the sediments with chromium, cadmium, zinc, lead and copper (Nocoń, 2009; Cempiel *et al.*, 2014).

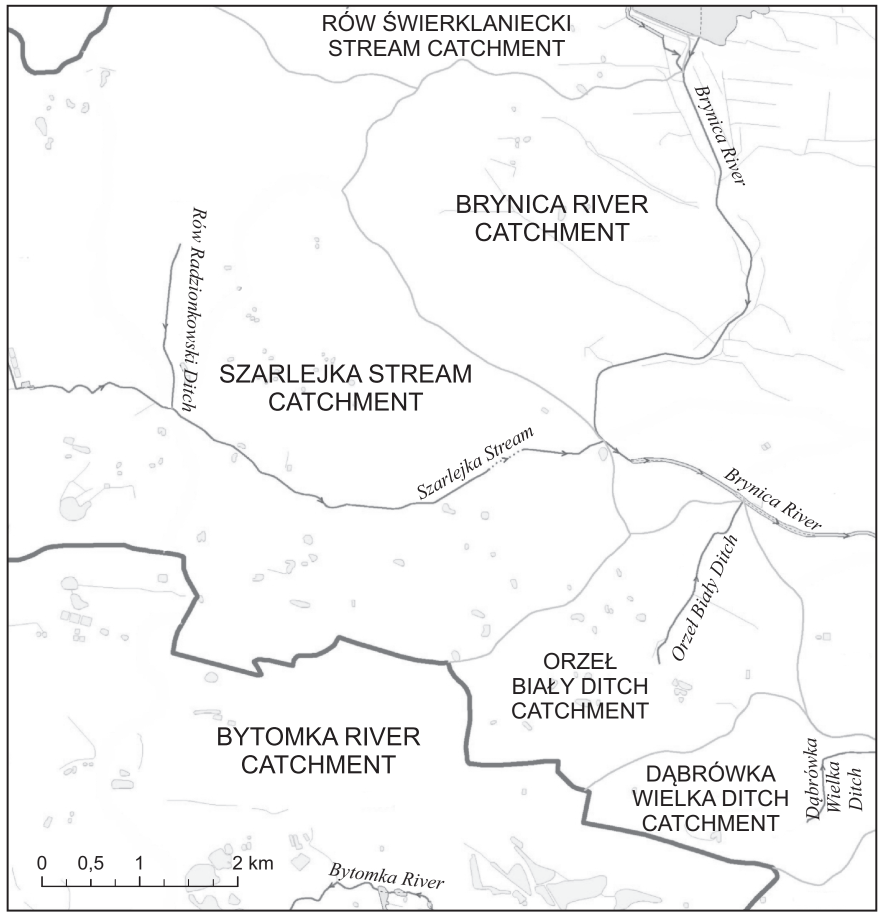

Fig. 3. Location of watercourses and stagnat water reservoirs and catchment areas (according to Mapa...)

In the alluvial sediments of the analyzed river course, the accumulation of lithogenic elements – calcium, cobalt, chromium, iron, magnesium, manganese, nickel, sulfur and vanadium, is three or more times greater than the geochemical background level in the sediments of the Silesian-Cracow region (Table 4). The sediments also show a very clear enrichment with manganese and strontium.

The sediments of the Bytomka River, its tributary the Graniczny Potok Stream, and especially the stagnant water bodies in its drainage basin at the southern boundary of the map sheet area, are heavily polluted with metals. In the vicinity of the Mickiewicz Park in Bytom, the sediments of small reservoirs contain: silver up to 8 mg/kg, arsenic 760 mg/kg, cadmium 126 mg/kg, chromium 471 mg/kg, iron 37.61%, nickel 162 mg/kg, lead 2,810 mg/kg, and zinc 29,590 mg/kg. The probable source of these elements is the drainage of old waste heaps from Zn-Pb ore mining and iron smelting. In this region, the Bytomka River is recharged by the Graniczny Potok Stream that transports sediments from water bodies of the Żabie Doły Natural and Landscape Complex, where waste from zinc and lead ore flotation were stored (Cempiel *et al.*, 2014).

Sediments of the upper course of the Bytomka River (from the Metals Company Bobrek to Małgorzatki Street in Bytom) are polluted by cadmium (up to 78 mg/kg), copper (up to 1,539 mg/kg), mercury (up to 5.22 mg/kg), lead (up to

1,053 mg/kg) and zinc (up to 3,041 mg/kg). They also contain 504 mg/kg – 12,760 mg/kg of manganese.

