Szczegółowa mapa geochemiczna Górnego Śląska

Detailed geochemical map of Upper Silesia

1:25 000

Arkusz
Sheet **BYTOM**

Redaktorzy
Editors *Anna Pasieczna Agnieszka Konon*

Państwowy Instytut Geologiczny
Państwowy Instytut Badawczy
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Autorzy: Anna Pasieczna, Katarzyna Strzemińska, Agnieszka Konon, Kamil Bala, Angelika Szczypczyk

Recenzent: prof. dr hab. Izabela Bojakowska

Tłumaczenie: Krzysztof Leszczyński

Redakcja: Monika Masiak

Skład: Łukasz Borkowski

Projekt okładki: Łukasz Borkowski na podstawie projektu serii Wojciecha Markiewicza

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INTRODUCTION

Geochemical mapping at the scale of 1 : 25,000 for the map sheet Bytom M-34-50-D-c 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 the Climat and Environment).

The major part of the map sheet area covers the cities of Bytom and Zabrze. This region is located in the northwestern part of the Upper Silesian Industrial District (USID, GOP in Polish), which is one of the most industrialized and urbanized areas in Poland.

Both historical and contemporary mining of hard coal and the historical mining of Zn-Pb ores are the main factors that affected the condition of natural environment. Activities of these industries, which were developing most intensely in the 19th and 20th centuries, resulted in the pollution of soils, stream and river sediments, and surface water with metals, arsenic and sulphur (Lis, Pasieczna, 1995a, b, 1997). As a result of modern economic transformations, many of the environmentally burdensome and water-consuming mining-related companies have been closed down or modernized.

Despite the industrial type of the study area, there are also valuable natural objects. On the border between Bytom and Tarnowskie Góry, there is the Segiet nature reserve for beech forest protection, and the Suchogórski Rock Labyrinth, with preserved traces of historical Zn-Pb ore mining. Near the reserve, there is an underground tunnel system (Podziemia Tarnogórsko-Bytomskie), protected as a wintering site for bats under the Natura 2000 network.

The results of geochemical research presented in a cartographic form with the explanatory text and tabular summaries, depict the current quality of soils, sediments of inland water reservoirs, and surface water, and 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 quality tests of soils as part of state monitoring.

The geochemical data from the study should also be used in the preparation of registers of historical pollution maintained by the General Directorate for Environmental Protection (in accordance with the EPL Act) and in conducting Environmental Impact Assessments (in particular for the cumulative impact assessment).

The 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;
- **T. Kołecki, W. Markowski** – 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. Kałwa –** 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. Kałwa, 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 SHEET AREA

Geographic and administrative location. The Bytom M-34-50-D-c map sheet covers the area located in the Silesian Upland within the lower-rank unit called the Katowice Upland (Kondracki, 2009).

The study area is part of the Silesian urban-industrial agglomeration located in the central part of the Silesian Voivodeship. Within its limits, there are districts of cities with poviat rights: Bytom (Sucha Góra, Stolarzowice, Miechowice, Karb, western parts of the Stroszek and Szombierki districts) and Zabrze (Grzybowice, Rokitnica, Mikulczyce and Biskupice). The northern part of the map area belongs to the Tarnowskie Góry poviat and includes parts of the Tarnowskie Góry and Zbrosławice communes (Pls. 1–63).

Topography, geomorphology and hydrography. The ground surface in the map sheet area generally descends towards the south-west (from 346 m a.s.l. in the Segiet Reserve and 340 m a.s.l. on the Cipiorg Hill to 250 m a.s.l. in the lower reach of the Potok Mikulczycki Stream).

In many places, the natural topography of the area is strongly transformed as a result of mining activity over centuries. A characteristic feature of the relief altered due to the mining of Zn-Pb ores in the northeastern part of the map sheet area are numerous anthropogenic forms: heaps, humps, troughs, embankments, pits and ditches. In the same area, dolomite was mined in the Blachówka and Lazarówka quarries.

In the south of the map sheet area, there are several tens of open pits or sinkholes that formed as a result of hard coal mining. They are filled with ponds, the largest of which is the Brantka subsidence pond located on the border of Miechowice and Karb.

Most of the map sheet area is located in the Odra River catchment. The northeastern part is the only area drained by the Seget (Segiet) Stream that belongs to the Vistula River drainage basin. The hydrographic network is altered by a variety of industrial activities and by the engineering and canalization of riverbeds, degrading their valleys. The Potok Mikulczycki, also known as the Potok Rokitnicki Stream in the upper course, and as the Potok Żernicki Stream in the lower course, flows through the central part of the map sheet area. The upper part of the Potok Mikulczycki Stream catchment is characterized by a dense network of tributaries, natural in character. The stream, flowing into the Bytomka River, is fed by the streams of Dopływ spod Górników and Dopływ w Mikulczycach. Part of its drainage basin is in many places densely built-up, and its tributaries are engineered and canalized (Cempiel *et al*., 2014). The western part of the map area is drained by the streams of Dopływ z Ptakowic and Potok Grzybowicki (in the Drama River drainage basin).

Building and land use. Unbuilt areas occupy about 75% of the map sheet. These are mainly forests covering the valleys of the Potok Rokitnicki and the Seget streams in the central-eastern part of the study area, and agricultural land in the west (Pls. 2 and 3). Other unbuilt areas include roadside green belts, city lawns and parks, allotment gardens, water bodies, and railway areas.

The areas occupied by residential, service (services and trade) and industrial development (infrastructure of hard coal mines, transport bases) are located mainly in the south-eastern region of the map sheet. As regards the built-up areas, low-rise urban development predominates (16% of the map sheet). High-rise urban development covers 4%, and industrial areas account for 5% (mines, foundries, metal plants, landfills and waste dumps).

Economy. The near-surface occurrence of Zn-Pb ore deposits enabled their extraction in the northeastern part of the map sheet area (present-day Segiet Reserve, Cipiorg Hill, and Sucha Góra) already since the 1620s (Molenda, 1960, 1972; Grzechnik, 1978; Majorczyk, 1986). Galena mines were also active in Zbrosławice and Ptakowice (Urząd...). The historical regions of Zn-Pb ore mining are the Hipolit mining area (south of the Segiet Reserve), in which there were 30 mineshafts (Krisowe szlaki ...), and the Planeta forest area in Repty Stare, where the Planet-Grube mines (Jędrzejczyk-Korycińska, 2009) and Verona-Grube (Geognostische Karte…) were built.

The earliest exploitation was limited mainly to the extraction of silver-bearing galena. In the 19th and 20th centuries, calamine, limonite and dolomite were also mined (Tarnowskie Góry...). In the Tarnowskie Góry-Bytom region, the number of mineshafts in the years 1529–1627 was about 20,000 (Kerber, 1977). From the second half of the 19th century to 1914, the extraction of galena was carried out in the following localities: Piekary Rudne (202 mineshafts), Ptakowice (277 mineshafts), Sucha Góra (54 mineshafts), and Stolarzowice (4 mineshafts) (Chrobok, 2009).

In the south and east of the map sheet area, hard coal has been mined for many years in the Pstrowski, Miechowice and Bobrek mines. Currently, the KWK Bobrek-Piekary mining company has been created as a result of the merger of the Piekary and Bytom mines, in which coal mining is planned until around 2030 (Węglokoks…).

GEOLOGY AND MINERAL DEPOSITS

Most of the map area is located within a structural unit called the Bytom Trough, which is the northern portion of the Upper Silesian Coal Basin (USCB). It is part of the Paleozoic Variscan structure, cut by numerous faults. Carboniferous, Permian, Triassic, Neogene and Quaternary deposits have been found here (Buła, Kotas, 1994). The study area has a rich history of geological research due to the presence of metal ores, hard coal, and rock raw materials.

The coal-bearing **Carboniferous** basement is represented by the Malinowice Beds (Namurian A – Visean). These are clastic terrigenous sediments with numerous levels of marine fossils, composed mainly of clay-muddy rocks with interbeds of fine-grained sandstones.

The coal-bearing Carboniferous deposits occur at a depth of approx. 200–1600 m. They constitute a complex of claystone-mudstone-sandstone rocks that represent the Marginal Beds of the Upper Carboniferous Paralic Series (Namurian A), the Upper Silesian Sandstone Series of the Upper Namurian (Namurian B and C), and the Lower Westphalian Mudstone Series (Westphalian B).

The Paralic Series is composed of sandstones and claystone-mudstones interbedded with thin coal seams, coaly shales, and occasional sapropelic shales. They were deposited in terrestrial and nearshore environments with periodic marine inundations, as evidenced by the presence of beds containing marine fossils in the section, accompanied by numerous intercalation yielding freshwater fossils. A characteristic feature of this series is its sedimentary cyclicity. The maximum thickness of the Paralic Series in the axis of the Bytom Trough (in the southern part of the map area) is about 1000–1100 m; it wedges out towards the north.

The Upper Silesian Sandstone Series is represented by limnic and deltaic deposits – sandstones, conglomerates, mudstones and claystones with hard coal seams. Their thickness is up to 600 m in the southeastern area. The section consists of two lithostratigraphic units: the Saddle Beds and the Ruda Beds, overlying unconformably the Paralic Series (Kotas, Malczyk, 1972). The top of the sandstone series is marked by the last level containing freshwater fossils, which accompanies the hard coal seams of 407 and 408 that are the most important correlation levels in the USCB (Dybova, Jachowicz, 1957). Approximately 60 hard coal seams have been counted within the series (Jureczka, Kotas, 1995), each about 4–8 m in thickness.

The Mudstone Series consists of mudstones, claystones and sandstones with numerous hard coal seams, up to 1.5 m thick. These deposits, attaining a thickness of 150 m, occur only in the southeastern part of the map area. The bottom portion of the series is represented by the Załęże Beds that correspond in age to the Westphalian A, and its top part consists of the Orzesze Beds included in the lower Westphalian B. The boundary between the Westphalian A and Westphalian B is marked by a tuff level of seam 327 (Porzycki, 1972). The series is overlain by Triassic rocks (Buła, Kotas, 1994).

Permian sandstones, conglomerates, claystones and mudstones occur only at the northern boundary of the map sheet area and fill the tectonic graben of the Tarnowskie Góry Trough. It is part of a larger unit, the Sławków Graben, which forms the northern and northeastern boundary of the USCB (Siedlecka, 1964; Kiersnowski, 1991). The Permian deposits are represented by cherry-coloured mudstones with pyrite concentrations, as well as sandstones and marls that pass into clay shales, overlain by a series of conglomerates and sandstones. The conglomerates contain pebbles of Devonian limestones, quartzites, porphyries and melaphyres. The presence of tuff was reported from their cement (Żero, 1968). The total thickness of the Permian molasse in the map sheet area does not exceed 100 m.

In most of the study area, the Carboniferous succession is overlain by **Triassic** rocks. Their variable thickness, constrained by both the tectonic setting and relief of the top surface of the Carboniferous succession, ranges from several tens of metres in the southern part of the research area to about 200 m in the east.

The Lower Triassic deposits overlie the erosionally truncated Upper Carboniferous and occur under the Middle Triassic rocks. Their stratotype section has been described in the Świerklaniec region (Świerklaniec map sheet, NE of the Bytom sheet) as the Świerklaniec Beds. These are terrestrial rocks composed of sands clays and sandstones, locally conglomeratic, grading into mudstones and claystones. Their thickness ranges from several to over 40 m.

The complete Middle Triassic section is represented by a characteristic epicontinental facies called the Muschelkalk. These deposits are exposed in the north and in the southeastern region of the map area, forming a string of fragmented outcrops (Pl. 1) marked in the relief by a chain of hills.

The terrigenous Świerklaniec Beds are overlain unconformably by marine deposits, previously referred to as the Röt. These are mainly dolomitic limestones, marly dolomites, dolomitic marls, sandy marls, and occasional cavernous limestones. The thickness of these deposits is variable and ranges from 30–50 m in the study area.

The marly-dolomitic series is overlain by limestones assigned to the Błotnica Beds and the Gogolin Beds, with a total thickness of 40–60 m. The Gogolin Beds are overlain by Zn-Pb ore-bearing dolomites, 20–40 m in thickness, with a maximum in the Tarnowskie Góry Trough (in the northeastern part of the map sheet area). They are composed of crystalline dolomites, and less frequent limestones that occur mainly in nests. These epigenetic rocks formed as a result of hydrothermal alteration of limestones, mainly of the Górażdże, Terebratula and Karchowice beds. They are characterized by intense fracturing and the presence of irregular cavities, often filled with lead, zinc and iron sulfides. In outcrops, oxidized sulfides concentrate in calamines and iron ore (limonite) nests.

Limestones and marls of the Górażdże, Terebratula and Karchowice beds, which occur above the ore-bearing dolomites, are included by Kotlicki (1995) in the Kalinowice Formation. In the study area, this formation has undergone metasomatosis almost completely and is part of the Zn-Pb ore-bearing dolomites. Light grey crystalline limestones with hornstones, of the Górażdże Beds, about 20 m thick, are exposed on the surface south of Zbrosławice. On the surface in the research area, deposits of the Karchowice Beds have been found in an inactive quarry near Mikulczyce (extreme southern part of the map sheet area).

Due to the difficulties in separating the diplopora dolomites from the Tarnowice Beds dolomites in the Triassic section over most of the map sheet area, both are shown as undivided deposits. The diplopora dolomites are included in the Jemielnica Beds, occur on the surface near Bytom, and reach a maximum thickness of 30 m, while the dolomites and limestones of the Tarnowice Beds are up to 20 m thick.

The **Neogene** succession is composed of regoliths accumulated mainly in karst sinkholes and chimneys developed at the top of Triassic carbonates, as well as clays, muds, sands and marls representing coastal zone deposits of a Miocene sea. The karst sinkholes range in diameter from several to even hundreds of metres. They are filled with clays, sands, muds and loams of variegated colours, as well as with limonite ores and calamines that were subject of intense exploitation in the 19th century in the Sucha Góra and Stolarzowice regions. These deposits also occur in the Blachówka quarry and in several boreholes, reaching a thickness of several metres.

Quaternary deposits cover approx. 90% of the map sheet area (Pl. 1). Their lithology is constrained by the sub-Quaternary relief, and their distribution and thickness increase towards the south.

Deposits of the South Polish glaciations fill mainly the bottom of the Bytomka River fossil valley. These are glaciofluvial sands and gravels, up to 25 m in thickness, as well as clays and muds of ice-dammed lakes, up to 10 m thick, covered mostly by a till layer.

The majority of the area is covered by sediments of Middle Polish glaciations. These are ice-dammed lake clays and muds, glaciofluvial sands and gravels, and glacial tills containing pebbles of crystalline rocks or limestones and quartz. Sand, gravels, muds and glacial tills of kame flows are occasionally found (in the Sucha Góra region). There are also sands, gravels, boulders and tills of end moraines, building the hills near Stolarzowice, Ptakowice and Grzybowice, which mark the ice-sheet standstill zone during its maximum range.

The undivided Quaternary deposits are mainly weathering (eluvial) mantles of sands, loams and muds on glacial tills, up to 4 m thick, as well as sands, gravels and fluvial-deluvial muds in the bottoms of dry valleys. The Holocene sediments of river valleys are represented by fluvial sands, gravels and muds of floodplain terraces, up to 8 m thick, and alluvial muds of valley bottoms (sandy muds abounding in humic substances).

Mineral deposits. Currently, 14 mineral deposits have been documented in the map sheet area, including nine multi-seam coal deposits, two clay deposits for construction ceramics, one dolomite deposit, one limestone deposit, and one sand deposit (Szuflicki *et al*., 2020). They are located mainly in the eastern part of the map sheet.

The first small **hard coal** mines operated here in the already in the mid-19th century. Some of them were established on the site of mining plants that had previously extracted calamine. Due to both the depletion of this raw material at the end of the 1850s and the increasing demand for energy resources, the mines started to extract hard coal. An example is the Karsten-Zentrum mine (Dymitrow after 1945, later Centrum), which was established in 1881 as a result of merging several fields of small mines, and originated from the former Teresa calamine mine. In later years, the number of mines and the hard coal production increased dynamically in the Rokitnica, Stroszek and Miechowice regions. The Castellengo mine (Rokitnica after 1945) was established, the construction of which started in 1857, while its activity in 1899. In the early 19th century, hard coal was mined in several mines, including Preussengrube (Miechowice after 1945), Beuthengrube (Bytom after 1945), Abwehrgrube (later Mikulczyce), Concordia and Ludwig.

The Pstrowski mine (formerly Hedwigswunsch, Berta-Hedwig, Jadwiga) operated in 1854–1856 (Jaros, 1984). Since 2002, its deposits have been exploited by the Siltech mine. Coal was mined in the Miechowice mine in the period 1902–2005. After closing down, all of its shafts and buildings were dismantled. Mining activity in the Bobrek mine has been carried out since 1907.

Over the next years, the mines were subject to multiple combinations of individual mines and their name changes (especially after World War II and in the 1990s).

The hard coal deposits that occur in the southeastern part of the map sheet or fall within its boundaries to a different extent bear the following names: Powstańców Śląskich, Bobrek-Miechowice, Bytom I, Bytom III, Centrum, Jadwiga 2, Bytom I-1, Bobrek-Miechowice-1 and Bobrek-Miechowice-2. The number and boundaries of hard coal deposits have been subject to frequent changes in recent years due to the depletion of resources and the documenting of smaller deposits within the existing ones.

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).

