Detailed geochemical map of Upper Silesia

1:25 000

Sheet **SIEMIANOWICE ŚLĄSKIE**

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The scale of the maps in the atlas is 1:35,000

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INTRODUCTION

A general geochemical study of Poland (Lis, Pasieczna, 1995a, b) has shown that the highest environmental contamination of soils, aquatic sediments, and surface waters occurs in the Silesian region. In 1996, work on the Detailed Geochemical Map of Upper Silesia, scale 1:25,000, began in this area, starting with the development of the pilot sheet Sławków M-34-63-B-b (Lis, Pasieczna, 1999). Geochemical studies in the Siemianowice Śląskie M-34-63-A-a map sheet area are a continuation of detailed mapping work conducted systematically by the Polish Geological Institute – National Research Institute and financed by the National Fund for Environmental Protection and Water Management after approval of the Ministry of Climate and Environment.

The map sheet area is located in the Metropolis GZM, which is the most industrialized and urbanized region of Poland (Rozporządzenie..., 2017). Much of its area lies within the administrative boundaries of a few cities with *poviat* rights: Mysłowice, Katowice, Chorzów, Siemianowice Śląskie and Piekary Śląskie, which are located in Upper Silesia, as well as Sosnowiec, which is located in the Dąbrowa Basin. The north-eastern part of the map sheet, also situated within the Zagłębie Basin, is part of the będziński district represented by the cities of Będzin and Czeladź. Much of the map sheet area is an anthropogenically transformed industrial and post-industrial region. For many years, its economic activity was associated primarily with the mining of hard coal and the smelting of iron and non-ferrous metals. At the turn of the 20th and 21st centuries, the production of hard coal and of the metallurgy industry decreased significantly as a result of restructuring and reorganization of the mining industry. Most of the industrial plants have been closed down. Currently, more and more brownfield sites are being revitalized to be used for urban and commercial development and recreational purposes.

The study area also has natural values. There are several municipal parks in Sosnowiec, Będzin, Czeladź and Siemianowice Śląskie. In Siemianowice Śląskie is the Przełajka Protected Landscape Area and three ecological sites: Pszczelnik Park, Bażantarnia and Michałkowicka Kępa. In Katowice, the Szopienice-Borki Natural Landscape Complex has been established. There are also animated nature monuments – 23 monumental trees (Geoserwis).

The results of geochemical studies, presented in cartographic form, accompanied by textual commentary and tabular summaries, show the present status of the quality of soils, aquatic sediments, and surface waters relative to the regional geochemical background and applicable legal norms.

The information gathered may be useful in the preparation of planning documents, including, in particular, ecophysiographic studies that are normally produced prior to the drafting of local spatial development plans and/or studies on conditions and directions of spatial development. Geochemical data may also be used to prepare strategic and sectoral documents, including environmental protection programmes, revitalization programmes (in the part presenting the environment condition), as well as forecasts of the environmental impact of draft strategic documents. In addition, they can be a source of information when drawing up environmental impact assessments, particularly for the reports on the environmental impact of projects. The research results on soils, sediments and waters can also be used to prepare various reports and assessments presenting the environment condition.

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

A number of specialists participated in the preparation of this report:

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CHARACTERISTICS OF THE MAP SHEET AREA

Geographical and administrative location. According to the physico-geographical division, the entire Siemianowice Śląskie M-34-63-A-a map sheet area is situated in the Silesian Upland within the lower-order unit called the Katowice Upland (Richling *et al.*, 2021), which is a plateau composed of Carboniferous coal-bearing deposits and outliers of the Triassic cover. Large areas of the map sheet are covered by Quaternary sediments.

The sheet area includes parts of the Dąbrowa Basin and Upper Silesia of the Metropolis GZM (Rozporządzenie..., 2017). These are parts of quarters of cities with *poviat* rights: Siemianowice Śląskie, Katowice and Sosnowiec. The southern part of the map sheet encompasses the quaters of Katowice (Załęże, Dąb, Wełnowiec-Józefowiec, Śródmieście, Koszutka, Bogucice, Dąbrówka Mała, Zawodzie, Szopienice-Burowiec and Janów-Nikiszowiec). The north-western part belongs to Siemianowice Śląskie (quarters: Centrum, Bytków, Michałkowice, Przełajka and Bańgów), and the central-eastern part – to Sosnowiec (quarters: Milowice, Pogoń and Stary Sosnowiec). The north-eastern portion of the study area is the territory of the cities of Czeladź and Będzin (quarters: Gzichów and Małobądz) located in the Będzin district. Small areas at the western, north-western and south-eastern boundaries of the map sheet belong to the cities with *poviat* rights: Chorzów, Piekary Śląskie and Mysłowice, respectively.

Surface relief, geomorphology and hydrography. The map sheet area spans the plateaus composed of Carboniferous and Triassic rocks covered by a thin layer of Quaternary sediments. They are dissected by the Rawa Stream and Brynica River valleys (Wilanowski, 2016a). More distinct hilly landforms (rising up to an elevation of 310–315 m a.s.l.) are observed along outcrops of thickly bedded sandstones. The highest elevated point, 318.9 m a.s.l., is located in Chorzów. The landscape of the north-eastern part of the map sheet is conspicuous by heights (up to 300 m a.s.l.) composed of Triassic carbonates. The lowest-lying region, at 245 m a.s.l., is the area around the pond Hubertus IV in Mysłowice.