Dąbrówka Wielka Ditch. The chemical composition of sediments of this minor watercourse is affected by the drainage of the catchment area polluted by the production of ZGH Orzeł Biały (Chrobok, 2009). The alluvial sediments are polluted with arsenic (up to 321 mg/kg), cadmium (up to 791.1 mg/kg), cobalt (up to 131 mg/kg), copper (up to 403 mg/kg), nickel (up to 1,307 mg/kg), lead (up to 3,080 mg/kg) and zinc (up to 62,660 mg/kg). Moreover, they are enriched in calcium (up to 20.84%), iron (up to 4.68%) and manganese (up to 3,832 mg/kg).

The sediment pollution is caused mainly by the weathering of waste heaps from which potentially toxic elements migrate into the environment in the form of both primary and secondary mineral phases. This is proved by studies from other regions of the world. Analyzes of river sediments into which leachate flows from landfills of post-flotation metal ores (Au, Ag, Cu, Pb, Zn) in Mexico showed that about 30% of cadmium and lead and up to 75% of arsenic in the sediments are in primary mineral forms, and their arsenic, cadmium and lead concentrations in the vicinity of the landfills reach 32,000 mg/kg, 514 mg/kg and 30,000 mg/kg, respectively (Rodriguez-Hernandez *et al*., 2021).

Szarlejka Stream and its catchment. The stream, which is a tributary of the Brynica River, is channelized along a considerable length, and some of its sectors run in an underground tunnel. The Szarlejka Stream valley is covered with post-mining and metallurgical heaps (Pl. 1) and deformed with troughs that formed as a result of historical exploitation of Pb-Zn ores, limonite and hard coal. Wastewater, municipal water and underground water from coal mines are discharged into the stream. The Szarlejka Stream is fed by the Radzionków Ditch being its left-bank tributary flowing through the centre of Radzionków. It is channelized and covered along its entire length, and carries domestic sewage to the Centralna sewage treatment plant in Bytom (Szadkowska, Gwóźdź, 2015).

The contents of most of the elements analyzed in the drainage basin sediments is approx. twice as high as the geochemical background value for the Silesian-Cracow region (expressed as medians) (Table 4).

The Szarlejka River sediments contain high levels of metals present in Pb-Zn ores: silver 2–8 mg/kg, cadmium 2.3–29.2 mg/kg, lead 128–6,775 mg/kg, and zinc 381–5,073 mg/kg. High accumulation of these elements, as well as arsenic (up to 213 mg/kg), was also recorded in sediments of minor water bodies in the Szarlejka Stream drainage basin (in wastelands at Żołnierska Street, near the heat plant, and near Kocie Górki in Radzionków). The cadmium concentration here is 100.5 mg/kg, lead 2,362 mg/kg, and zinc 11,930 mg/kg. Pollution with potentially toxic elements is of anthropogenic nature in the drainage basin sediments and is caused by the activity of open-pit calamine mines and zinc foundries in Radzionków (Krawczyk *et al*., 2002).

The composition of the drainage basin sediments is marked by high accumulation of barium in samples from the Radzionków Ditch (423–682 mg/kg), which originates probably from surface runoff from barium-rich soils in the drainage basin of this watercourse.

Stagnant water bodies. At the southern boundary of the map sheet area (limited to the north by Siemianowicka Street and from the west by Chorzowska Street) there are Zn-Pb ore flotation ponds left. Some of them, located on the border of Bytom, Chorzów and Piekary Śląskie, are called the Żabie Doły Nature and Landscape Complex, established mainly to protect water birds. On the surface and under a thin cover of Neogene deposits, there are Triassic ore-bearing dolomites containing zinc and lead ores (Wyczółkowski, 1957). They were mined and processed as early as the 12th century, and the extraction of the ores was accompanied by the formation of flotation waste tailings and sinkholes. Since around 1860, the Biały Szarlej zinc and lead ore mine had operated in this area. At the final stage of its activity (1989), it was transformed into Zakłady Górniczo-Hutnicze (ZGH) Orzeł Biały Company (Machowski, 2010). The largest waste heap of ZGH Orzeł Biały was located north of the Żabie Doły reservoirs. Other heaps of zinc-lead ores from their historical mining are scattered and today almost invisible in the topography of the area, but they are the feature polluting the environment.

After the 1920s, the first of the reservoirs were used as settling tanks for waste collected as a result of Zn-Pb ore flotation processes of operating plants. In their surroundings, heaps of post-production waste existed. More reservoirs were created in the 1950s. In the past, the reservoirs were separated by railway embankments.