The hard coal resources of categories A-C2 have been documented from a depth of 535 m (Jadwiga 2 deposit) to 1050 m (Centrum deposit). The deposit series consists of coal seams of the Orzesze Beds (group 300), Ruda Beds (400), Saddle Beds (500) and Paralic Series (groups 800, 700 and 600 – Namurian A), ranging in thickness from 200 to 1000 m. Power coals (type 32–33) and, less frequently, gas and coke coals occur within the deposit series (type 34). The thickness of single economic coal seams ranges from 1 to 10 m. Their calorific value is 13,400–31,600 kJ/kg, ash content 2.9–52%, and sulfur content 0.2–2.0%. The Saddle Beds coals are of the best quality. They contain the least amount of ash and sulfur, and their seams are characterized by large thicknesses and a small number of gangue intergrowths. Coals of the Ruda and Orzesze beds contain more sulfur and ash (from a few percent to 40%). Due to many years of exploitation, the industrial resources of most of the hard coal deposits are either small (up to 15 million t) or none in some of them. The largest economic resources have been documented in the Bytom III deposits – approx. 73 million t, and in the Bobrek-Miechowice and Bobrek-Miechowice 1 – approx. 38 million t.

Most of the mining areas are affected by natural hazards – methane, dust, fire and rock bursts.

In the last 30 years, major changes in the mining structure took place in the Bytom Trough, consisting in the liquidation of several mines and hard coal mining plants in the Bytom region. Currently, the only active mine is KWK Bobrek-Piekary and two small mining plants. Mining is carried out using a longwall system, mostly by caving, occasionally with the use of hydraulic filling. The hard coal production is small, ranging from 0.12 to 0.18 million t, only the coal extraction from the Bytom III deposit is significant and amounts to approx. 1 million t (Szuflicki *et al*., 2020).

The map sheet area hosts deposits of **rock materials**: carbonates (Triassic limestones and dolomites), clays for construction ceramics (clays, loams, and clay shales), and sands.

The Bobrowniki-Blachówka dolomite deposit in the northeastern part of the map sheet is represented by diplopore and ore-bearing dolomites of the Muschelkalk, overlain by Quaternary deposits with an average thickness of 9.2 m. The thickness of the deposit series is 40–55.4 m. The total resources are 36.6 million t (including 25.8 million t of dolomites documented as crushed and dimension stones). The raw material can be used in metallurgy, agriculture, glass industry and for the production of crushed aggregate. Exploitation of the dolomites (carried out from the beginning of the 20th century to 1997) has been abandoned for economic reasons, the deposit has been reclaimed, and a ski centre called Sportowa Dolina Dolomites operates in this area.

The undeveloped Zbrosławice limestone deposit has been documented within outcrops of Middle Triassic wavy limestones. They are slightly karstified and occur under a sandy till bed of an average thickness of about 5 m. The resources are about 0.07 million t.

Bedded deposits of clay raw materials for building ceramics occur over small areas. The Miechowice deposit has been documented within outcrops of Triassic clays that are a weathering mantle of Middle Triassic limestones and dolomites, and partly also of Quaternary tills. The abandoned Bobrek deposit is represented by Quaternary clays and tills.

The Sucha Góra sand deposit, located on the outskirts of the southern boundary of the reclaimed Bobrowniki-Blachówka quarry, has not been exploited so far. The Quaternary variously grained sands with an average thickness of 6 m directly overlie eroded Triassic dolomites. The sands are not of very good quality and they contain 3–6.4% of mineral dusts.

HUMAN IMPACT

The natural environment condition of the study area is a consequence of industrial activity and urbanization. The transformations were caused mainly by near-surface mining of silver-bearing galena and calamine and by underground mining of hard coal. This economic activity has led to changes in the landscape and hydrographic network, and to soil, sediment and water pollution. In the areas of former hard coal mining, there are depressions, sinkholes, ditches and crevices. The Zn-Pb ore mining has left mineshafts, drifts, voids and heaps of waste from ore flotation. In the south of the study area, deformation on degraded soils results in the damage of buildings, technical infrastructure, and communication routes (Aktualizacja..., 2012). Post-industrial areas are gradually reclaimed through afforestation and levelling of tailings dumps, often used as material for road construction.

Atmospheric air. Air pollutants (areal, point and linear) are emitted from the municipal and housing sector sources, from industrial activities, and from communication means.

Linear pollution from road transport is dependent on traffic intensity. The areas surrounding A1 motorway and numerous access roads to the cities are most exposed to adverse changes in air quality. The main sources of point pollutant emissions are industrial plants (processing, mining, and combined heat and power plants) and furnaces for individually heated houses.

According to the annual air quality assessment, carried out by the Provincial Inspectorate of Environmental Protection, emissions of sulfur and nitrogen oxides dominate in the Silesian Voivodeship among the point sources (67% and 53%, respectively), and PM10 and PM2.5 among the surface sources (Stan..., 2020). The main sources of pollutant emissions were industrial processing, electricity and mining plants. As a result of using air purifying devices in many plants, the emitted particulate matter and gas pollutants are being successively reduced.

In the total gas emissions, the dominant pollution in the Silesian Voivodeship is carbon dioxide. Other important gaseous pollutants include methane, carbon monoxide and sulfur dioxide and nitrogen dioxide. Moreover, in the summer period under conditions of high temperature and strong solar radiation, the ozone content is exceeded.

The emissions of organic compounds (including aromatic hydrocarbons and solvents, formaldehyde and phenol) and heavy metals come from industrial plants of various sectors. The emission of odours occurs mainly in the vicinity of sewage treatment plants, and municipal and industrial waste landfills.

Surface water and groundwater. Surface water in the study area are polluted with wastewater discharges from treatment plants, household wastewater from residential buildings, rainwater, and saline mine waters (Aktualizacja..., 2014). Industrial plants use settling tanks of mine water, backfill water, cooling water, and sewage treatment ponds. Integrated water and wastewater management programs are about to reduce the pollution load on surface water.

The majority of the map sheet area is within the Potok Mikulczycki Stream and Bytomka River drainage basins. In both these watercourses, underground waters from coal mines, with elevated concentrations of chlorides, sulfates and suspended solids, are most harmful.

In addition to flowing waters, there are numerous surface reservoirs for retention purposes in the study area, which formed as a result of subsidence due to mining activities. The largest reservoir of this kind is the Brantka pond on the border of Miechowice and Karb districts. It has an island that sometimes becomes a peninsula. There is a remnant of the Koch shaft of the historical Fryderyk Zn-Pb ore mine.

Pollutants affecting the quality of surface water also penetrate into groundwater in the Quaternary, Triassic and Carboniferous deposits (Krzanowska *et al*., 2004).

The Quaternary aquifer system is degraded as a result of drainage activity of hard coal mines and is of little utility significance.

The Triassic aquifer system is either unconfined or partially covered with Quaternary deposits and recharged by infiltration of precipitation directly in the outcrop areas and through the Quaternary permeable sediments (Razowska-Jaworek, Brodziński, 2016). The Triassic major groundwater basins in the western part of the map sheet area are the Bytom Basin (MGB No. 329) and the Gliwice Reservoir (MGB No. 330), whose boundary zone runs near Radzionków. The Gliwice MGB has been polluted with trichlorethane and tetrachloroethane by Zakłady Chemiczne Tarnowskie Góry chemical company (Szadkowska, Gwóźdź, 2015).

The groundwater level of the Carboniferous aquifer system is degraded and lowered by mining drainage.

Soils. The map sheet area is covered by natural podzolic soils and brown earths (cambisols) that developed on glacial and fluvial sediments. As a result of long-time and intense economic activity, they have been significantly transformed. Due to intense industrial activity, the soils in many regions are degraded and polluted (especially with heavy metals: lead and cadmium), as is the entire environment (Wieczorek, 2009).

In places of waste storage and intense dust emissions from industrial plants and transportation means, the soil profile is commonly incompletely developed due to repeated reworking and drying. Natural constituents are mixed with foreign materials. Local soil pollution with metals is related to the historical mining and smelting of zinc and lead ores, as well as the impact of post-mining waste (gangue heaps, sludge tanks, coal sludge, underground water) and energy industry waste. Sometimes, the use of mining waste in the reclamation of post-industrial areas and in road and water construction contributes to the spread of pollutants permeating into the soil.

The soils most polluted with arsenic, cadmium, zinc, lead, mercury and copper are found in urban areas of Zabrze and Bytom (Pasieczna, 2003), while the agricultural soils in the northwestern part of the map sheet area are locally polluted with cadmium, lead and zinc (Lis, Pasieczna, 1995b).

Landfills. In the southeastern part of the map sheet area, there are clusters of heaps and settling tanks covering large areas (up to 2 km^2). Tailings heaps (of gangue rock, slag from zinc and lead smelting and from iron metallurgy, and flotation waste from enrichment of Zn-Pb ores) are the remnants left after mining of Zn-Pb ores and hard coal for several centuries. The leaching and dispersion of their potentially toxic components create the greatest risk of environmental pollution.

Material of the heaps, after enrichment of Zn-Pb ores from the northeastern part of the sheet area, contains increased amounts of arsenic, cadmium, lead, zinc and thallium in both ore minerals and soluble secondary mineral phases (Cabała, 1996).

Post-mining waste from coal mines is characterized by a low content of substances harmful to the natural environment. They are therefore used for engineering, levelling, backfilling and the production of building materials. Some of the tailings heaps have been levelled or reclaimed, but the operating plants constantly enforce the management of waste from their current production.

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). In total, 1330 samples were taken from a depth of 0.0–0.3 m and 1257 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 (314 and 274 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. 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 ac-

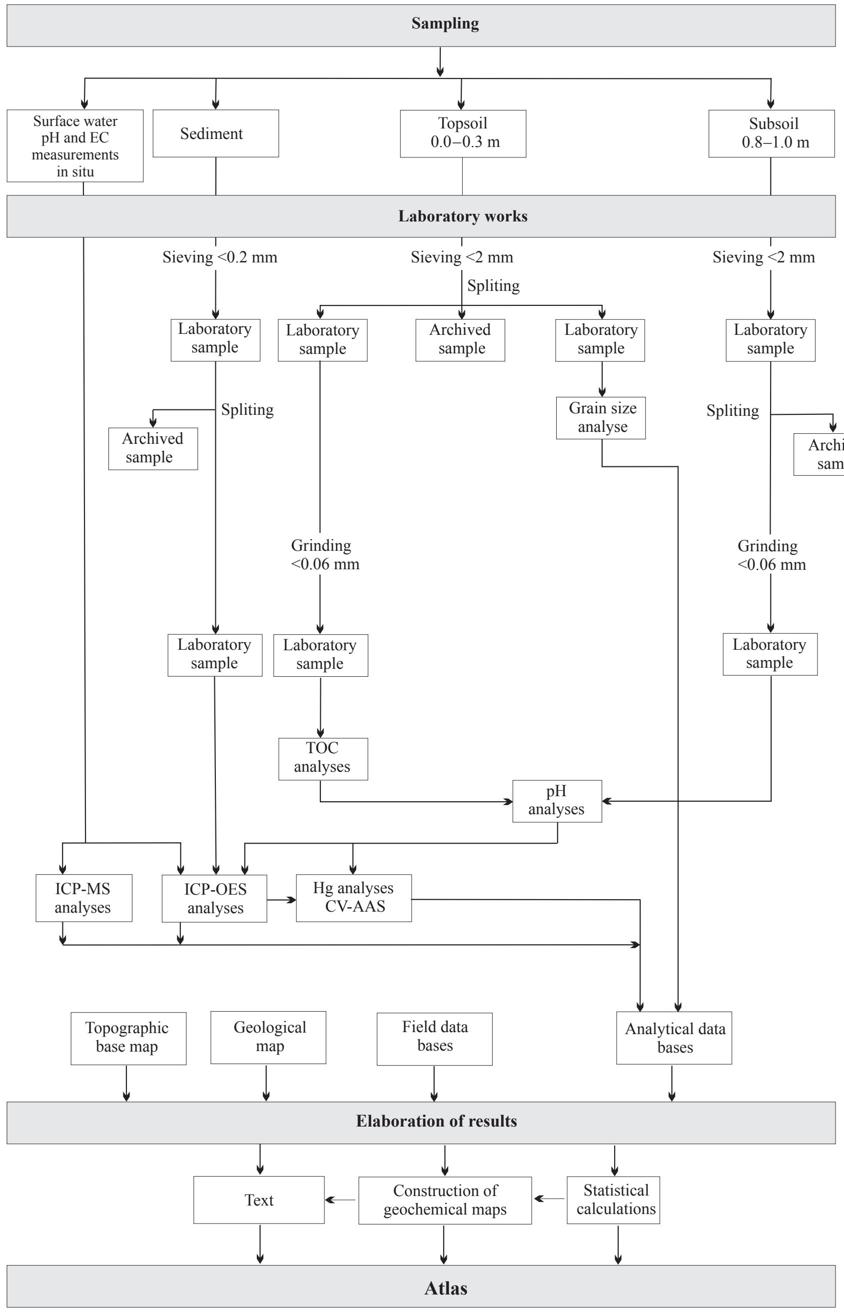

Fig. 1. Scheme of the work performed

curacy 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 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. 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%.

Granulometric analyses of soils from the depth of 0.0–0.3 m were performed at the at the Polish Geological Institute'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),

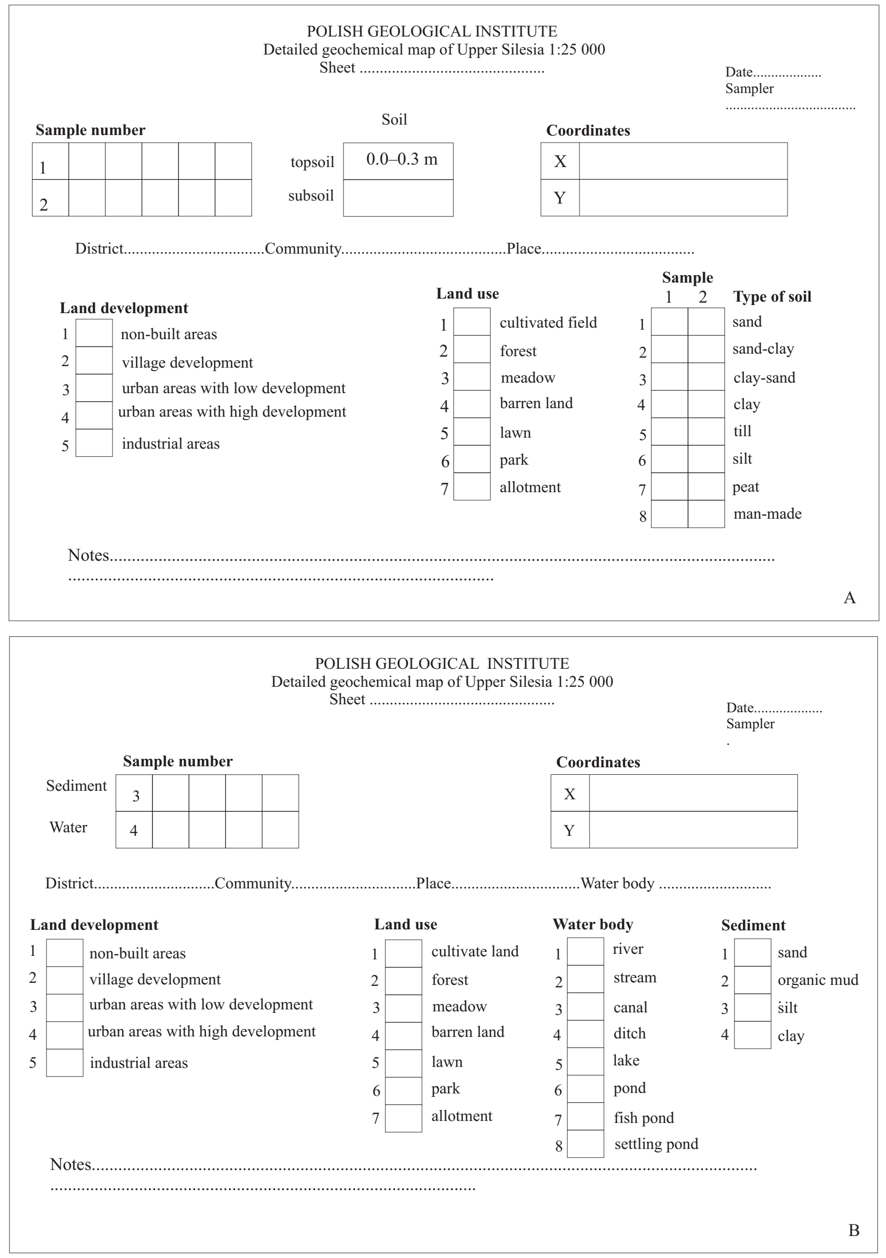

Fig. 2. Sampling cards of soils (A) as well as sediments and surface water (B)

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; reambulation Wilanowski, Lewandowski, 2016). The vector images of the map sheet that were developed as a result of digitization were com-

Tabela 1
Table

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/dm³	0,05
Al	ICP-OES	%	0,01	ICP-MS	μg/dm³	0,5
As	ICP-OES	mg/kg	3	ICP-MS	μg/dm³	2
B				ICP-OES	mg/dm³	0,01
Ba	ICP-OES	mg/kg	1	ICP-OES	mg/dm³	0,001
Be				ICP-MS	μg/dm³	0,05
C_{org} (TOC)	*	%	0,02			
Ca	ICP-OES	%	0,01	ICP-OES	mg/dm³	0,1
Cd	ICP-OES	mg/kg	0,5	ICP-MS	μg/dm³	0,05
Co	ICP-OES	mg/kg	1	ICP-MS	μg/dm³	0,05
Cr	ICP-OES	mg/kg	1	ICP-OES	mg/dm³	0,003
Cu	ICP-OES	mg/kg	1	ICP-MS	μg/dm³	0,05
Fe	ICP-OES	%	0,01	ICP-OES	mg/dm³	0,01
Hg	CV-AAS	mg/kg	0,02			
K				ICP-OES	mg/dm³	0,5
Li				ICP-MS	μg/dm³	0,3
Mg	ICP-OES	%	0,01	ICP-OES	mg/dm³	0,1
Mn	ICP-OES	mg/kg	2	ICP-OES	mg/dm³	0,001
Mo				ICP-MS	μg/dm³	0,05
Na				ICP-OES	mg/dm³	0,5
Ni	ICP-OES	mg/kg	1	ICP-MS	μg/dm³	0,5
P	ICP-OES	%	0,002	ICP-OES	mg/dm³	0,05
Pb	ICP-OES	mg/kg	2	ICP-MS	μg/dm³	0,05
S	ICP-OES	%	0,003			
Sb				ICP-MS	μg/dm³	0,05
Se				ICP-MS	μg/dm³	2
SiO_2				ICP-OES	mg/dm³	0,1
SO_4				ICP-OES	mg/dm³	1
Sr	ICP-OES	mg/kg	1	ICP-OES	mg/dm³	0,003
Ti	ICP-OES	mg/kg	5	ICP-OES	mg/dm³	0,002
Tl				ICP-MS	μg/dm³	0,05
U				ICP-MS	μg/dm³	0,05
V	ICP-OES	mg/kg	1	ICP-MS	μg/dm³	1
Zn	ICP-OES	mg/kg	1	ICP-OES	mg/dm³	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

bined 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. Data sumarized in 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 Bytom 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 m 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 elements in soil 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 Bytom 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 concentrations 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 soil pollution include the deposition of dust and gases from industrial plants, transportation means, corrosion of building materials, and heating of housing estates, as well as the use of plant protection products (Wong *et al*., 2006; Albanese, Breward, 2011). Particularly sig-

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 2

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	
	a	<1	0,17	<3	18	0,26	0,01	<0,5	<1	3	3	0,12	<0,02	0,01	7	<1	0,007	2	0,006	2	13	4	2	3,89
Gleby ogółem	b	22	2,16	781	1423	44,52	20,56	1191,0	47	281	3666	26,39	7,58	8,11	16 922	163	0,280	15 158	1,750	473	628	169	89 442	9,72
Soils as a whole	c	<1	0,65	14	141	3,76	0,66	7,0	5	14	24	1,47	0,11	0,23	715	11	0,043	386	0,045	25	94	19	1261	6,52
n = 1330	d	<1	0,62	9	113	2,73	0,22	2,4	4	12	15	1,17	0,07	0,12	433	9	0,037	152	0,030	15	82	17	292	6,40
	e	<1	0,62	8	103	2,50	0,19	2,0	4	11	13	1,04	0,07	0,10	424	8	0,038	133	0,026	12	77	17	215	6,79
	a	<1	0,17	<3	18	0,26	0,01	<0,5	<1	3	3	0,12	<0,02	0,01	7	<1	0,008	2	0,006	2	13	4	2	3,89
Tereny bez zabudowy	b	22	1,87	781	1399	44,52	20,56	1191,0	47	131	3633	26,39	7,58	8,11	16 922	163	0,280	15 158	1,670	473	614	169	89 442	9,12
Non-built-up areas	c	<1	0,65	14	127	3,81	0,53	7,5	5	13	22	1,44	0,11	0,21	698	11	0,039	408	0,043	20	86	18	1335	6,22
n = 984	d	<1	0,62	9	105	2,70	0,16	2,2	4	11	13	1,13	0,08	0,11	394	8	0,034	151	0,028	12	76	17	248	6,10
	e	<1	0,61	8	95	2,49	0,15	1,8	4	10	12	1,02	0,07	0,09	405	7	0,035	135	0,024	10	73	16	184	6,45
	a	<1	0,32	5	48	0,86	0,01	0,5	<1	6	5	0,60	0,03	0,03	30	2	0,014	38	0,016	2	45	9	86	4,30
Tereny z zabudową wiejską	b	<1	0,80	16	245	5,57	2,45	8,2	7	17	29	1,78	0,10	0,30	956	15	0,081	547	1,754	59	177	21	4137	7,83
Village areas	c	<1	0,59	8	128	2,60	0,42	2,6	4	10	15	1,05	0,07	0,11	464	8	0,046	148	0,122	20	83	16	465	6,63
n = 18	d	<1	0,58	7	115	2,30	0,22	2,1	4	10	13	1,01	0,06	0,10	391	8	0,043	115	0,031	16	78	16	250	6,55
	e	<1	0,61	7	110	2,17	0,21	1,8	5	10	13	1,02	0,07	0,10	416	8	0,043	110	0,024	14	76	16	193	6,92
	a	<1	0,21	3	39	0,53	0,06	<0,5	1	4	5	0,36	<0,02	0,05	133	2	0,019	2	0,007	6	37	5	9	4,43
Tereny z zabudową miejską niską	b	9	2,16	243	1423	23,67	13,96	71,7	17	149	355	10,96	1,71	4,21	5667	69	0,190	13 080	0,310	319	628	57	39 686	9,72
Low-block urban areas	c	<1	0,65	15	195	3,52	1,04	5,8	5	17	27	1,54	0,11	0,28	779	12	0,059	384	0,043	43	117	19	1200	7,34
n = 209	d	<1	0,62	10	151	2,88	0,54	3,4	5	14	20	1,28	0,07	0,18	572	10	0,053	173	0,034	28	99	17	509	7,30
	e	<1	0,61	8	147	2,63	0,50	2,5	5	13	17	1,13	0,07	0,15	500	10	0,052	140	0,032	25	89	17	367	7,50
	a	<1	0,34	<3	70	1,09	0,11	0,7	2	7	7	0,60	0,02	0,06	186	5	0,022	36	0,015	9	51	8	95	4,80
Tereny z zabudową miejską wysoką	b	3	1,05	202	454	11,04	5,65	18,5	12	281	338	5,86	0,54	2,55	7605	75	0,128	1193	0,130	130	415	143	5686	9,29
Tower-block urban areas	c	<1	0,64	16	164	2,98	0,97	3,6	5	27	33	1,37	0,09	0,26	853	13	0,050	185	0,039	37	124	23	629	7,56
n = 49	d	<1	0,62	8	146	2,62	0,63	2,8	4	17	20	1,21	0,07	0,18	571	11	0,046	132	0,034	29	112	19	418	7,52
	e	<1	0,63	7	138	2,41	0,54	2,7	4	13	18	1,12	0,07	0,15	450	10	0,046	116	0,032	29	101	17	367	7,63
	a	<1	0,24	<3	36	0,43	0,14	<0,5	1	7	6	0,39	<0,02	0,05	134	4	0,007	18	0,010	8	43	5	69	6,03
Tereny przemysłowe	b	19	1,50	559	446	19,17	9,24	92,0	18	116	624	7,40	2,86	4,24	2810	52	0,160	4024	0,610	206	397	63	14 067	9,28
Industrial areas	c	1	0,68	23	159	4,69	1,20	6,0	6	22	42	1,91	0,16	0,35	727	15	0,042	286	0,066	42	123	22	1059	7,63
n = 70	d	<1	0,66	11	124	2,97	0,72	2,8	5	18	24	1,56	0,08	0,22	588	13	0,036	126	0,042	30	106	20	450	7,60
	e	<1	0,64	9	126	2,64	0,60	2,9	5	16	20	1,45	0,07	0,19	510	12	0,034	106	0,036	32	100	19	427	7,69
	a	<1	0,25	<3	36	0,43	0,02	<0,5	2	5	3	0,40	<0,02	0,04	152	3	0,016	20	0,006	3	38	6	51	5,32
Pola uprawne	b	9	1,58	75	1399	11,47	2,81	71,7	17	46	98	10,96	0,44	1,46	4276	41	0,210	13 080	1,750	473	296	61	10 798	8,13
Cultivated fields	c	<1	0,59	7	89	1,60	0,26	2,5	4	10	11	0,98	0,06	0,11	489	7	0,049	153	0,025	13	73	16	302	6,86
n = 327	d	<1	0,58	6	80	1,48	0,18	1,8	4	10	10	0,90	0,05	0,09	435	7	0,046	80	0,018	10	70	15	194	6,83
	e	<1	0,58	6	75	1,42	0,17	1,7	4	10	9	0,88	0,05	0,09	432	6	0,046	64	0,017	9	69	15	163	6,94
	a	<1	0,17	<3	18	0,28	0,01	<0,5	<1	3	3	0,12	<0,02	0,01	7	<1	0,008	2	0,006	2	13	4	2	3,89
Lasy	b	16	1,87	382	1047	44,52	20,56	1191,0	47	71	974	26,39	1,71	8,11	16 922	163	0,160	14 950	1,240	288	577	110	89 442	8,57
Forests	c	<1	0,65	17	139	4,74	0,51	10,6	5	13	19	1,66	0,12	0,22	801	12	0,030	574	0,044	17	84	19	1820	5,48
n = 493	d	<1	0,62	12	115	3,68	0,10	2,2	4	11	14	1,21	0,10	0,10	330	8	0,025	226	0,032	9	74	18	229	5,37
	e	<1	0,61	11	115	3,62	0,06	1,8	4	10	13	1,06	0,10	0,08	325	7	0,023	220	0,029	8	74	17	165	4,98
	a	<1	0,34	4	51	0,88	0,06	1,1	2	6	5	0,54	0,03	0,05	173	4	0,028	2	0,010	4	42	9	5	4,92
Łąki	b	3	1,21	21	601	9,82	0,91	52,5	9	19	46	2,23	0,37	0,25	1248	70	0,110	2946	0,070	83	139	28	38 122	7,92
Meadows	c	<1	0,69	8	152	3,32	0,28	4,2	5	12	17	1,14	0,09	0,11	515	11	0,055	237	0,031	24	74	18	1255	6,46
n = 44	d	<1	0,67	8	130	2,90	0,22	2,9	5	11	15	1,08	0,08	0,10	464	9	0,052	110	0,028	19	71	17	318	6,43
	e	<1	0,66	8	116	2,73	0,20	2,7	5	11	15	1,06	0,08	0,10	484	9	0,052	97	0,027	17	69	17	269	6,44
	a	<1	0,24	<3	36	0,26	0,03	<0,5	1	5	6	0,36	<0,02	0,04	86	3	0,007	16	0,008	4	23	5	64	4,54
Nieużytki, ugory	b	22	2,16	781	833	42,42	16,73	230,3	30	131	3633	10,74	7,58	6,59	6486	72	0,280	15 158	1,670	369	628	169	41 151	9,46
Barren lands	c	<1	0,68	18	157	4,69	1,22	7,0	6	18	47	1,71	0,16	0,38	799	15	0,049	431	0,075	41	111	21	1431	7,29
n = 238	d	<1	0,65	10	124	3,01	0,52	2,9	5	15	21	1,39	0,08	0,20	543	12	0,041	154	0,040	25	94	19	440	7,24
	e	<1	0,64	8	108	2,62	0,45	2,5	5	13	17	1,21	0,07	0,16	477	11	0,040	129	0,034	22	85	18	339	7,47