The concentration of heavy metals and sulfur in the sediments of these reservoirs is very high. The maximum concentration of silver is 128 mg/kg, arsenic 2,974 mg/kg, cadmium 9,695 mg/kg, copper 1,539 mg/kg, iron 4.42%, nickel 475 mg/kg, lead 27,190 mg/kg, sulfur 13.780%, and zinc 69,330 mg/kg.

Other reservoirs containing very highly metal-polluted sediments are clustered in the upper part of the Orzeł Biały Ditch drainage basin (near the ZGH Orzeł Biały mine heaps). In this area, the concentrations are as follows: silver 10 mg/kg, arsenic 1,740 mg/kg, cadmium 150 mg/kg, copper 7,922 mg/kg, lead 5,637 mg/kg, and zinc 29,290 mg/kg.

Sediments of small reservoirs located in the northwestern part of the map sheet area (Sucha Góra region) are polluted by Zn-Pb ore association elements. They contain arsenic (up to 114 mg/kg), cadmium (up to 427.2 mg/kg), lead (up to 3,705 mg/kg) and zinc (up to 59,190 mg/kg).

SURFACE WATER

Anthropogenic impact on water resources has the quantitative (change in water conditions), qualitative (water pollution, changes in chemistry) and topographical (transformation of watercourse channels and water body basins) aspects. Consequently, adverse changes have ecological effects, such as disturbance of habitat conditions, disappearance of certain species, and reduction in biodiversity (Bańkowska, Sikora, 2010).

The chemistry of water discharged from industrial plants to the watercourses was different in different periods. Until the last years of the 20th century, when the dominant mining sector was the extraction of Zn-Pb ores, waters and sediments were polluted primarily with metals. After World War II, coal mining was becoming more and more important, resulting in discharging mine waters rich in chlorides, sulfates lithium, sodium, potassium and uranium into the rivers and streams (Aktualizacja…, 2011, 2012). Currently, the pollution of waters with phosphates discharged into waters from sewage is increasing.

The studies of waters comprised their chemical composition, specific electrolytic conductivity and acidity. In order to compare and facilitate the assessment of the quality of the waters, the content of their individual components, and the values of statistical parameters and indicators of surface water quality, which are used in Poland, are presented (Rozporządzenie..., 2019) (Table 5). The table also demonstrates the values of indicators for mineral waters and drinking waters in accordance with the EU recommendations (EU Directive 1998/83/EC; EU Directive 2009/54/EC).

The pH value of water in the watercourses and stagnant water bodies from the map sheet area only sporadically exceeds the recommendations for class I and II waters (Table 5). On the other hand, their mineralization, signaled by EC values, many times exceeds the value of 0.45 mS/cm, assumed as the limit value for class II waters (Rozporządzenie..., 2019). The high electrolytic conductivity value of water is caused by the discharges of hard coal mine waters, municipal sewage, and industrial sewage from metallurgical plants.

Brynica River and its catchment. The river flows through the areas of Miasteczko Śląskie and Świerklaniec and through the Kozłowa Góra dammed reservoir, which serves as a water supply to the water treatment station of the Górnośląskie Przedsiębiorstwo Wodociągów company.

The pH of the drainage basin waters is commonly 7.5–8.5, falling within the range of this indicator for class II waters (Rozporządzenie..., 2019). The drainage basin waters are characterized by high variability of EC values. In the Brynica River, upstream of the Szarlejka Stream mouth, and in its left-hand tributaries, the EC is in the range of 0.12–0.60 mS/cm. In the watercourses that drain the Carboniferous outcrops in the Kozłowa Góra region and downstream of the Szarlejka Stream mouth, the EC varies from 0.93 to 1.48 mS/cm. The increased EC value in the watercourses of the Lipka-Kozłowa Góra region results mainly from the concentrations of boron (0.20–0.40 mg/dm^3), calcium (100–140 mg/dm^3) and sulfates (200–250 mg/dm^3). Their natural sources are the outcrops of Carboniferous claystones and mudstones with coals, subjected to erosional processes.

The contents of lithogenic elements in waters remain at a similar level across the entire drainage basin. The most frequently reported ones are: arsenic 2–3 µg/dm^3, barium 0.060–0.120 mg/dm^3, calcium 50–100 mg/dm^3, potassium <50 mg/dm^3, lithium <40 mg/dm^3 and silica <10 mg/dm^3.