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
Ogródki działkowe Allotments n = 34	a	<1	0,38	4	63	1,25	0,11	1,2	3	7	8	0,56	0,03	0,06	209	6	0,027	4	0,014	8	38	10	6	5,83
	b	3	1,70	97	507	17,30	4,28	119,3	12	49	74	5,16	0,68	1,69	1514	40	0,110	2574	0,350	195	387	41	32 410	8,44
	c	<1	0,75	12	208	4,04	0,86	7,4	5	16	25	1,45	0,10	0,25	570	13	0,058	243	0,055	50	126	20	1707	7,25
	d	<1	0,71	9	178	3,41	0,52	3,2	5	14	21	1,30	0,08	0,17	504	11	0,054	133	0,038	35	111	19	427	7,22
	e	<1	0,71	7	189	3,37	0,44	2,5	5	13	22	1,23	0,07	0,14	470	11	0,048	126	0,034	41	111	19	344	7,37
Parki Parks n = 9	a	<1	0,47	8	104	2,26	0,25	0,9	4	9	14	1,05	0,05	0,12	328	10	0,028	50	0,029	21	75	13	173	6,58
	b	2	1,17	115	554	19,69	2,41	22,3	14	31	69	4,99	0,21	0,54	2275	36	0,087	603	0,237	112	339	50	3185	8,09
	c	<1	0,73	29	288	6,93	0,95	8,3	7	17	36	2,23	0,11	0,26	735	17	0,047	287	0,076	54	160	25	1505	7,35
	d	<1	0,71	19	246	5,73	0,75	5,7	6	16	32	1,96	0,10	0,23	602	15	0,044	218	0,059	48	144	23	1039	7,33
	e	<1	0,66	13	233	6,69	0,68	5,9	5	16	31	1,92	0,08	0,20	543	12	0,043	264	0,045	43	136	25	1476	7,61
Trawniki Lawns n = 185	a	<1	0,21	<3	39	0,53	0,09	<0,5	1	4	5	0,36	<0,02	0,05	156	2	0,011	24	0,007	6	41	5	74	4,80
	b	19	1,20	559	1423	23,67	7,77	56,9	23	281	624	7,98	1,15	4,21	7605	75	0,190	4024	0,400	319	493	143	17 072	9,72
	c	<1	0,65	18	195	3,70	1,08	5,7	5	22	35	1,59	0,09	0,31	850	14	0,055	305	0,048	44	130	21	1159	7,57
	d	<1	0,63	10	155	2,96	0,68	3,5	5	16	23	1,35	0,07	0,21	620	12	0,049	175	0,038	32	113	18	582	7,54
	e	<1	0,63	9	156	2,70	0,64	2,9	5	14	20	1,28	0,07	0,17	547	12	0,049	146	0,035	31	106	18	462	7,63
Gleby piaszczyste Sandy soils n = 779	a	<1	0,19	<3	18	0,43	0,01	<0,5	<1	3	3	0,12	<0,02	0,01	7	<1	0,008	2	0,006	2	13	4	2	3,89
	b	16	1,87	150	571	15,49	12,51	230,3	24	38	75	19,61	0,63	5,52	15 705	75	0,160	15 158	1,750	88	387	63	38 122	8,34
	c	<1	0,59	10	110	2,81	0,29	3,6	4	10	12	1,10	0,08	0,14	522	7	0,038	307	0,028	12	73	16	496	6,02
	d	<1	0,57	8	96	2,33	0,11	1,9	3	10	11	0,96	0,07	0,09	350	6	0,033	133	0,023	9	69	15	193	5,92
	e	<1	0,58	8	90	2,19	0,12	1,8	4	10	10	0,92	0,07	0,08	383	6	0,036	118	0,021	9	70	15	170	6,18
Gleby gliniaste Clay soils n = 110	a	<1	0,17	3	22	0,28	0,02	<0,5	<1	7	4	0,36	0,02	0,04	22	4	0,010	27	0,008	3	14	10	43	3,89
	b	16	1,78	382	601	13,26	20,56	536,7	47	71	3633	26,39	0,33	8,11	16 922	163	0,140	14 950	0,510	171	344	110	77 921	8,50
	c	1	0,76	22	111	3,01	1,04	18,0	6	16	50	2,44	0,10	0,41	1351	18	0,040	1063	0,036	16	77	23	4868	6,28
	d	<1	0,72	12	96	2,26	0,20	3,4	5	14	15	1,57	0,08	0,14	565	11	0,036	267	0,027	12	70	20	486	6,13
	e	<1	0,69	12	91	2,15	0,17	2,0	5	12	13	1,20	0,07	0,11	450	9	0,035	203	0,026	11	72	18	222	6,55
Gleby torfiaste Peaty soils n = 12	a	<1	0,48	8	70	3,99	0,02	<0,5	1	8	11	0,67	0,10	0,04	55	4	0,021	123	0,040	4	13	12	54	4,02
	b	1	0,99	40	506	34,16	1,36	19,9	8	25	39	2,82	0,35	0,30	1013	24	0,123	1082	0,321	70	181	28	1773	7,67
	c	<1	0,70	18	223	10,97	0,28	5,6	4	13	26	1,33	0,21	0,09	280	11	0,056	459	0,094	21	73	21	422	4,92
	d	<1	0,69	15	190	8,97	0,11	3,0	3	13	24	1,22	0,19	0,07	192	9	0,049	387	0,077	14	61	20	247	4,80
	e	<1	0,69	14	203	9,72	0,08	3,3	4	13	28	1,46	0,20	0,07	141	9	0,047	432	0,076	13	73	23	203	4,45
Gleby antropogeniczne Man-made soils n = 429	a	<1	0,21	2	30	0,26	0,04	<0,5	1	4	5	0,36	<0,02	0,05	134	2	0,007	2	0,007	5	36	5	6	4,76
	b	22	2,16	781	1423	44,52	16,73	1191,0	30	281	974	17,73	7,58	6,59	15 830	160	0,280	7436	1,670	473	628	169	89 442	9,72
	c	<1	0,72	20	203	5,50	1,25	10,3	6	22	40	1,91	0,15	0,36	915	17	0,052	354	0,078	52	136	23	1750	7,54
	d	<1	0,68	11	157	3,71	0,74	3,4	6	17	26	1,56	0,09	0,24	608	14	0,044	163	0,049	36	116	20	548	7,51
	e	<1	0,67	9	157	3,44	0,72	3,0	5	15	25	1,45	0,08	0,21	518	13	0,042	141	0,043	35	110	20	448	7,63
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 = 1257	a	<1	0,14	<3	8	<0,01	<0,5	<1	2	1	0,09	<0,02	0,02	8	<1	<0,002	<2	<0,003	1	15	2	6	4,30
	b	24	2,10	790	1425	20,50	1917,0	60	404	1663	30,60	8,40	9,40	37 307	180	0,400	49 157	2,900	622	687	268	123 226	9,30
	c	<1	0,66	9	74	0,56	5,4	5	13	16	1,32	0,05	0,22	536	11	0,021	261	0,028	19	110	16	909	6,64
	d	<1	0,60	4	44	0,11	0,6	3	10	8	0,93	0,02	0,11	201	8	0,014	28	0,008	8	96	13	85	6,54
	e	<1	0,64	4	36	0,10	<0,5	4	11	8	0,97	0,02	0,10	185	7	0,013	16	0,006	7	88	14	49	6,89
Tereny bez zabudowy Non-built-up areas n = 949	a	<1	0,16	<3	8	<0,01	<0,5	<1	2	1	0,09	<0,02	0,02	8	<1	<0,002	<2	<0,003	1	15	2	6	4,30
	b	24	2,10	790	1425	20,50	1917,0	41	253	1663	30,60	1,10	9,40	37 307	180	0,400	49 157	2,900	622	687	268	123 226	9,10
	c	<1	0,66	9	60	0,48	6,1	5	12	15	1,33	0,04	0,22	538	10	0,018	293	0,029	15	109	16	993	6,38
	d	<1	0,61	3	38	0,08	0,5	3	10	7	0,90	0,02	0,10	174	7	0,012	23	0,007	7	94	13	68	6,29
	e	<1	0,64	3	32	0,07	<0,5	3	11	7	0,94	<0,02	0,10	153	7	0,011	14	0,005	6	88	14	43	6,63
Tereny z zabudową wiejską Village areas n = 18	a	<1	0,25	<3	13	<0,01	<0,5	<1	4	2	0,21	<0,02	0,03	35	2	0,003	3	<0,003	2	49	4	17	4,90
	b	<1	1,13	34	123	1,18	15,6	13	20	21	3,88	0,11	0,25	1967	27	0,039	1346	0,038	30	156	26	7805	8,86
	c	<1	0,65	5	42	0,19	1,3	5	11	9	1,22	0,03	0,11	327	9	0,015	96	0,010	9	93	14	491	6,76
	d	<1	0,62	<3	36	0,09	<0,5	3	10	7	0,95	0,02	0,09	178	7	0,013	17	0,006	7	88	13	51	6,68
	e	<1	0,65	<3	31	0,09	<0,5	4	10	8	1,06	<0,02	0,10	155	7	0,011	12	0,005	7	92	15	34	6,91
Tereny z zabudową miejską niską Low-block urban areas n = 188	a	<1	0,20	<3	12	0,02	<0,5	<1	2	2	0,12	<0,02	0,02	16	2	0,004	3	<0,003	2	30	2	12	4,95
	b	6	1,28	67	1127	11,80	83,1	60	215	120	5,91	8,40	3,42	4522	77	0,280	3165	0,240	255	335	83	26 968	9,32
	c	<1	0,63	8	118	0,79	3,4	5	14	16	1,19	0,09	0,23	507	10	0,030	169	0,022	29	113	16	673	7,34
	d	<1	0,59	5	68	0,26	1,0	4	11	10	0,99	0,03	0,14	303	8	0,022	54	0,011	14	101	14	164	7,30
	e	<1	0,61	5	55	0,18	0,8	4	10	9	1,00	0,03	0,12	302	8	0,021	56	0,009	11	94	14	130	7,47
Tereny z zabudową miejską wysoką Tower-block urban areas n = 46	a	<1	0,14	<3	12	0,03	<0,5	<1	3	2	0,15	<0,02	0,03	26	2	0,006	5	<0,003	2	49	3	16	6,78
	b	3	1,13	165	516	6,51	21,4	12	292	96	6,63	0,58	2,93	9203	55	0,109	1320	0,336	151	523	154	6822	9,26
	c	<1	0,64	12	120	0,95	2,6	4	20	15	1,17	0,06	0,23	675	10	0,030	128	0,033	30	116	19	482	7,83
	d	<1	0,60	6	94	0,54	1,5	4	13	12	1,02	0,04	0,15	424	9	0,026	70	0,019	22	106	16	227	7,81
	e	<1	0,67	6	111	0,60	1,6	4	12	14	1,07	0,05	0,14	431	10	0,027	75	0,022	24	104	17	256	7,87
Tereny przemysłowe Industrial areas n = 56	a	<1	0,23	<3	13	0,03	<0,5	<1	3	2	0,19	<0,02	0,02	15	2	0,004	4	<0,003	3	42	3	11	5,54
	b	8	1,30	221	807	3,71	31,7	30	404	253	12,15	1,56	1,12	2757	65	0,229	1787	0,204	458	488	80	6183	8,97
	c	<1	0,67	15	144	0,89	3,7	6	24	27	1,71	0,10	0,25	549	14	0,034	190	0,042	42	122	21	752	7,53
	d	<1	0,63	7	79	0,42	1,4	5	15	15	1,26	0,05	0,17	353	11	0,023	58	0,019	20	101	17	207	7,49
	e	<1	0,66	6	69	0,45	1,3	5	13	12	1,16	0,04	0,16	462	10	0,024	44	0,017	17	84	18	157	7,66
Pola uprawne Cultivated fields n = 327	a	<1	0,17	<3	9	0,02	<0,5	<1	2	1	0,12	<0,02	0,02	13	2	0,003	<2	<0,003	2	26	2	6	4,93
	b	5	1,54	91	1425	12,70	86,4	41	40	85	16,25	0,18	6,23	13 576	93	0,250	3856	0,100	622	315	75	18 061	8,56
	c	<1	0,61	4	41	0,19	1,2	4	10	7	1,03	0,02	0,13	311	8	0,016	61	0,006	9	92	14	199	6,76
	d	<1	0,57	<3	32	0,09	<0,5	3	9	6	0,78	<0,02	0,09	145	6	0,012	14	0,004	6	83	12	40	6,72
	e	<1	0,60	<3	30	0,09	<0,5	3	9	6	0,84	<0,02	0,09	135	6	0,012	11	0,004	6	78	12	33	6,89
Lasy Forests n = 477	a	<1	0,16	<3	8	<0,01	<0,5	<1	2	1	0,09	<0,02	0,02	8	<1	<0,002	3	<0,003	1	27	2	8	4,30
	b	18	2,10	790	1412	20,50	1917,0	60	253	1490	30,60	8,40	9,40	27 107	180	0,400	34 382	2,900	299	645	127	123 226	8,50
	c	<1	0,66	9	54	0,48	9,4	5	12	13	1,40	0,06	0,23	577	11	0,017	354	0,024	12	111	16	1429	5,83
	d	<1	0,60	3	35	0,05	0,5	3	10	7	0,90	<0,02	0,10	169	7	0,011	25	0,007	5	98	13	72	5,74
	e	<1	0,64	3	30	0,04	<0,5	3	10	7	0,95	<0,02	0,10	144	7	0,010	14	0,006	5	93	14	46	5,42
Łąki Meadows n = 44	a	<1	0,20	<3	15	0,02	<0,5	<1	3	1	0,14	<0,02	0,02	13	2	0,004	3	<0,003	2	35	4	11	5,53
	b	<1	1,41	28	210	5,27	7,4	30	33	37	5,91	0,14	2,83	2951	77	0,183	1013	0,072	57	233	47	5591	8,86
	c	<1	0,69	5	53	0,27	0,9	5	11	8	1,14	0,03	0,17	328	10	0,022	102	0,009	11	81	15	307	6,94
	d	<1	0,64	3	42	0,13	<0,5	4	10	7	0,91	0,03	0,10	162	7	0,015	24	0,005	8	74	13	67	6,91
	e	<1	0,66	3	39	0,14	<0,5	4	10	7	0,95	0,03	0,10	171	8	0,013	15	0,005	9	71	14	46	7,10
Nieużytki, ugory Barren lands n = 200	a	<1	0,22	<3	13	<0,01	<0,5	<1	3	2	0,14	<0,02	0,03	12	2	0,003	2	<0,003	2	15	3	12	4,71
	b	17	1,90	562	1021	16,26	160,7	30	404	1663	14,52	1,56	6,99	37 307	65	0,230	49 157	1,620	347	687	268	26 968	9,32
	c	<1	0,70	15	118	1,03	5,3	6	19	33	1,62	0,08	0,35	797	14	0,031	441	0,070	37	126	21	965	7,28
	d	<1	0,64	6	71	0,30	1,1	4	13	13	1,18	0,04	0,17	301	10	0,021	54	0,017	16	102	16	178	7,23
	e	<1	0,64	5	62	0,24	0,7	5	12	11	1,12	0,04	0,15	319	10	0,023	44	0,015	13	89	17	129	7,35

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
	a	<1	0,24	<3	13	0,03	<0,5	<1	3	2	0,20	<0,02	0,02	36	2	0,004	3	<0,003	2	45	4	8	5,35
Ogródki działkowe	b	3	2,05	92	458	4,13	99,6	14	52	76	5,29	0,25	1,31	1756	51	0,060	4005	0,400	151	309	42	38 326	8,20
Allotments	c	<1	0,71	7	71	0,38	3,9	4	12	11	1,08	0,03	0,16	259	9	0,017	160	0,022	19	129	15	1282	7,22
n = 34	d	<1	0,63	3	46	0,14	0,6	3	10	7	0,85	0,02	0,11	168	7	0,014	23	0,006	9	113	13	82	7,19
	e	<1	0,71	4	39	0,12	<0,5	3	10	7	0,90	<0,02	0,11	166	6	0,013	16	0,005	8	114	16	54	7,32
	a	<1	0,44	<3	41	0,08	<0,5	2	6	4	0,51	0,02	0,06	92	4	0,013	23	0,005	7	76	8	43	7,17
Parki	b	<1	1,27	21	690	2,17	7,9	15	24	67	2,54	0,17	0,55	748	38	0,101	206	0,224	255	335	43	1481	7,96
Parks	c	<1	0,70	9	204	0,86	3,4	6	12	21	1,37	0,06	0,23	451	14	0,033	96	0,046	58	152	19	556	7,57
n = 9	d	<1	0,66	7	126	0,48	2,0	5	11	15	1,22	0,05	0,18	398	11	0,027	74	0,022	29	137	17	320	7,57
	e	<1	0,56	7	98	0,28	2,7	5	11	11	1,22	0,03	0,14	479	8	0,024	68	0,020	17	120	14	389	7,60
	a	<1	0,14	<3	12	0,03	<0,5	<1	2	2	0,12	<0,02	0,02	15	2	0,004	4	<0,003	2	41	2	11	5,70
Trawniki	b	24	1,30	275	1127	11,80	37,6	17	292	253	7,34	0,68	3,42	9203	55	0,230	8750	0,660	458	523	154	21 669	9,26
Lawns	c	<1	0,66	14	144	1,02	3,6	5	17	21	1,39	0,06	0,27	659	12	0,033	243	0,039	38	128	19	845	7,69
n = 166	d	<1	0,63	7	91	0,45	1,5	4	13	13	1,13	0,04	0,17	417	10	0,026	74	0,017	21	113	16	242	7,67
	e	<1	0,67	6	87	0,48	1,6	5	12	13	1,12	0,04	0,16	473	10	0,025	75	0,020	21	112	17	249	7,78
	a	<1	0,14	<3	8	<0,01	<0,5	<1	2	1	0,09	<0,02	0,02	8	<1	<0,002	<2	<0,003	1	33	2	6	4,50
Gleby piaszczyste	b	17	1,42	790	522	12,70	160,7	41	52	35	30,62	0,47	6,23	37 307	46	0,180	49 157	0,060	109	295	74	33 853	8,56
Sandy soils	c	<1	0,46	5	33	0,17	1,4	3	7	5	0,73	<0,02	0,11	307	5	0,012	191	0,006	5	91	9	247	6,51
n = 417	d	<1	0,43	<3	26	0,04	<0,5	2	6	4	0,51	<0,02	0,06	113	4	0,009	14	0,004	4	83	8	37	6,44
	e	<1	0,43	<3	24	0,04	<0,5	2	6	4	0,50	<0,02	0,06	102	4	0,008	10	0,004	3	81	8	29	6,80
	a	<1	0,22	<3	12	<0,01	<0,5	<1	3	2	0,24	<0,02	0,03	20	2	<0,002	4	<0,003	2	15	4	10	4,30
Gleby gliniaste	b	18	2,12	387	270	20,54	296,2	60	95	75	24,66	0,50	9,43	27 107	138	0,420	34 382	2,850	231	314	127	77 761	8,86
Clay soils	c	<1	0,76	7	43	0,39	3,9	5	13	9	1,47	0,03	0,22	525	11	0,018	274	0,013	9	105	18	873	6,23
n = 575	d	<1	0,72	4	37	0,10	<0,5	4	12	8	1,13	<0,02	0,12	188	8	0,013	23	0,006	7	93	16	68	6,14
	e	<1	0,73	4	35	0,10	<0,5	4	12	8	1,07	0,02	0,11	165	8	0,012	14	0,005	7	84	16	45	6,43
	a	<1	0,23	<3	16	0,03	<0,5	1	5	2	0,30	<0,02	0,03	45	3	0,005	4	<0,003	3	42	5	13	4,71
Gleby antropogeniczne	b	24	2,10	562	1425	16,30	1917,0	28	404	1663	12,60	8,40	7,00	16 032	180	0,300	8939	1,600	622	687	268	123 226	9,30
Man-made soils	c	<1	0,75	21	207	1,52	14,8	7	24	46	1,94	0,15	0,42	921	19	0,043	344	0,095	62	153	25	2033	7,72
n = 264	d	<1	0,71	10	146	0,87	2,8	6	17	25	1,60	0,08	0,27	584	15	0,035	136	0,046	39	128	21	501	7,69
	e	<1	0,71	9	136	0,91	2,3	6	16	23	1,48	0,07	0,26	542	14	0,033	117	0,041	36	120	20	415	7,78

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)

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
	a	<1	0,05	<3	8	0,07	<0,5	<1	2	3	0,19	<0,02	0,03	28	3	0,008	8	0,004	4	11	2	23
Osady (wszystkie próbki) Sediments (all samples)	b	101	5,72	292	1171	20,17	732,2	492	63	274	15,33	14,12	3,51	36 570	145	1,940	14 640	2,483	1732	284	60	78 480
n = 314	c	1	0,69	15	135	1,09	20,8	13	16	28	1,90	0,21	0,24	1806	20	0,092	780	0,177	43	80	17	2140
	d	<1	0,58	10	105	0,60	6,6	7	14	20	1,40	0,09	0,17	654	15	0,059	264	0,090	24	73	16	759
	e	<1	0,63	9	111	0,52	5,5	6	13	19	1,28	0,09	0,15	592	15	0,059	223	0,075	22	69	17	635
	a	<1	0,09	<3	8	0,08	<0,5	1	2	3	0,19	<0,02	0,03	58	3	0,008	8	0,004	4	19	3	23
Strumienie i rowy bez nazwy Streams and ditches (without a name)	b	6	2,64	50	899	3,37	215,4	177	63	274	14,30	1,49	1,13	28 320	145	1,540	6421	1,120	115	284	41	11 600
n = 148	c	<1	0,67	11	126	0,61	12,9	11	13	21	1,62	1,11	0,17	1534	19	0,084	519	0,105	22	72	16	997
	d	<1	0,57	8	97	0,44	5,7	7	12	15	1,24	0,07	0,14	587	15	0,053	222	0,066	18	66	15	564
	e	<1	0,63	8	103	0,42	5,5	6	12	15	1,18	0,08	0,13	531	14	0,051	231	0,057	16	64	15	479
	a	<1	0,16	<3	29	0,08	0,6	1	4	6	0,44	0,02	0,04	76	4	0,008	15	0,046	7	58	6	77
Jeziora Lakes	b	101	1,23	292	423	10,32	732,2	11	26	51	13,04	1,34	3,51	4471	34	0,130	13 080	2,483	719	149	34	78 480
n = 20	c	6	0,58	25	135	2,77	41,6	6	14	26	2,17	0,18	0,51	800	16	0,046	881	0,431	107	97	18	4748
	d	<1	0,52	10	109	1,35	3,8	5	13	22	1,62	0,10	0,27	496	13	0,038	161	0,270	58	94	16	528
	e	<1	0,54	9	101	1,20	3,8	6	12	21	1,32	0,09	0,20	485	14	0,037	149	0,326	48	95	17	472
	a	<1	0,21	6	53	0,68	0,8	3	8	17	1,23	0,05	0,14	387	6	0,022	39	0,085	28	73	8	145
Jezioro Brantka The Brantka Lake	b	2	0,59	40	198	7,38	39,8	10	18	39	2,85	0,12	2,26	2461	24	0,048	937	0,749	120	135	21	7570
n = 6	c	<1	0,46	17	102	2,02	9,8	6	12	28	1,92	0,09	0,64	785	14	0,034	431	0,374	57	104	15	1775
	d	<1	0,44	13	93	1,28	4,1	6	12	26	1,81	0,08	0,40	591	13	0,032	224	0,296	51	103	15	678
	e	<1	0,51	10	96	0,86	4,3	5	12	27	1,74	0,08	0,39	455	12	0,032	338	0,343	49	108	17	514
	a	<1	0,05	<3	27	0,07	0,6	1	5	4	0,39	<0,02	0,04	28	4	0,09	23	0,008	4	11	2	71
Stawy Ponds	b	3	1,63	59	1171	20,17	454,9	25	54	220	10,18	0,40	0,66	29 410	88	0,140	3058	1,750	1732	274	54	31 300
n = 25	c	<1	0,62	18	157	2,77	40,7	8	19	42	2,77	0,12	0,23	2398	24	0,056	530	0,462	137	96	20	4292
	d	<1	0,52	12	111	1,02	6,8	6	15	26	1,84	0,08	0,17	546	16	0,046	209	0,228	41	85	17	821
	e	<1	0,60	13	114	0,90	5,7	7	14	32	1,56	0,09	0,15	529	17	0,058	206	0,238	33	86	17	846
	a	<1	0,05	3	49	0,42	0,7	2	5	16	0,54	<0,02	0,13	198	6	0,017	23	0,035	27	11	2	118
Dopływ w Mikulczycach Dopływ w Mikulczycach Stream	b	6	1,12	105	1171	20,17	18,6	35	34	188	10,18	14,12	0,82	29 680	63	0,160	1165	2,230	1732	242	25	3763
n = 15	c	1	0,54	17	240	3,33	7,3	10	17	58	2,10	1,05	0,33	6835	22	0,074	185	0,312	206	106	15	1069
	d	<1	0,43	11	168	1,71	4,3	7	15	45	1,56	0,11	0,30	1418	17	0,061	116	0,156	86	89	13	693
	e	<1	0,61	10	151	1,16	4,9	7	13	37	1,67	0,10	0,31	904	19	0,074	100	0,141	72	102	18	589
	a	<1	0,26	4	36	0,12	3,3	4	5	5	0,51	0,03	0,04	506	8	0,029	121	0,014	5	40	8	427
Dopływ z Ptakowic Dopływ z Ptakowic Stream	b	3	1,25	20	1091	1,54	30,8	113	28	64	5,83	0,16	0,42	36 570	72	0,200	780	0,470	48	126	34	5028
n = 10	c	<1	0,73	10	201	0,45	8,1	17	14	17	1,64	0,07	0,15	4543	21	0,097	268	0,082	17	61	19	1225
	d	<1	0,68	9	117	0,34	6,3	9	13	13	1,33	0,06	0,13	1287	17	0,084	231	0,045	14	58	18	894
	e	<1	0,73	9	89	0,30	5,3	7	13	11	1,20	0,06	0,12	787	16	0,077	218	0,033	12	57	19	773
	a	<1	0,41	4	45	0,16	0,8	2	10	5	0,56	0,03	0,07	177	5	0,026	29	0,016	7	32	9	117
Potok Grzybowicki Potok Grzybowicki Stream	b	5	1,06	41	502	2,51	7,3	14	31	37	7,07	0,15	0,27	27 270	26	0,200	230	0,190	132	112	60	1625
n = 13	c	<1	0,80	13	148	0,65	3,5	7	20	22	1,74	0,09	0,16	2822	15	0,084	146	0,082	30	72	23	457
	d	<1	0,78	10	124	0,47	2,9	6	19	19	1,37	0,08	0,15	827	14	0,070	129	0,063	22	69	20	340
	e	<1	0,81	9	139	0,44	3,3	7	18	21	1,34	0,09	0,15	760	15	0,066	139	0,062	22	71	19	373
	a	<1	0,10	<3	20	0,15	0,7	<1	4	5	0,27	<0,02	0,05	67	3	0,012	24	0,014	6	40	3	103
Potok Mikulczycki Potok Mikulczycki Stream	b	10	0,88	46	191	3,23	123,2	12	49	88	7,75	1,66	1,54	4765	32	0,180	6505	0,430	67	187	32	17 290
n = 38	c	1	0,48	12	98	0,83	15,9	5	17	26	1,40	0,18	0,28	697	13	0,068	889	0,099	25	82	14	1575
	d	<1	0,42	9	83	0,61	6,4	4	14	20	0,09	0,10	0,20	463	11	0,054	353	0,070	20	76	12	814
	e	<1	0,51	8	104	0,55	5,1	5	16	21	1,13	0,11	0,19	506	13	0,061	294	0,058	23	71	15	780
	a	<1	0,05	3	8	0,10	<0,5	<1	2	3	0,19	<0,02	0,03	28	3	0,008	8	0,004	4	11	2	23
Zlewnia Potoku Mikulczyckiego Potok Mikulczycki Stream catchment	b	10	2,64	105	1171	20,17	215,4	177	63	274	14,30	14,12	1,54	29 680	145	0,850	6505	2,230	1732	284	46	17 290
n = 172	c	<1	0,59	12	131	0,99	13,0	9	15	27	1,61	0,21	0,22	1843	18	0,072	569	0,136	41	80	16	1155
	d	<1	0,50	9	97	0,61	5,2	6	13	19	1,22	0,08	0,17	576	14	0,052	230	0,082	23	74	14	622
	e	<1	0,57	8	108	0,54	4,7	5	13	18	1,23	0,08	0,16	534	15	0,051	215	0,066	22	71	15	642

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
Seget Seget Stream n = 19	a	<1	0,51	11	89	0,37	18,9	6	11	17	1,42	0,10	0,03	300	18	0,045	396	0,070	16	30	13	1954
	b	11	5,72	67	434	5,52	235,8	492	50	122	15,33	0,54	2,43	28 570	114	1,940	14 640	0,540	69	173	44	16 660
	c	4	1,48	37	224	1,38	80,1	66	24	49	4,48	0,25	0,49	4650	49	0,231	4035	0,225	38	76	28	9288
	d	3	1,22	32	208	1,02	63,8	29	22	43	3,66	0,22	0,24	2536	43	0,140	2508	0,193	35	67	27	7829
	e	3	1,10	36	221	0,92	63,9	25	19	38	4,03	0,22	0,21	2507	48	0,101	2861	0,205	36	56	28	7913
Zlewnia Seget Seget Stream catchment n = 48	a	<1	0,10	<3	26	0,07	0,8	1	3	3	0,33	<0,02	0,03	69	3	0,008	29	0,008	4	29	6	73
	b	101	5,72	292	434	9,29	732,2	492	50	122	15,33	1,34	3,51	28 570	114	1,940	14 640	2,483	132	204	54	78 480
	c	4	1,05	31	162	1,57	70,4	31	19	36	3,33	0,19	0,43	2735	33	0,126	2323	0,315	39	81	23	7268
	d	1	0,83	19	137	0,82	26,2	12	17	29	2,31	0,14	0,21	1173	24	0,073	919	0,151	31	72	21	2745
	e	1	0,84	18	144	0,76	37,1	10	16	32	1,95	0,15	0,17	921	24	0,079	1000	0,152	29	63	20	3536
Zlewnia Bytomki Bytomka River catchment n = 20	a	<1	0,20	<3	46	0,09	0,7	3	5	7	0,79	<0,02	0,04	165	4	0,015	32	0,032	14	57	9	71
	b	3	1,24	68	234	10,32	56,3	14	54	220	4,44	11,79	0,73	1230	43	1,120	1216	1,610	719	274	28	11 100
	c	<1	0,58	22	136	2,98	12,3	7	21	56	2,35	0,80	0,38	631	19	0,158	339	0,470	154	112	19	2366
	d	<1	0,54	14	123	1,65	6,2	7	17	36	2,07	0,15	0,29	531	16	0,069	211	0,324	84	102	18	901
	e	<1	0,61	17	143	2,79	5,9	8	17	35	2,17	0,13	0,40	654	21	0,061	206	0,306	76	95	20	872
Zlewnia Dramy Drama River catchment n = 74	a	<1	0,16	<3	29	0,08	0,5	1	4	4	0,35	<0,02	0,03	58	4	0,008	15	0,008	4	19	5	66
	b	3	2,28	41	1091	3,37	170,6	113	31	71	7,92	0,29	0,82	36 570	72	1,540	6421	1,400	85	167	60	26 560
	c	<1	0,71	11	126	0,51	8,9	10	14	18	1,55	0,08	0,15	1434	16	0,097	388	0,102	19	68	18	1043
	d	<1	0,65	9	102	0,36	4,8	6	13	15	1,26	0,07	0,13	636	14	0,065	173	0,058	16	64	16	500
	e	<1	0,69	8	102	0,31	4,8	6	13	15	1,18	0,07	0,13	639	13	0,066	147	0,051	13	61	17	443
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

Tabela 5
Table

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

Wody powierzchniowe Surface water	Parametry Parameters	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	a	0,14	6,0	<0,05	4,7	<2	0,01	0,020	<0,05	18,1	<0,05	<0,05	<0,003	0,22	0,01	<0,5	<0,3	2,0	0,001	<0,05	2,2	<0,5	<0,05	<0,05	4	<0,05	<2	0,2	0,080	<0,002	<0,05	<0,05	<1	<0,003
(wszystkie próbki)	b	12,94	9,4	0,06	1007,5	21	1,39	0,375	1,16	293,7	10,42	10,19	0,004	10,30	35,86	97,1	1007,4	232,5	7,732	32,31	2182,5	20,5	4,04	93,95	1235	71,23	40	48,6	4,486	0,023	1,05	9,04	20	3,959
Surface water	c	0,87	7,9	<0,05	33,0	2	0,17	0,083	<0,05	105,3	1,12	0,60	<0,003	2,21	0,23	12,0	61,0	29,4	0,415	1,52	102,9	2,9	0,18	2,00	204	1,01	<2	11,2	0,445	<0,002	0,07	1,07	1	0,178
(all samples)	d	0,62	7,9	<0,05	19,0	<2	0,10	0,074	<0,05	94,2	0,19	0,19	<0,003	1,82	0,04	8,3	11,1	19,0	0,103	0,73	35,9	2,0	0,06	0,48	136	0,51	<2	8,6	0,324	<0,002	0,05	0,57	<1	0,027
n = 274	e	0,57	7,9	<0,05	16,4	<2	0,08	0,072	<0,05	98,3	0,11	0,17	<0,003	1,92	0,03	8,3	7,6	16,3	0,111	0,91	37,7	2,3	<0,05	0,43	126	0,46	<2	11,8	0,285	<0,002	<0,05	0,69	1	0,021
Strumienie i rowy	a	0,14	6,0	<0,05	5,8	<2	0,02	0,024	<0,05	18,1	<0,05	<0,05	<0,003	0,38	0,01	1,0	0,4	2,0	0,001	<0,05	2,9	<0,5	<0,05	<0,05	6	0,05	<2	1,8	0,080	<0,002	<0,05	<0,05	<1	<0,003
(bez nazwy)	b	4,11	8,7	0,06	1007,5	10	0,78	0,375	1,16	293,7	10,42	8,24	0,004	10,30	35,86	43,7	1007,4	232,5	7,136	9,45	481,0	20,5	3,96	93,95	1235	7,56	5	28,8	1,221	0,023	1,05	9,04	14	0,826
Streams and ditches	c	0,66	7,8	<0,05	39,7	<2	0,12	0,091	<0,05	113,8	1,29	0,70	<0,003	2,36	0,42	10,6	50,9	25,1	0,476	1,25	45,3	3,6	0,17	2,83	192	0,59	<2	12,9	0,340	<0,002	0,06	1,23	1	0,127
(without a name)	d	0,56	7,8	<0,05	19,6	<2	0,08	0,080	<0,05	101,0	0,31	0,22	<0,003	1,97	0,04	7,5	8,1	16,9	0,106	0,60	26,3	2,8	0,06	0,59	139	0,41	<2	12,1	0,294	<0,002	0,05	0,53	<1	0,042
n = 122	e	0,56	7,8	<0,05	17,1	<2	0,06	0,077	<0,05	104,7	0,26	0,21	<0,003	1,99	0,02	7,2	5,5	15,3	0,115	0,75	30,7	3,2	<0,05	0,47	133	0,39	<2	12,4	0,287	<0,002	<0,05	0,67	<1	0,048
	a	0,29	7,6	<0,05	5,1	<2	0,07	0,027	<0,05	41,3	<0,05	<0,05	<0,003	0,30	0,01	8,9	3,2	10,5	0,003	0,31	14,9	<0,5	<0,05	<0,05	17	0,28	<2	1,5	0,203	<0,002	<0,05	0,17	<1	<0,003
Jeziora	b	5,54	9,1	<0,05	36,1	7	1,23	0,114	<0,05	190,0	0,09	0,49	<0,003	9,40	0,15	46,9	980,7	163,3	1,808	6,16	1753,7	5,6	0,33	0,94	854	71,23	2	13,6	4,142	<0,002	0,17	3,34	2	0,003
Lakes	c	1,39	8,3	<0,05	13,5	3	0,51	0,056	<0,05	120,7	<0,05	0,17	<0,003	2,29	0,03	23,8	332,3	73,8	0,280	1,55	306,9	1,3	0,06	0,20	446	6,91	<2	7,7	1,067	<0,002	<0,05	1,48	<1	<0,003
n = 11	d	0,87	8,3	<0,05	11,2	2	0,32	0,052	<0,05	106,9	<0,05	0,08	<0,003	1,50	0,02	20,4	77,3	48,5	0,062	1,15	91,8	0,8	<0,05	0,10	234	0,71	<2	6,4	0,689	<0,002	<0,05	0,99	<1	<0,003
	e	0,83	8,3	<0,05	8,9	3	0,53	0,053	<0,05	102,7	<0,05	<0,05	<0,003	1,89	0,02	19,9	115,7	44,2	0,065	1,10	132,7	0,6	<0,05	0,10	486	0,41	<2	7,3	0,539	<0,002	<0,05	1,40	1	<0,003
	a	0,60	8,0	<0,05	20,2	3	0,22	0,064	<0,05	104,4	<0,05	<0,05	<0,003	1,53	0,01	12,2	20,6	67,7	0,007	0,70	48,4	0,6	<0,05	0,11	418	0,99	<2	0,7	0,751	<0,002	<0,05	1,29	<1	<0,003
Jezioro Brantka	b	1,27	8,9	<0,05	44,1	3	0,24	0,077	<0,05	115,1	<0,05	0,07	<0,003	1,88	0,02	13,9	51,7	70,0	0,335	0,83	49,7	1,2	<0,05	0,66	438	1,25	<2	1,3	0,778	<0,002	<0,05	1,33	1	<0,003
The Brantka Lake	c	0,76	8,6	<0,05	32,2	3	0,23	0,069	<0,05	110,4	<0,05	<0,05	<0,003	1,73	0,01	12,9	37,9	68,5	0,064	0,74	49,2	0,8	<0,05	0,28	430	1,06	<2	1,1	0,767	<0,002	<0,05	1,31	<1	<0,003
n = 8	d	0,72	8,6	<0,05	31,3	3	0,23	0,069	<0,05	110,4	<0,05	<0,05	<0,003	1,73	0,01	12,9	40,0	68,5	0,027	0,74	49,2	0,8	<0,05	0,21	430	0,01	<2	1,1	0,767	<0,002	<0,05	1,31	<1	<0,003
	e	0,62	8,7	<0,05	30,9	3	0,23	0,069	<0,05	110,6	<0,05	<0,05	<0,003	1,74	0,01	12,8	40,6	68,3	0,024	0,74	49,4	0,8	<0,05	0,16	431	1,04	<2	1,1	0,768	<0,002	<0,05	1,31	<1	<0,003
	a	0,21	7,1	<0,05	4,7	<2	0,01	0,034	<0,05	29,2	<0,05	<0,05	<0,003	0,22	0,01	<0,5	<0,3	5,7	0,003	<0,05	2,2	<0,5	<0,05	<0,05	4	<0,05	<2	0,3	0,089	<0,002	<0,05	<0,05	<1	<0,003
Stawy	b	9,08	8,9	<0,05	238,9	6	1,04	0,180	<0,05	263,9	0,39	0,67	<0,003	6,01	0,45	97,1	471,4	112,1	3,686	2,72	1464,0	3,6	4,04	2,34	795	2,57	3	42,5	3,039	<0,002	0,07	6,84	2	0,018
Ponds	c	1,04	8,0	<0,05	29,8	2	0,19	0,097	<0,05	80,7	0,05	0,12	<0,003	1,31	0,06	12,1	45,1	26,6	0,322	0,91	133,5	1,1	0,21	0,40	157	0,61	<2	5,0	0,515	<0,002	<0,05	0,87	<1	0,004
n = 28	d	0,58	8,0	<0,05	16,9	<2	0,10	0,088	<0,05	67,9	<0,05	0,08	<0,003	0,87	0,03	6,5	8,5	16,7	0,069	0,53	25,4	0,8	<0,05	0,16	67	0,41	<2	2,2	0,304	<0,002	<0,05	0,40	<1	0,003
	e	0,55	8,0	<0,05	14,6	2	0,10	0,096	<0,05	57,9	<0,05	0,10	<0,003	0,75	0,02	5,6	8,0	16,8	0,064	0,75	30,5	0,8	<0,05	0,21	58	0,37	<2	2,1	0,241	<0,002	<0,05	0,59	<1	<0,003
Dopływ w Mikulczycach	a	0,24	7,3	<0,05	11,2	<2	0,05	0,030	<0,05	44,3	<0,05	<0,05	<0,003	1,08	0,01	5,4	6,0	9,2	0,020	0,12	24,3	<0,5	<0,05	<0,05	27	0,14	<2	1,5	0,163	<0,002	<0,05	0,34	<1	<0,003
Dopływ w Mikulczycach	b	13,08	8,5	<0,05	40,9	9	1,39	0,306	<0,05	255,5	0,20	2,81	0,003	5,93	0,23	47,3	312,1	134,0	7,732	3,34	2175,0	4,5	1,20	0,90	692	3,18	6	48,6	4,486	<0,002	0,07	2,52	4	0,025
Stream	c	3,49	8,0	<0,05	21,9	5	0,47	0,090	<0,05	138,1	0,07	0,45	<0,003	2,46	0,07	19,3	85,6	58,1	1,172	1,36	696,5	1,9	0,48	0,27	273	0,85	2	16,7	1,472	<0,002	<0,05	1,02	2	0,016
n = 12	d	1,36	8,1	<0,05	20,0	4	0,23	0,069	<0,05	117,6	0,06	0,17	<0,003	2,19	0,05	13,8	32,7	39,3	0,264	1,06	200,7	1,6	0,21	0,13	163	0,53	<2	10,7	0,733	<0,002	<0,05	0,84	1	0,012
	e	1,17	7,8	<0,05	21,8	4	0,21	0,056	<0,05	133,3	0,06	0,23	<0,003	2,31	0,04	10,3	18,8	36,6	0,198	1,20	128,8	1,7	0,44	0,16	167	0,44	<2	14,1	0,565	<0,002	<0,05	0,70	1	0,020
	a	0,43	7,1	<0,05	4,8	<2	0,05	0,045	<0,05	78,0	0,07	<0,05	<0,003	1,86	0,02	7,7	5,8	7,3	0,051	0,38	31,0	<0,5	<0,05	<0,05	71	0,23	<2	9,4	0,233	<0,002	<0,05	0,40	<1	0,006
Potok Grzybowicki	b	2,12	8,1	<0,05	24,0	9	0,58	0,153	<0,05	143,0	0,27	0,39	<0,003	4,38	0,17	26,8	327,2	43,8	0,379	32,31	616,1	1,6	0,54	1,72	402	6,70	40	48,6	0,550	<0,002	0,15	1,74	20	0,025
Potok Grzybowicki Stream	c	1,06	7,7	<0,05	14,1	3	0,13	0,091	<0,05	92,3	0,14	0,17	<0,003	2,96	0,05	12,8	49,4	16,0	0,146	6,72	152,3	1,2	0,14	0,37	148	2,38	8	14,5	0,322	<0,002	0,11	0,75	4	0,012
n = 13	d	0,96	7,7	<0,05	12,8	3	0,09	0,084	<0,05	90,9	0,13	0,12	<0,003	2,87	0,04	12,2	24,2	13,2	0,126	3,74	89,6	1,0	0,09	0,21	132	1,98	3	12,9	0,308	<0,002	0,10	0,70	2	0,011
	e	0,88	7,7	<0,05	15,4	3	0,06	0,074	<0,05	86,4	0,14	0,10	<0,003	2,80	0,04	11,0	21,7	9,2	0,119	2,82	59,9	1,4	0,10	0,19	131	2,11	2	11,8	0,276	<0,002	0,10	0,70	3	0,008
	a	0,38	7,4	<0,05	5,6	<2	0,04	0,041	<0,05	70,6	<0,05	<0,05	<0,003	0,46	0,01	2,0	2,7	9,4	0,016	0,23	11,5	1,0	<0,05	0,15	63	0,20	<2	0,2	0,203	<0,002	<0,05	0,31	<1	<0,003
Potok Mikulczycki	b	1,54	9,4	0,05	78,6	6	0,52	0,130	0,05	187,8	6,66	3,58	<0,003	5,27	0,59	29,4	609,2	140,6	3,097	7,42	133,5	8,9	2,03	10,95	825	1,41	<2	16,7	0,889	0,002	0,09	6,05	6	0,686
Potok Mikulczycki Stream	c	0,79	8,0	<0,05	21,1	2	0,17	0,074	<0,05	107,5	1,41	0,47	<0,003	2,43	0,09	11,8	73,0	34,7	0,238	1,60	57,4	2,6	0,23	1,38	228	0,66	<2	10,0	0,378	<0,002	0,06	1,21	2	0,171
n = 38	d	0,72	8,0	<0,05	17,2	<2	0,13	0,071	<0,05	105,3	0,23	0,20	<0,003	2,24	0,05	9,9	21,1	25,5	0,122	1,17	48,7	2,2	0,09	0,77	184	0,60	<2	7,9	0,349	<0,002	0,05	0,93	1	0,036
	e	0,76	7,9	<0,05	14,5	<2	0,10	0,072	<0,05	100,3	0,09	0,17	<0,003	2,15	0,04	8,5	11,3	17,3	0,117	1,10	43,0	2,1	0,07	0,76	138	0,55	<2	11,4	0,286	<0,002	0,06	0,82	1	0,016
Zlewnia Potoku	a	0,17	6,8	<0,05	5,6	<2	0,01	0,024	<0,05	33,0	<0,05	<0,05	<0,003	0,26	0,01	0,3	1,0	4,1	0,001	<0,05	2,9	<0,5	<0,05	<0,05	18	0,05	<2	0,2	0,094	<0,002	<0,05	<0,05	<1	<0,003
Mikulczyckiego	b	13,08	9,4	0,06	353,0	9	1,39	0,306	0,17	293,7	9,75	6,16	0,004	10,30	35,86	47,3	1007,4	232,5	7,732	9,45	2175,0	11,2	2,03	45,54	1235	3,18	6	48,6	4,486	0,010	1,05	9,04	14	0,826
Potok Mikulczycki Stream	c	0,98	7,9	<0,05	23,7	2	0,18	0,083	<0,05	117,8	0,83	0,54	<0,003	2,33	0,34	11,6	67,9	33,3	0,555	1,50	113,0	2,8	0,18	1,62	227	0,57	<2	12,2	0,474	<0,002	0,06	1,35	1	0,106
catchment	d	0,67	7,9	<0,05	17,0	<2	0,11	0,075	<0,05	107,8	0,16	0,19	<0,003	1,95	0,04	8,6	15,1	22,8	0,146	0,95	43,3	2,2	0,06	0,50	166	0,46	<2	10,4	0,355	<0,002	<0,05	0,77	1	0,024
n = 155	e	0,62	8,0	<0,05	14,6	<2	0,09	0,072	<0,05	103,2	0,11	0,18	<0,003	2,01	0,03	8,3	8,2	19,6	0,130	0,98	40,3	2,3	<0,05	0,47	142	0,45	<2	12,1	0,303	<0,002	0,05	0,88	1	0,005