The Brynica River waters are polluted with some components by the waters of its tributaries. Sodium and phosphorus are sourced from the Szarlejka Stream waters. Upstream and downstream of its mouth, the concentrations are <20 mg/dm^3 and 120–240 mg/dm^3 of sodium, and <0.05 mg/dm^3 and >0.25 mg/dm^3 of phosphorus, respectively. Upstream and downstream of the mouth of the Orzeł Biały Ditch, the levels in the Brynica waters are as follows: cadmium <0.05 and up to 0.27 µg/dm^3, sulfates 120–150 and 380–990 mg/dm^3, and thallium <0.05 and 1.55–6.41 µg/dm^3, respectively. The sources of pollution of the waters from the Orzeł Biały Ditch are underground water from the Orzeł Biały mine, water from the Staw 10 treatment plant, underground water from the ZG Bytom II mine, municipal wastewater from Montomet firm, and waters from mine water settling pond of the Orzeł Biały mine (Program...; Zmiana...).

In the catchment, a specific elemental composition is found in the waters of an unnamed watercourse draining the Gajówka region (in the northeastern edge of the map sheet area). Accumulations of aluminum (>400 µg/dm^3), beryllium (0.35–0.62 µg/dm^3), cadmium (13.3–34.9 µg/dm^3), iron (9.55–2.25 mg/dm^3) and lead (11–39 µg/dm^3), as well as increased contents of cobalt, manganese, nickel, thallium and zinc, have been recorded there. The drainage basin of this watercourse is covered with Quaternary glaciofluvial sands and gravels and deluvial-fluvial deposits, but the composition of the waters indicates that we cannot rule out the local Zn-Pb mining as a pollution source in this area.

Bytomka River and its catchment. The Bytomka River drainage basin covers the southwestern part of the map sheet area. The analyzed river sector is characterized by the lack of natural tributaries and the channel is sealed almost along its entire length. It is recharged by ditches and wastewater collectors, and there are many subsidence ponds, and settling and flotation tanks in the drainage basin. The Bytomka River waters are polluted by wastewater from the sewage treatment plant in Bytom (at Małgorzatki Street), runoff from the Bytom Główny railway station area, and the waters from the drainage of facilities in the closed Szombierki hard coal mine.

The river water is alkaline (pH 8.0–8.6), and the fluctuations of this indicator are in the range of 4.5–9.0 in the drainage basin. The specific electrolytic conductivity of the waters is in the range of 2.83–7.51 mS/cm, which proves their strong mineralization caused by the inflow of mine waters and municipal sewage.

The Bytomka River waters are polluted primarily by a population of components from mine dewatering: boron (up to 2.70 mg/dm^3), potassium (up to 58.3 mg/dm^3), lithium (up to 415.0 µg/dm^3), sodium (up to 1,532.6 mg/dm^3) and sulfates (up to 1,313 mg/dm^3). They are also rich in magnesium and calcium from the same sources, and poor in arsenic (5–6 µg/dm^3) and barium (up to 0.028 mg/dm^3).

Dąbrówka Wielka Ditch. The electrolytic conductivity values range from 0.31 to 0.79 mS/cm and the pH is 7.6–9.7 in the ditch waters. They are characterized by an increased concentration of copper (up to 16.04 μg/dm^3), molybdenum (up to 19.90 μg/dm^3), lead (up to 63.68 μg/dm^3), antimony (up to 7.45 μg/dm^3) and selenium (up to 35 μg/dm^3).

Orzeł Biały Ditch. The water of the watercourse is highly polluted by thallium (6.22–6.29 μg /dm^3), cadmium (9.83–10.01 μg/dm^3), zinc (8.61–8.73 mg/ dm^3) and sulphates (up to 1000 mg/dm^3). Below the estuary of the ditch to the Brynica River, anomalies of the above-mentioned elements are also visible in its waters, which in this section belong to non-class waters.

Szarlejka Stream and its catchment. The stream waters are characterized by the electrolytic conductivity value in the range of 0.38–3.73 mS/cm and the pH of 8.3–8.9. They are slightly enriched in metals, the main source of which is probably the drainage of bedrock. These include molybdenum in the upper reach of the stream (5.09–5.29 μg/dm^3), and cobalt (0.40–0.90 μg/dm^3) downstream. Municipal wastewater discharge results in the water pollution by phosphorus, the concentration of which ranges most often from 2.17 to 2.64 mg/dm^3.

Stagnant water bodies. In the water bodies located at the southern boundary of the map sheet, the EC value varies considerably, ranging from 0.20–0.50 mS/cm in some of them to 0.60–3.50 mS/cm in others.