Tabela 5 cd.
Table 5 cont.

Wody powierzchniowe Surface water	Parametry Parameters	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
Seget Seget Stream n = 19	a b c d e	0,21 0,57 0,41 0,40 0,39	7,2 8,8 7,7 7,7 7,6	<0,05 <0,05 <0,05 <0,05 <0,05	9,0 121,7 49,8 36,2 32,7	<2 5 <2 <2 <2	0,02 0,38 0,06 0,05 0,05	0,037 0,105 0,064 0,061 0,062	<0,05 0,15 0,07 0,06 0,05	36,3 146,5 65,1 60,2 53,5	<0,05 9,67 4,45 2,28 4,49	<0,05 10,19 1,46 0,53 0,50
Zlewnia Seget Seget Stream catchment n = 37	a b c d e	0,21 1,27 0,47 0,43 0,41	7,1 8,9 7,9 7,9 7,9	<0,05 <0,05 <0,05 <0,05 <0,05	6,4 121,7 36,8 27,0 26,3	<2 5 <2 <2 <2	0,02 0,38 0,10 0,07 0,05	0,033 0,180 0,070 0,066 0,063	<0,05 0,15 <0,05 <0,05 <0,05	29,2 146,5 75,2 67,8 60,2	<0,05 9,67 2,40 0,40 0,39	<0,05 10,19 0,82 0,21 0,21
Zlewnia Bytomki Bytomka River catchment n = 24	a b c d e	0,30 5,54 1,24 0,82 0,59	7,4 8,9 8,0 8,0 8,1	<0,05 <0,05 <0,05 <0,05 <0,05	4,7 238,9 30,6 15,7 12,9	<2 21 4 2 2	0,07 1,23 0,38 0,22 0,11	0,020 0,152 0,080 0,064 0,080	<0,05 0,07 <0,05 <0,05 <0,05	40,8 263,9 100,5 83,8 73,6	<0,05 0,12 <0,05 <0,05 <0,05	<0,05 1,94 0,38 0,10 <0,05
Zlewnia Dramy Drama River catchment n = 58	a b c d e	0,14 2,12 0,69 0,58 0,59	6,0 8,1 7,6 7,5 7,6	<0,05 <0,05 <0,05 <0,05 <0,05	4,8 1007,5 56,3 22,2 18,5	<2 10 2 <2 <2	0,02 0,38 0,09 0,08 0,08	0,020 0,375 0,093 0,081 0,084	<0,05 1,16 0,06 <0,05 <0,05	18,1 217,0 92,8 84,9 92,8	<0,05 10,42 1,53 0,39 0,20	<0,05 8,24 0,69 0,23 0,23
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
II klasa [1] Class II		≤0,45	7,3–8,2	≤5	≤400	≤50	≤2	≤0,5	≤0,8	≤76,2	1	≤50
Naturalne wody mineralne [2] Natural Mineral Water						10		1			3	
Wody pitne [3] Drinking Water		2,5	≥6,5–9,5≤		200	10	1				5	

Wody powierzchniowe Surface water	Parametry Parameters	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
Seget Seget Stream n = 19	a b c d e	<0,003 <0,003 <0,003 <0,003 <0,003	0,71 4,14 2,00 1,79 1,86	0,01 2,40 0,20 0,06 0,04	1,8 13,8 3,9 3,2 2,3	1,8 26,9 4,7 3,5 2,6	2,1 38,7 9,3 7,6 7,3	0,005 3,550 0,342 0,084 0,063	<0,05 3,01 0,85 0,22 0,12	2,7 59,3 24,6 17,0 12,5	1,2 8,9 5,0 4,4 5,3	<0,05 0,09 <0,05 <0,05 <0,05
Zlewnia Seget Seget Stream catchment n = 37	a b c d e	<0,003 <0,003 <0,003 <0,003 <0,003	0,22 4,53 1,67 1,34 1,70	0,01 2,40 0,13 0,04 0,05	1,0 14,7 6,4 4,8 4,8	1,8 51,7 12,4 6,8 5,4	2,0 70,0 22,8 12,9 8,5	0,005 3,550 0,334 0,078 0,062	<0,05 3,02 0,81 0,31 0,71	2,2 59,3 28,9 19,0 27,0	<0,5 8,9 3,3 2,2 2,3	<0,05 0,33 <0,05 <0,05 <0,05
Zlewnia Bytomki Bytomka River catchment n = 24	a b c d e	<0,003 <0,003 <0,003 <0,003 <0,003	0,42 6,01 1,67 1,33 1,48	0,01 0,15 0,03 0,02 0,01	3,3 46,9 19,4 13,2 14,2	<0,3 980,7 199,2 26,1 13,5	5,9 163,3 51,3 310 21,7	0,003 0,293 0,086 0,042 0,065	0,21 3,60 1,20 0,92 0,93	6,8 1753,7 266,3 81,9 45,8	<0,5 3,2 1,1 0,6 0,5	<0,05 0,37 0,07 <0,05 <0,05
Zlewnia Dramy Drama River catchment n = 58	a b c d e	<0,003 <0,003 <0,003 <0,003 <0,003	0,57 8,28 2,42 2,06 2,17	0,01 1,45 0,10 0,04 0,04	1,7 97,1 13,6 9,0 10,1	0,4 327,2 16,1 4,8 3,6	4,2 44,2 14,1 12,0 10,9	0,001 1,725 0,229 0,070 0,104	<0,05 32,31 2,15 0,56 0,60	2,9 616,1 55,6 23,3 24,0	<0,5 20,5 3,5 2,5 2,8	<0,05 4,04 0,33 0,08 <0,05
Wartości wskaźników jakości wód powierzchniowych i pitnych; surface water and drinking water quality guidelines												
I klasa [1] Class I		≤0,05	≤50	0,1			≤5		≤40		10	≤0,18
II klasa [1] Class II		≤0,05	≤50	0,3			≤27,8		≤40		20	≤0,22
Naturalne wody mineralne [2] Natural Mineral Water		0,05						500			20	
Wody pitne [3] Drinking Water		0,05						50		200	20	

Wody powierzchniowe Surface water	Parametry Parameters	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
Seget Seget Stream n = 19	a b c d e	0,36 29,15 4,86 2,90 3,75	9 362 99 79 82	0,24 7,47 1,13 0,53 0,36	<2 <2 <2 <2 <2	4,0 20,7 12,5 11,3 14,5	0,104 0,603 0,191 0,173 0,144	<0,002 <0,002 <0,002 <0,002 <0,002	<0,05 0,19 0,08 0,07 0,08	0,09 0,70 0,34 0,26 0,33	<1 3 <1 <1 <1	0,016 3,959 1,303 0,599 1,275
Zlewnia Seget Seget Stream catchment n = 37	a b c d e	0,10 29,15 3,01 1,15 1,50	4 438 158 90 83	<0,05 7,56 1,09 0,54 0,44	<2 <2 <2 <2 <2	0,7 20,7 8,3 5,3 7,9	0,089 0,778 0,328 0,251 0,222	<0,002 <0,002 <0,002 <0,002 <0,002	<0,05 0,19 0,06 <0,05 <0,05	<0,05 1,81 0,60 0,35 0,40	<1 3 <1 <1 <1	<0,003 3,959 0,678 0,059 0,057
Zlewnia Bytomki Bytomka River catchment n = 24	a b c d e	<0,05 0,96 0,22 0,09 0,06	19 854 325 144 147	0,12 2,57 0,82 0,62 0,65	<2 3 <2 <2 <2	0,3 15,5 6,1 2,7 1,9	0,194 4,142 0,873 0,533 0,356	<0,002 <0,002 <0,002 <0,002 <0,002	<0,05 0,17 0,05 <0,05 <0,05	0,07 6,84 1,15 0,60 0,60	<1 2 <1 <1 <1	<0,003 0,109 0,016 0,005 <0,003
Zlewnia Dramy Drama River catchment n = 58	a b c d e	<0,05 93,95 3,10 0,47 0,36	6 402 120 101 103	<0,05 71,23 2,22 0,57 0,41	<2 40 3 <2 <2	1,9 42,5 12,4 11,6 11,9	0,080 0,540 0,263 0,244 0,261	<0,002 0,023 <0,002 <0,002 <0,002	<0,05 0,94 0,08 0,06 0,06	<0,05 2,80 0,57 0,30 0,43	<1 20 2 1 <1	<0,003 0,660 0,118 0,047 0,068
Wartości wskaźników jakości wód powierzchniowych i pitnych; surface water and drinking water quality guidelines												
I klasa [1] Class I		10	≤31,6	≤2	≤20			≤0,05	≤2		≤50	≤1
II klasa [1] Class II		10	≤37,7	≤2	≤20			≤0,05	≤2		≤50	≤1
Naturalne wody mineralne [2] Natural Mineral Water		10		5	10							
Wody pitne [3] Drinking Water		10	250	5	10							

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] Wartości wskaźników jakości wód powierzchniowych w Polsce; surface water quality guidelines in Poland (Rozporządzenie..., 2019)

[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)

nificant changes in the soil chemistry are caused by metal ore mining and metallurgy, and the greatest threats include the impact of waste from such 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 due to Zn-Pb ore mining and processing (Pasieczna, 2018).

The map sheet area is characterized by a large variety of soil types depending on the bedrock type, topography, water conditions, plant cover, and human activity. The most important soil-forming factor is the chemical composition of soil parent rocks. In the map sheet area, these rocks are represented by various lithologies of Triassic, Neogene and Quaternary deposits (Pl. 1), which are the basis for the development of different types of soils. Rendzinas were formed from Triassic limestones and dolomites (exposed in the northeastern part of the map area). Brown earths and gleyed soils developed from Quaternary glacial tills (predominant in the south and west). Quaternary glaciofluvial sands are the parent rocks of podzolic soils. Fluvisols prevail in the river valleys covered with Holocene alluvial muds. Areas of urban and industrial development and mineral deposit extraction, surfaces of artificial slopes and reclaimed heaps, and river channels of engineered watercourses are covered with anthropogenic soils.

Grain-size composition. The percentage of particles of specified sizes in soil is called its mechanical composition, grain-size composition, granulation, granulometric composition, or particle-size distribution (Mocek *et al*., 2000; Ryżak *et al*., 2009). Under natural conditions, the soil grain size changes very little and is one of the most important features affecting its physical, chemical and biological properties.

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 permanently 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 soil grain-size composition determines highly its resistance to degradation and has a significant impact on the content of chemical elements. The soils that show a high proportion of clay and silt fractions are usually characterized by an increased content of chemical elements, but their mobility is lower under hypergenic conditions compared to sandy soils. These soils are more resistant to the leaching of nutrients from plants and can retain a greater amount of toxic components (including heavy metals) without harming the environment.

The sand fraction (1.0–0.1 mm) prevails in the grain-size composition of the studied soils. The median of its content is 47%, and the medians of the silt and clay fractions are 23% and 22%, respectively.

In the topsoil layer of many regions, the original grain-size composition has been significantly modified due to near-surface mining of Zn-Pb ores, hard coal, and dolomite deposits. The large proportion of anthropogenic soils is manifested by the distribution of clay fraction (<0.02 mm), especially in the eastern part of the study area (Pl. 6). The alternating meridionally arranged soil zones contain <15% and >20% of this fraction, respectively. The western part is dominated by soils containing >20% of the clay fraction and <20% of the silt fraction (0.1–0.02 mm), which developed mainly from glacial tills.

Acidity. In both the topsoil (0.0–0.3 m) and subsoil (0.8–1.0 m), worth noting is the location of acidic soils (pH <6.30). They occur in forest areas (Pl. 2) arranged in a circular pattern around the Stroszek and Górniki residential areas in Bytom. In the western part of the map sheet, neutral soils (pH 6.3–7.4) prevail, while in the east and south, alkaline soils (pH> 7.4) and, locally, strongly alkaline ones (pH> 8) are found.

The largest areas of alkaline soils occur in the southeastern and northeastern ends of the map sheet, which can be associated with industrial activity (from coal mines and from dusting of material of mine heaps and dolomite quarries). The reason for soil alkalization is also the long-term emission of solid particles from coal combustion plants, in which the CaO content can reach 10% (Zapotoczna-Sytek *et al*., 2013). Other alkalizing factors include the use of measures to remove snow from the streets, and dust emissions from industrial plants and domestic fireplaces.

Geochemistry. Soils are a component of the natural environment particularly exposed to anthropogenic transformations. They are visible mainly in urbanized and industrial areas, where the basic geochemical features, dependent on the soil parent material, are very poorly legible, and the spatial distribution of the analyzed elements allows predominantly a clear identification of pollution from various industrial activities.

In the topsoil, the median value of the analyzed elements (aluminum, calcium, cobalt, magnesium, phosphorus, nickel, sulfur and strontium) that are sourced mainly from parent rocks is either close to the median value of the geochemical background (soils in the Silesian-Cracow region) or greater (approx. twice as much for barium, manganese, sulfur, titanium, vanadium and iron). There is also an accumulation of elements emitted to the environment chiefly as a result of industrial activities. The contents of arsenic, cadmium, chromium, copper and zinc are twice as high, while of lead, it is even three times as high as the regional geochemical background level (Table 2). The median value of mercury does not differ from its regional level, which may indicate that this element is dispersed even from distant emission sources.

Soils of the western part of the map sheet area are poorer in organic carbon (<3%) compared to the eastern regions (3–12%). Soils in the areas of coal mining dumps contain the greatest amounts of organic carbon (>12%), attaining a maximum of 44.52%. The content of this component is clearly dependent of the soil use type. The median content of organic carbon in forest soils is 3.62%, whereas in arable land soils, it is merely 1.42% (Table 2).

In both depth intervals, the soils usually contain 0.40–0.80% aluminum. The aluminum content exceeds 0.80% only in the southeastern part of the map sheet area, where the parent rocks are represented by weathered Quaternary tills.

The barium content in arable soils of Europe was found to range from 2.6 to 818 mg/kg (Reimann *et al*., 2014). The barium content distribution in the studied soils is significantly different, in both terms of its occurrence in topsoil and subsoil, and the location. In the western part of the map sheet area, the topsoil usually contains 60–120 mg/kg of barium, while the deeper soil layer is much poorer in this element (<60 mg/kg of this element).

The content of barium in subsoil can be considered as a manifestation of its natural source – outcrops of Quaternary tills. The natural concentration of barium in soils of the Polish Lowlands rarely exceeds 50 mg/kg, and in Upper Silesia, it is within the range of 100–200 mg/kg (Lis, Pasieczna, 1995a, b). Some amount of this element was probably introduced into the topsoil (containing >240 and locally >480 mg/kg of barium) due to technological processes. One of the possible sources is the use of barite in liquids used for coal enrichment, as evidenced by its highest content in the areas of mines and mine tailings heaps located in the southeast of the map sheet. Barium is also abundant in dusts from the combustion of coal and liquid fuels.

The median of phosphorus content in the topsoil layer is twice as high as in the subsoil (0.038% and 0.013%, respectively). In both layers, acidic soils of forests are the least abundant in phosphorus. In the topsoil of forests phosphorus content is 0.015–0.030%, when deeper it decreases to <0.015%. Arable-field topsoil in the western part of the map sheet area commonly contain 0.030−0.060% of phosphorus. The source of the increased content of this element in the surface layer of arable lands may be the direct use of phosphorus fertilizers, and in urban areas it may originate from municipal wastewater discharges and excessive fertilization of allotment gardens.

The spatial distributions of calcium, magnesium, manganese and strontium contents in the topsoil and subsoil layers show a great similarity resulting mainly from the presence of carbonates in the bedrock. The soils of both depth intervals, naturally enriched with these elements (>1% calcium, >0.50% magnesium, >800 mg/kg manganese, and >40 mg/kg strontium), occur in the Blachówka, Lazarówka and Sucha Góra areas on the border of Bytom and Tarnowskie Góry and in the Bobrek and Miechowice areas in Bytom. The lowest contents of these elements are found in forest soils around the Górniki, Stolarzowice and Helenka residential areas in Bytom.

The area rich in calcium and manganese is greater in the topsoil than in subsoil, which indicates that part of these elements is of anthropogenic origin (due to soil fertilization, and dust emissions from industrial plants and quarries).

The manganese content anomaly (as well as the increased content of calcium, magnesium and strontium) in the Górniki residential area is probably the effect of mining waste stored in a mine waste heap from Zn-Pb ore mining in this area.

The content of sulfur in soils of arable fields in Europe ranges from <0.0005 to 0.26% (Reimann *et al*., 2014). In the topsoil layer of Poland and the Silesian-Cracow region, the contents are 0.012% and 0.015%, respectively (Lis, Pasieczna, 1995a, b). In most of soils from both depth intervals (topsoil and subsoil), the content of sulfur does not exceed 0.080% in the map sheet area. A local increase in its content (>0.160%) is observed in soils surrounded by waste heaps of hard coal mines in the southeastern part of the map area (Bobrek, Potok Miechowicki Stream valley, a heap in Wesoła). The probable source of sulfur is the oxidation of pyrite dispersed in gangue rocks stored in the heaps.

Distinct anthropogenic anomalies of silver, arsenic, cadmium, lead and zinc were found in the areas of historical exploitation of Zn-Pb ores (in the upper part of the Seget Stream drainage basin, in the Górniki residential area in Bytom, and in the Miechowice, Karb and Bobrek districts of Bytom). These are the areas of Triassic ore-bearing dolomites (Biernat, 1954 reambulation Wilanowski, Lewandowski 2016), where there are scattered heaps of washing waste from Zn-Pb ore mining of the dolomites, which are a source of the metals (Degenhardt, 1870; Molenda, 1960, 1972; Grzechnik, 1978; Jędrzejczyk-Korycińska, 2009; Szadkowska, Gwóźdź, 2015).

Anomalies of silver (>1 mg/kg), arsenic (>40 mg/kg), cadmium (>4 mg/kg), lead (> 100 mg/kg) and zinc (>500 mg/kg) cover greater areas in the topsoil layer, but are characterized by higher intensity in subsoil. Extreme levels of these elements occur only on a local scale.

The arsenic content in natural soils is 7.2 mg/kg on average, while in soils polluted by metal mining and smelting, or developed on outcrops of ore-bearing deposits, it can reach a level of several percent (Wenzel, 2013). An increase in arsenic content in topsoil is clearly marked in the eastern part of the map sheet area compared to the western part (above and below 10 mg/kg, respectively). In the subsoil layer, increased levels were recorded only in the areas of lead and zinc anomalies. This points to both the ore-bearing dolomites as the main source of arsenuc in the soils and the pollution of the topsoil likely mainly due to dust emissions from fuel combustion. This factor is suggested by similar spatial distributions of arsenic and mercury that enters the soil mainly due to dust fall from the combustion of large amounts of hard coal, in which it is bound with both organic and mineral substances (Bojakowska, Sokołowska, 2001; Hławiczka, 2008).

The maximum concentration of arsenic (781 mg/kg) in topsoil was found in Bobrek in a green area at a reclaimed waste heap. The pollution is probably due to the impact of the remains of a heap of the Bobrek ironworks that operated in this area in 1856–1994

(Brudzyński, 1999). In the subsoil layer, wasteland near Elektrownia Street contains 790 mg/kg of arsenic, while 562 mg/kg was reported from near a heap in Wesoła.

Mineral topsoils of Europe shows an average cadmium concentration of 0.14 mg/kg (Salminen, 2005); in Poland, its average concentration does not exceed 0.5 mg/kg, whereas in Upper Silesia, it is 1.3 mg/kg (Lis, Pasieczna, 1995a, b). Cadmium is considered one of the most undesirable metals in the environment, which is detrimental to all biological processes (Kabata-Pendias, Szteke, 2015).

The most heavily cadmium-polluted soils (>64 mg/kg) occur west of the Zielone Wzgórza residential area, in Stroszek and Górniki residential areas, and south of the intersection of J. Nowaka-Jeziorańskiego and Miechowicka streets in Bytom. In topsoil, the highest cadmium concentrations were found in the forest area the Segiet Nature Reserve (1,191 mg/kg), in the Hipolit forest (230.3–536.7 mg/kg), and in the Potok Miechowicki Stream valley (232.4 mg/kg).

The world's average lead concentration in soils is estimated at 27 mg/kg. In the soils of European countries, it is 22.6 mg/kg (de Vos, Tarvainen, 2006), in the soils of Poland 13 mg/kg, and in the Silesian-Cracow region 44 mg/kg (Lis, Pasieczna 1995a, b). The average zinc concentration in the world's soils ranges from 30 to 100 mg/kg, in the soils of Europe, it is 48 mg/kg on average (Salminen, 2005), in Poland 35 mg/kg, and in the Cracow-Silesian region 104 mg/kg (Lis, Pasieczna, 1995a, b). Given these data, the map sheet soils can be considered very heavily polluted with lead and zinc. The topsoil layer of forests in the vicinity of Stroszek, in the Potok Rokitnicki Stream valley, and in the Górniki residential area is among the most polluted sites with lead and zinc (>10,000 mg/kg). In the same areas, the subsoil layer is also heavily polluted, although the anomalies are less extensive here. The zinc concentration in several locations exceeds 30,000–40,000 mg/kg. The area of lead and zinc anomalies is found also in the southeastern part of the map sheet. In some soils, the concentrations of lead and zinc reach 12,790 mg/kg and 62,144 mg/kg here, respectively.

In the areas of historical exploitation of Zn-Pb ores and modern hard coal mining (especially around mine heaps), both the topsoil and subsoil show increased contents of cobalt, chromium, copper, iron, nickel and vanadium. The main anthropogenic source of these metals are processes related to the mining, processing and smelting of non-ferrous metal ores, the production of metallic alloys, as well as discharges of industrial sewage, and leachates from landfills (Kabata-Pendias, Szteke, 2015).

In the northeastern part of the map sheet and in the Bobrek district of Bytom, some soils of the surface layer of industrial areas contain >160 mg/kg chromium, >320 mg/kg copper, and >4% iron.

The concentration of mercury in the world's soils is approx. 0.02–0.3 mg/kg (Migaszewski, Gałuszka, 2016). In the Polish Lowlands, the median of its concentration is <0.05 mg/kg, while in the Silesian agglomeration it is 0.05 mg/kg (Pasieczna, 2003). In the map sheet area, mercury pollution (>0.20 mg/kg) is found in both depth intervals, but in the topsoil layer, the anomalies occupy larger areas. In topsoil, the strongest mercury anomaly (with a maximum of 7.58 mg/kg) occurs in alluvial soils of the Dopływ w Mikulczycach Stream, while in subsoil, 8.40 mg/kg of mercury was recorded near a waste dump of the coal mine and railway tracks in Bobrek. In the natural environment, mercury is considered one of the most toxic metals, even at very low concentrations, due to its chemical and biological activity and the variability of its forms (Kabata-Pendias, Mukherjee, 2007).

The 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 their ease of accumulation and the harmful effects of their excess on plants and soil microorganisms, and consequently on human health, the percentage of the sheet area polluted with these metals to different extents has been estimated (Table 6). About 1% of the analyzed soils from both depth intervals contain harmful amounts of arsenic (>100 mg/kg). The cadmium, lead and zinc pollution is marked more clearly. In the topsoil 6.39% of soils contain >15 mg/kg of cadmium, 10.38% of soils >600 mg/kg of lead, and 8.95% of soils >2000 mg/kg of zinc. At the depth of 0.8–1.0, the proportion of soils polluted with these metals decreases and amounts to 4.29% for cadmium, 5.17% for lead, and 6.20% for zinc.

For topsoil, the assessment of the degree of metal pollution was carried out by classifying the soil into use groups 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 85.03 to 100% of the analyzed soils have been classified into groups I–III (meeting the conditions of multifunctional use – residential buildings, arable lands and forests) were classified. Group IV (soils that can be used only for industrial purposes) accounts for 0.22–2.10% of soils, while 0.08–10.38% of soils represent those of toxic content (Table 7). In many cases, the current land use is inappropriate and requires monitoring and reclamation. The cadmium, zinc and lead concentrations in soils of some forests and agricultural land are so high that these areas should not be used even for industrial purposes. An example of soil classification (in a cartographic form) indicating their proper use (in accordance with Rozporządzenie.., 2016) is presented on the map of the distribution of cadmium content (Pl. 63). Approximately 6.39% of the map sheet area is covered with soils containing >15 mg/kg of cadmium, which can be considered toxic.

SEDIMENTS

Bottom sediments of inland watercourses and stagnant water bodies accumulate from mineral and organic suspension originating from erosion and precipitation of water constituents. Their chemical composition is dependent on lithology, climate and the mode of management and use of drainage basin (Zgłobicki, 2008; Hinwood *et al*., 2012; Rzętała *et al*., 2013; Cánovas *et al*., 2015).

In industrial, urban and agricultural areas, sediments may accumulate potentially harmful trace elements and organic compounds that occur in waste dump leachates, industrial and municipal sewage discharged into surface water, and in runoff waters (Ciszewski, 1997, 2002, 2005; Bojakowska *et al*., 2006; Kozieł, Zgłobicki, 2010; Sojka *et al*., 2013; Cempiel *et al*., 2014). High concentrations of both trace elements (zinc, copper, chromium, cadmium, lead and mercury) and persistent organic pollutants may cause their accumulation in the trophic chain to contents that are toxic to aquatic organisms. As a result of biological, chemical and physical processes, harmful components of sediments may be re-released into water (Friese, 2002; Harnischmacher, 2007), and polluted sediments displaced into floodplain terraces are the reason for the growth of content of many substances in the soils of river valleys (Ibragimow *et al*., 2010).

Within the map sheet area, the investigations covered bottom sediments of watercourses and reservoirs in the basin basins of Potok Mikulczycki, upper Bytomka River, Seget Stream, and upper Drama River (Fig. 3).

The Potok Mikulczycki Stream and its catchment. The stream is also called the Potok Rokitnicki Stream in its upper reach and the Potok Żernicki Stream in the lower reach. It flows through forests, farmlands and the districts of Zabrze (Rokitnica, Grzybowice, Mikulczyce), where some of its sectors are covered. It drains areas composed mainly of Quaternary glacial tills. In the upper course, it is fed by the Dopływ spod Górników Stream, whereas in the lower course by the Dopływ w Mikulczycach Stream.

The contents of elements of lithogenic origin – barium, calcium, cobalt, magnesium, nickel, phosphorus, sulfur, strontium and vanadium – in alluvial sediments of the stream and its drainage basin are similar or slightly higher than the geochemical background level in the sediments of the Silesian-Cracow region, determined by the median values (Table 4).

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 km²	%	Obszar/Area km²	%
As	<10	50,12	60,75	71,01	86,07
	10–25	25,49	30,90	6,95	8,43
	25–50	4,41	5,34	2,36	2,86
	50–100	1,61	1,95	1,31	1,59
	>100	0,87	1,05	0,85	1,03
Cd	<2	40,63	49,25	66,94	81,14
	2–5	26,11	31,65	7,02	8,51
	5–10	7,94	9,62	3,74	4,53
	10–15	2,54	3,08	1,24	1,51
	>15	5,27	6,39	3,54	4,29
Pb	<100	32,38	39,25	65,89	79,87
	100–200	20,09	24,36	5,71	6,92
	200–500	19,72	23,91	5,64	6,84
	500–600	1,74	2,11	0,98	1,19
	>600	8,56	10,38	4,26	5,17
Zn	<300	51,73	62,71	66,55	80,66
	300–500	9,73	11,80	4,06	4,93
	500–1000	8,68	10,53	3,80	4,61
	1000–2000	4,96	6,02	2,95	3,57
	>2000	7,38	8,95	5,11	6,20

The aluminum content is most often in the range of 0.5–1.0%, locally >2.5%. Arsenic was found in most of the drainage basin sediments to be within the limits of natural concentration (<3–30 mg/kg).

The anomalies of barium content (>600 mg/kg) are found locally in sediments of the catchments of the upper part of the Potok Mikulczycki Stream are probably due to the chemical composition of bedrock. A high barium content coexisting with the concentrations of calcium (up to 20.17%), iron (up to 10.18%), manganese (up to 29 680 mg/kg) and strontium (up to 1,732 mg/kg) is observed in the sediments of the initial course of the Dopływ w Mikulczycach Stream. It, may be related to the leachate from settling tanks of the Pstrowski mine, where heavy liquids (containing calcium, iron and barium compounds) were discharged after the coal enrichment process (Górnictwo…, 2015).

Sediments of the upper reach of the Potok Rokitnicki Stream, Dopływ spod Górników Stream, and minor watercourses in this part of the drainage basin show remarkable concentrations of silver (2–10 mg/kg), cadmium (30–215.4 mg/kg), lead (500–6,505 mg/kg) and zinc (1,100–26,560 mg/kg). The high metal content is related to the drainage of historical areas of Zn-Pb ore mining, where the Hipolit, Planeta and Verona mines operated (Degenhardt, 1870; Jędrzejczyk-Korycińska, 2009; Geognostische Karte…; Krisowe szlaki….). The increased contents of iron (6–14%), manganese (1,500–28,320 mg/kg), cobalt (>40 mg/kg) and nickel (>20 mg/kg) in sediments of this part of the drainage basin may probably be associated with the presence of limonite iron ores and their historical exploitation. The accumulation of these elements is related to the favorable environment

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	1290 96,99%	26 1,95%	14 1,06%
Ba	<1000	1000–1500	>1500	1326 99,70%	3 0,22%	1 0,08%
Cr	<500	500–1000	>1000	1330 100%	–	–
Zn	<1000	1000–2000	>2000	1131 85,03%	80 6,02%	119 8,95%
Cd	<10	10–15	>15	1204 90,53%	41 3,08%	85 6,39%
Co	<100	100–200	>200	1330 100%	–	–
Cu	<300	300–600	>600	1324 99,77%	3 0,23%	3 0,23%
Ni	<300	300–500	>500	1330 100%	–	–
Pb	<500	500–600	>600	1164 87,52%	28 2,10%	138 10,38%
Hg	<10	10–30	>30	1330 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

of their sorption in alluvial-type sediments that are rich in organic matter, clay minerals, and iron oxides and hydroxides.