Not only do the EC values vary, but also the contents of the analyzed elements. The water bodies in the eastern part of the Bytomka River drainage basin store mostly water containing high levels of calcium (>400 mg/dm^3) and magnesium (>160 mg/dm^3). They are polluted by cadmium (up to 182.05 μg/dm^3), cobalt (up to 154.34 μg/dm^3), copper (up to 32.58 μg/dm^3), iron (up to 89.92 mg/dm^3), potassium (up to 373.3 mg/dm^3), lithium (up to 415.0 mg/dm^3), nickel (up to 2,972.9 μg/dm^3), lead (up to 541.03 μg/dm^3), antimony (up to 88.81 μg/dm^3), sulfates (up to 2.450 mg/dm^3), thallium (up to 100.53 μg/dm^3) and zinc (up to 38.588 mg/dm^3). The source of these pollutants are leachate from zinc metallurgy waste heaps and industrial sewage discharges after this production

The pollution level in the waters of reservoirs within the Dąbrówka Wielka Ditch drainage basin (near the waste dump in the Jutrzyny residential area) is particularly high. They contain extreme concentrations of cadmium (up to 1,084.70 μg/dm^3), cobalt (up to 179.39 μg/dm^3), copper (up to 140.53 μg/dm^3), potassium (up to 559.2 mg/dm^3), lithium (up to 647.9 mg/dm^3), molybdenum (up to 25.50 μg/dm^3), sulfates (up to 2,602 mg/dm^3) and thallium (up to 150.31 μg/dm^3). They are also rich in calcium and magnesium.

CONCLUSIONS

1. Anthropogenic sources of pollution in the natural environment of the map sheet area are: historical mining of zinc and lead ores, historical zinc smelting, production of lead from lead-acid battery scrap at the ZGH Orzeł Biały Company, mining of hard coal, impact of industrial waste dumps (gangue, slags, settling tanks, coal sludge, and other sludge) mine water discharges, urbanization and transport.

2. The lithology of parent rocks of the soils reflects itself in their grain-size composition. The soils that developed on glaciofluvial deposits abound in the sand fraction, while those formed on carbonate rocks and anthropogenic covers are rich in the silt and clay fractions.

3. The chemical composition of the soils has been significantly modified by anthropogenic factors, and their natural components are mixed with foreign materials, often reworked many times, soaked with saline mine waters, and dried.

4. The distribution of the contents of elements (aluminum, barium, calcium, cobalt, magnesium, manganese, nickel, phosphorus, strontium, sulfur, titanium and vanadium) in the soils, which are sourced from the parent rocks, is disturbed by anthropogenic effects. A clear relationship between the bedrock chemistry and the soils is marked mainly in the outcrops of Triassic carbonates, where the soils abound in calcium, magnesium, iron and manganese.

5. The acidity depends mainly on the mode of soil use. In both the topsoil and subsoil, neutral and alkaline soils predominate, occupying larger areas in the subsoil (0.8–1.0 m). Alkalization is caused by dust fall, mainly due to coal combustion for heating and industry purposes, as well as by the use of building materials abundant in calcium.

6. In the areas of historical mining of zinc and lead ore deposits and zinc smelters, in the area of the inactive Bobrek ironworks and the ZGH Orzeł Biały Company, and in the vicinity of heaps and dumps due to their activities, strong anthropogenic anomalies of silver, arsenic, cadmium, copper, sulfur, lead and zinc are observed in the soils. Strongly contaminated soils with these metals are found in both the western (Buchacz-Dąbrowa Miejska-Nowy Dwór region) and eastern (from Brzozowice through Brzeziny and Jutrzyny to the Arki Bożka residential area and Żabie Doły) parts of the map sheet area.

7. The pollution of the sediments and surface water is anthropogenic in nature. Its source is the discharges of underground water from active and closed hard coal mines, industrial and municipal sewage, as well as the drainage of post-mining and metallurgical waste heaps.

8. The sediments of most of the watercourses and stagnant water reservoirs are heavily polluted by metals due to the historical exploitation of zinc and lead deposits, historical zinc smelting, the recent lead production from lead-acid battery scrap at the ZGH Orzeł Biały Company (arsenic, zinc, cadmium, copper, lead, silver and iron), and the discharges of mine, industrial and municipal waste waters. The most heavily polluted sediments are found in settling tanks left after the flotation of Zn-Pb ores.

9. The surface waters are characterized by high variability in terms of the content of chemical elements, acidity and electrolytic conductivity. The salinity of most watercourses is associated with discharges of mineralized mine water. Water discharged from hard coal mines causes pollution with barium, boron, chlorine, potassium, lithium, molybdenum, sodium, strontium, sulfates, rubidium, thallium and antimony. In the areas of landfills from mining of zinc and lead ores and their processing, the water are polluted with arsenic, antimony, cadmium, cobalt, copper, nickel, zinc, lead and thallium. They are also rich in calcium, iron, manganese and sulfates.

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