In the sediments of the Potok Mikulczycki Stream drainage basin, about 36% of the samples show the mercury content similar to the regional geochemical background level (0.06 mg/kg). Some sediments contain 0.07–0.20 mg/kg of this element, exceeding 1 mg/kg at several locations (Grzybowice area, Kocha shaft on the Brantka pond). The maximum mercury concentration (14.12 mg/kg) was found in the Dopływ w Mikulczycach near Parkowa and Św. Wawrzyńca streets. It is a wooded wasteland where plant protection products or other mercury-containing substances may have been illegally deposited. The increased content of this metal in the upper part of the drainage basin can be associated with the leaching of dispersed waste from the historical mining of Zn-Pb ores. In the lower part, it is related to the emission from high-temperature coal combustion in the Jadwiga coking plant, located in Zabrze-Biskupice, beyond the southern boundary of the map sheet.

Bytomka River catchment. The southeastern periphery of the map area, including the industrial and urbanized districts of Bytom, is the upper part of the Bytomka River drainage basin. The river rises near the Bytom-Karb railway station and is fed mainly by water from mines (Cempiel *et al.*, 2014). Along the entire length across the map sheet, the river has no natural tributaries and its channel is sealed. It is fed by ditches and pipelines that carry polluted sewage. The most massive wastewater discharges come from the Bobrek and KWK Bobrek-Centrum sewage treatment plants (Cempiel *et al.*, 2014). Through the Rów Miechowicki Ditch (also known as Julka), water from the modernized Miechowice Sewage Treatment Plant (at Łaszczyka Street) is discharged to the Bytomka. It also receives sanitary sewage from the western part of Piekary Śląskie.

In subsidence basins or post-mining workings located in the drainage basin area, there are numerous closed water bodies, and the soil's chemical composition is anthropogenically altered in many places. Mineshafts and settling ponds of the closed Szombierki and Rozbark coal mines and the operating Bobrek-Centrum mine, as well as railway junctions are located here. Some of the pollution in the drainage basin sediments may come from these sources. Earlier studies showed their significant pollution by chromium, cadmium, zinc, lead and copper (Nocoń, 2009; Cempiel *et al.*, 2014). Stagnant water bodies located at the southern boundary of the map sheet area reveal increased contents of calcium (5.72–10.32%) and strontium (220–720 mg/kg).

Sediments of the Potok Miechowicki Stream that feeds the Bytomka River are polluted with metals (10.7–46.7 mg/kg cadmium, 82–130 mg/kg copper, 0.49–11.79 mg/kg mercury, 350–1,216 mg/kg lead, and 3,817–7,175 mg/kg zinc) and phosphorus (0.123–1.117%). Sewage discharges from treatment plants seem to be the most likely source of these elements.

Seget Stream and its catchment. In the upper part of the drainage basin, there are Triassic ore-bearing dolomites, containing zinc and lead ores (Biernat, 1954; reambulation Wilanowski, Lewandowski, 2016), on the surface and under a thin cover of Quaternary sediments. They have been mined and processed for several centuries. The sediments are polluted by leachate from flotation tailings heaps left after enrichment of Zn-Pb ores.

Almost all sediments of the Seget Stream contain metals present in the ores. The highest concentrations were found in the sediments of the upper part of the stream draining the historical mining area; the amounts are as follows: 2–11 mg/kg silver, 18.9–235.8 mg/kg cadmium, 1.42–15.33% iron, 300–28,570 mg/kg manganese, 396–14,640 mg/kg lead and 1954–16,600 mg/kg zinc. Worth noting is also the presence of cobalt and titanium in the sediments: 80–492 mg/kg and 120–200 mg/kg, respectively. In turn, the concentration of copper (115–122 mg/kg) in the Blachówka residential area may originate from recent anthropogenic sources. Sediments enriched with this element were recorded near a car service facility and an illegal waste dump.

In the Seget Stream drainage basin (on the border of the Miechowice and Karb districts of Bytom) there is the Brantka subsidence pond that formed after World War II as a result of improper coal mining. In this area, the Zn-Pb ores were mined in the historical Fryderyk mine, and the pond shore is the site of the Koch shaft remains (Bytom; Miechowice). At the northern shore of the pond, the maximum concentrations of silver, arsenic, cadmium, iron, mercury, lead and zinc in the sediments are 101 mg/kg, 292 mg/kg, 732.2 mg/kg, 13.04%, 1.34 mg/kg, 13,080 mg/kg, and 78,480 mg/kg, respectively.

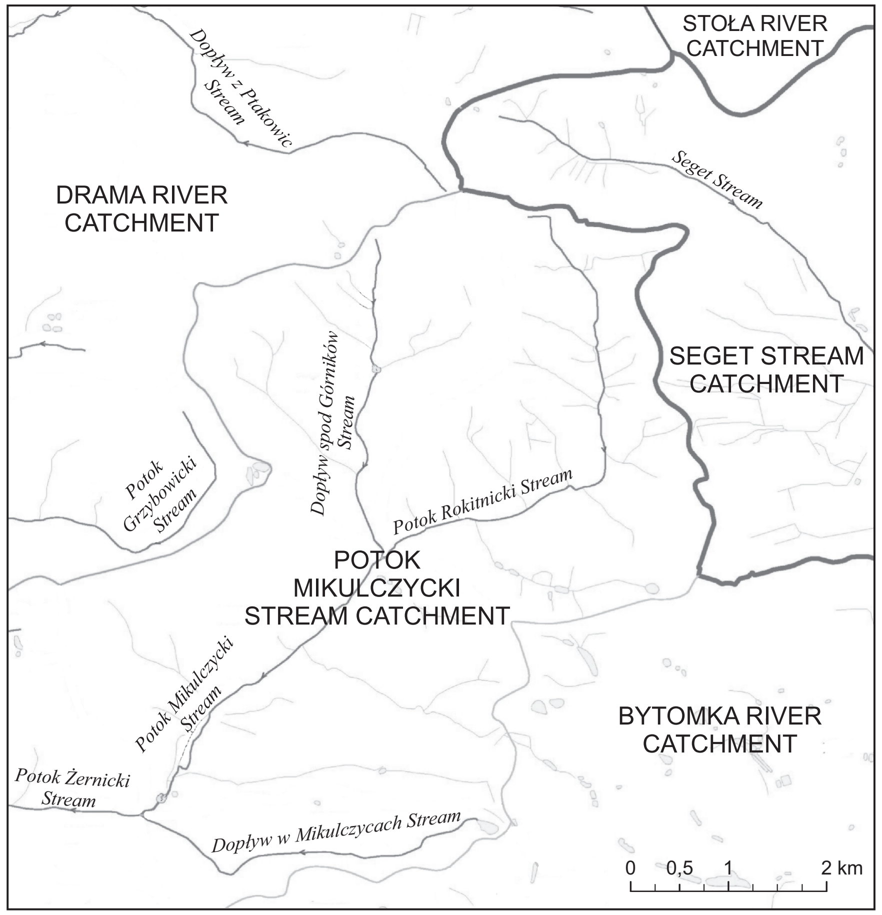

Fig. 3. Location of watercourses and stagnat water reservoirs and catchment areas (according to Mapa...)

The Drama Stream catchment covers the northwestern, largely agricultural part of the map sheet area. In this region, the Drama Stream is fed by the streams of Dopływ z Ptakowic Stream and Potok Grzybowicki Stream. The contents of most elements in the analyzed sediments are slightly higher than the geochemical background levels of the Silesian-Cracow region (expressed by their median values) (Table 4). Clear depletion is visible in the case of calcium, while enrichment in the case of manganese.

In the Dopływ z Ptakowic Stream valley and its unnamed tributary, the Triassic Zn-Pb ore-bearing dolomites are exposed on the surface. They have been continuously eroded, providing alluvial material, but they were also the subject of historical extraction of galena in Ptakowice and Zbrosławice. The permanent pollution of sediments by waste that left due to silver smelting from galena is evidenced by the concentrations of cadmium (26.6–33.8 mg/kg), lead (780–6,421 mg/kg) and zinc (1,366–4,105 mg/kg). The sediments also contain increased concentrations of cobalt (40–87 mg/kg) and manganese (6,300–14,000 mg/kg).

SURFACE WATER

The anthropogenic impact on water resources is of quantitative (change in water relations), qualitative (water pollution, changes in chemistry), and topographic (transformation of the shape of watercourse channels or water body basins) nature. As a consequence, adverse changes cause ecological effects, such as disturbance of habitat conditions, disappearance of certain species, and reduction in biodiversity.

In the areas of hard coal mining, one of the most important problems is the discharge of mine water to rivers and streams long after mining has ceased. They may cause oxidation of iron compounds, dissolution of calcite, and precipitation of goethite.

The water study was performed to find out the content of some chemical components, electrolytic conductivity and acidity. In order to compare and facilitate the assessment of the water quality, 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. The indicators values follow those specified in the methodologies used in Poland (Rozporządzenie.., 2019). Additionally, 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) are given (Tab. 5).

The pH value of water in the map sheet area does not meet the normative recommendations only in a few cases. The waters of pH <6 occur at points in the upper course of an unnamed watercourse (right-hand tributary of the Dopływ spod Górników Stream) that feeds the Potok Mikulczycki Stream. The pH >8.8 was recorded in several samples downstream of the mouth of the Dopływ w Mikulczycach Stream. Water of the ponds (including the Brantka pond) shows alkaline pH.

Mineralization, as reflected by the EC value, exceeds the value of 0.45 mS/cm in most of the waters, which is assumed as the limit value for class II waters (Rozporządzenie..., 2019).

The Potok Mikulczycki Stream and catchment. The stream water is characterized by the electrolytic conductivity value in the range of 0.38–1.54 mS/cm and the pH in the range of 7.4–9.4. In the drainage basin, mineralized waters (EC above 1 mS/cm) occur in the upper course of the unnamed stream flowing into the Dopływ spod Górników Stream, and in the lower course of the Potok Mikulczycki Stream, downstream of the sites of sewage discharges from the Zabrze-Rokitnica, Zabrze-Mikulczyce and Zabrze sewage treatment plants. Grzybowice (Wodociągi). The most polluted waters (EC 6.54–13.08) are found in the initial course of the Dopływ w Mikulczycach Stream, because they are loaded with substances from settling ponds of coal mines. The change in water chemistry due to mine water discharges is evidenced by comparing the concentration of elements characteristic for mine waters in the upper and lower parts of the catchment. The concentrations of lithium, magnesium and sodium are 3–13 mg/dm^3 and 100–500 mg/dm^3, 9–23 mg/dm^3 and 40–120 mg/dm^3, and 20–300 mg/dm^3 and 440–2,190 mg/dm^3, respectively. The contribution of mine waters to the pollution is also emphasized by the concentration of boron and sulfates, which are, respectively, 0.02–0.24 mg/dm^3 and 70–150 mg/dm^3 in the upper part of the drainage basin, and 0.30–1.40 mg/dm^3 and 300–700 mg/dm^3 in the lower part.

Because of the content of sulfates in the waters of the Potok Mikulczycki Stream catchment, they are substandard waters. They are also classified as substandard waters due to the concentrations of calcium (>35 mg/dm^3) and magnesium (>25 mg/dm^3). The phosphorus load in the waters of an unnamed watercourse flowing into the Potok Mikulczycki upstream Gajdzikowe Górki (0.39–0.73 mg/dm^3), and of the Potok Rokitnicki Stream (1.19–2.03 mg/dm^3) also classify them as substandard waters. Due to the concentration of >0.3 mg/dm^3 of iron, 45% of water samples in the drainage basin, the waters are classified as substandard waters. At several places, its concentration exceeds 1.50 mg/dm^3, reaching a maximum of 35.86 mg/dm^3 in the waters of the forest sector of an unnamed stream flowing from Górniki-Wieszowa area.

In the upper part of the Potok Mikulczycki Stream catchment, the waters are polluted by metals sourced probably from the erosion of outcrops of Zn-Pb ore-bearing dolomites and scattered post-flotation wastes from processing of zinc-lead ores. In the lower part, the sources of pollution are constituents of wastewater discharged from sewage treatment plants and those of waters of mines settling tanks discharged into the Dopływ w Mikulczycach Stream.

Excessive metal content is noted in the waters of a sector of the Potok Mikulczycki Stream forest valley where significant concentrations of cadmium (2.24–6.66 μg/dm^3), lead (2.79–10.95 μg/dm^3) and zinc (0.404–0.686 mg/dm^3) were found. It is difficult to identify unambiguously the source of these elements, but their coexistence indicates a relationship with the occurrence of Zn-Pb mineralization.

In the southern part of the drainage basin, increased concentrations of molybdenum (2.06–9.45 μg/dm^3) and uranium (2.82–9.04 μg/dm^3) were recorded in the waters of an unnamed watercourse draining a waste heap of the closed Mikulczyce coal mine. They are related probably to the leaching of these elements from the heap material.

Bytomka River catchment. The analyzed drainage basin waters come predominantly from stagnant water bodies. Apart from a few exceptions, they do not meet the standards for waters of quality classes I and II due to the levels of pH and electrolytic conductivity. The median EC value is 0.59 mS/cm, which proves their significant mineralization.

Some of the analyzed waters of reservoirs located at the southern boundary of the map sheet area are loaded with a group of constituents from mine waters: boron (up to 1.23 mg/dm^3), lithium (up to 980.7 μg/dm^3), sodium (up to 1,753.7 mg/dm^3) and sulfates (up to 854 mg/dm^3). These waters are also rich in magnesium and calcium from the same sources, while the concentrations of arsenic (median 2 μg/dm^3) and barium (median 0.08 mg/dm^3) are low. Due to the contents of calcium, magnesium and sulfates, they are classified as substandard waters.

Seget Stream and its catchment. The electrolytic conductivity values of the waters indicate their low salinity (the average EC in the drainage basin is 0.47 mS/cm), and the pH is in the range of 7.1–8.9.

In the upper part of the stream, the concentrations of cadmium (up to 9.67 μg/dm^3), cobalt (up to 10.1 μg/dm^3), lead (up to 29.15 μg/dm^3) and zinc (up to 3.959 mg/dm^3) are high. The thallium concentration (<0.05–0.17 μg/dm^3) does not exceed the limit for water quality classes I and II. Throughout the analyzed course of the stream, the contents of other elements are invariable and indicate a slight pollution level.

Drama River catchment. The electrolytic conductivity of the drainage basin waters varies within the range of 0.14–2.12 mS/cm. The lowest EC values (0.10–0.50 mS/cm) are found in the watercourses of the northern part of the map sheet area, while the highest ones are recorded in the upper reach of the Potok Grzybowicki. The pH of most of the tested waters remains within the limits set for water quality classes I and II. There are only a few cases of pH values ranging from 6.0 to 6.9.

The poor quality of the drainage basin waters is due to increased concentrations of beryllium (up to 1.16 μg/dm^3), cadmium (up to 10.42 μg/dm^3) and lead (up to 93.95 μg/dm^3) in the water bodies and in the upper reaches of no-name watercourses feeding the Dopływ z Ptakowic Stream.

In the upper course of the Potok Grzybowicki Stream, there are increased concentrations of molybdenum (8.30–32.31 μg/dm^3), sodium (222–616 mg/dm^3), sulfates (160–402 mg/dm^3), antimony (2.17–6.70 μg/dm^3) and selenium (14–40 μg/dm^3), which qualifies these waters as substandard.

The Wieszówka Stream drainage basin waters are polluted mainly by a high concentration of phosphorus (1.15–3.96 mg/dm^3), exceeding the limit value for water quality class II.

CONCLUSIONS

1. The anthropogenic sources of environmental pollution are hard coal mining, historical exploitation and processing of zinc and lead ores, iron smelting, industrial waste (gangue heaps, coal sludge and mud settling tanks, underground mine water discharges), urbanization and transport.

2. The sand fraction (1.0–0.1 mm) prevails in the grain-size composition of the topsoil, and the large share of anthropogenic soils is reflected in the clay fraction content (<0.02 mm), especially in the eastern part of the map sheet area.

3. The pH of soils depends mainly on the mode of their use. In both depth intervals, acidic soils predominate, although the topsoil shows higher acidity. Alkaline soils were found locally in industrial and urbanized areas.

4. The chemical composition of the soils has been significantly changed by anthropogenic factors. Their natural constituents have been mixed with foreign materials, often reworked many times, soaked with salt water, and dried.

5. The spatial distribution of elements in the soils, which originate primarily from the parent rocks, is diverse. In the topsoil, the median values of aluminum, calcium, cobalt, magnesium, phosphorus, nickel, sulfur and strontium are similar to the median values of the geochemical background (in the Silesian-Cracow region). The approximately two-fold enrichment recorded for barium, manganese, sulfur, titanium, vanadium and iron is presumably related to anthropogenic sources of these elements.

6. Both depth intervals of the soils show remarkable accumulations of elements emitted to the environment as a result of industrial activity. The contents of arsenic, cadmium, chromium, copper and zinc are twice as high, and of lead even three times as high as the value of the regional geochemical background level.

7. There are numerous anthropogenic anomalies of silver, arsenic, cadmium, lead and zinc in the areas of historical mining of zinc and lead deposits, in the vicinity of the closed Bobrek ironworks, and near heaps left after these activities. The most polluted soils by these metals are found in the residential areas of Bytom (Blachówka, Lazarówka, Sucha Góra in the north, Górniki in the west), as well as the Bobrek and Miechowice regions in the east of the map sheet.

8. The pollution of sediments and surface water is anthropogenic in nature. Its sources are discharges of mine waters of active hard coal mines, and industrial and municipal wastewater, as well as the drainage of waste heaps from coal and zinc-lead ore mines, and the ironworks.

9. Sediments of watercourses and stagnant water bodies in the northern part of the map sheet area are heavily polluted mostly by metals associated with the historical mining of zinc and lead ores (cadmium, lead, zinc, silver and cobalt).

10. The tested waters are mainly alkaline. The definite anthropogenic pollution of most of the waters in the southern part of the map sheet area is associated with discharges of mineralized mine waters containing not only sulphates but also boron, potassium, lithium and sodium. In the watercourses draining the areas of sewage treatment plants, the waters are polluted with phosphorus.

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