The whole map sheet area lies within the Vistula River basin, in the 4rd order catchment of the Brynica River. The north-eastern part of the sheet is included in the 4th order catchment of the Czarna Przemsza River from the Przeczyce reservoir dam to the Brynica River. The hydrographic network of the study area consists mainly of the Brynica River and its tributaries: Rów Michałkowicki ditch, Rów Śmiłowski ditch, and Bolina and Rawa streams.

On the border of Sosnowiec, Katowice and Mysłowice, there are numerous water bodies formed as a result of many years of both sand exploitation for hard coal mining and land subsidence due to underground extraction. One of them, Stawiki lake, is located in Sosnowiec and covers an area of 7.8 ha. In Katowice, there are the Borki, Morawa and Hubertus I and II ponds, 9 ha, 35 ha, 7 ha, and 17 ha in area, respectively. Hubertus III reservoir covers an area of 21 hectares and is located on the border of Katowice and Mysłowice. Hubertus IV reservoir, 7 ha in area, is located in Mysłowice. Stawiki lake and partly Hubertus III have been developed to perform recreational functions. The others are angling fisheries. Some of the ponds located in Katowice are included in the Szopienice-Borki Nature and Landscape Complex (Geoserwis). At the southern boundary of the map sheet is the Staw Upadowy pond created on the site of the currently inactive Upadowa IV working pit, as well as one of the reservoirs of the Valley of Three Ponds (Dolina Trzech Stawów). In the Bańgów quarter of Siemianowice Śląskie, the Rzęsa pond (about 13 ha in area) was created in a former sand pit (Staw Rzęsa – https://dziecilubia-slaskie.pl/miejsca/staw-rzesa/ [access 14.12.2024]). In the Bytków quarter (near the western boundary of the map sheet) the Stawy Brysiowe ponds are located.

Land development and land use. The map sheet area is characterized by dense and highly stylistically diverse housing development, both residential and industrial, surrounding historic centres of the cities. Most of the study area is an urban-industrial agglomeration. Urban development occupies about 41% of the area, whereas industrial development about 18% (Pl. 2). In the undeveloped areas, there are many parks and neighborhood greens. In Siemianowice Śląskie, these are the following parks: Górnik, Bażantarnia, Pszczelnik, Park Hutniczy, and Park Miejski, in Czeladź: Grabek, Prochownia, Park Jordana, and Park Kościuszki, in Sosnowiec: Park Tysiąclecia, Park Kresowy and pilot Jan Fusiński Park, in Katowice: Powstańców Śląskich Park, Alojzy Budniok Park, and Wełnowiecki Park, and in Chorzów: Voivodeship Park of Culture and Recreation (Wojewódzki Park Kultury i Wypoczynku). There are also numerous allotment gardens in the map sheet area. The A4 motorway connecting the eastern and western borders of Poland, national roads (DK) 79, 86 and 94, and a number of railway lines run across the Siemianowice Śląskie sheet.

Economy. For many years, economic activity in the map sheet area was associated primarily with hard coal mining and iron and non-ferrous metallurgy. It lasted until the turn of the 20th and 21st centuries, when most industrial plants were closed down or transformed.

Hard coal was mined by the "Gottwald", "Katowice", "Michał", "Siemianowice", "Czeladź" and "Saturn" mines (Jaros, 1984), which were put into liquidation in the 1990s. Construction of the "Gottwald" Mine, which changed its name several times, began in 1904, but coal mining ceased there in 2004. Today, the shopping, service and entertainment centre Silesia City Center is located on its site. The "Katowice" Mine, which operated in the Bogucice quarter from 1823 to 1999, is now the site of cultural organizations (including the Silesian Museum, the Polish National Radio Symphony Orchestra, and the International Congress Centre). The "Siemianowice" Mine (which changed its name several times) was in operation from 1885 to 1993. In 1975, it was merged with the "Michał" Mine that had been in operation since 1883. In 2012, the Park Tradycji was opened after the renovation of the engine house and the hoist shaft of the "Michał" Mine, as well as following the reclamation of the adjacent area of the Michałkowice quarter (SCK...).

The "Czeladź" Mine (also known to the local community as the "Piaski" Mine) had been in operation since 1858. In 1973, as a result of its merger with the "Milowice" Mine, it changed its name to "Milowice-Czeladź", and then, in 1976, became part of the "Saturn" Mine – Ruch II and Ruch III. The KWK "Saturn" mine (operating from 1950 to 1990 under the name of "Czerwona Gwardia" ("Red Guard") produced coal between 1887 and 1996 (Konopelska, 2006). At the beginning of the 20th century, it was one of the most modern plants in the Dąbrowa Basin. Today, the former power station of the "Saturn" Mine houses the "Elektrownia" Gallery of Contemporary Art, and the mine itself is part of the "Industrial Monuments Route" of the Silesian Voivodeship.

The beginnings of the metal industry in the study area date back to the 14th–16th centuries, when the first forges (workshops smelting iron from local bog iron ores using charcoal as fuel) were established in Roździeń and Szopienice. Intense development of iron smelting took place in the 19th century. One of the establishments created at that time was the short-lived Dietrich ironworks that operated on the site of a pre-existing forge (at the junction of today's Obrońców Westerplatte, Morawa and Bednarska streets) in Szopienice-Burowiec (Katowice). In the Zawodzie quarter of Katowice, there is the FERRUM SA ironworks (originally the Rhein & Co. iron foundry) producing steel pipes (FERRUM SA), founded in 1874. Near the south-western boundary of the map sheet, the Baildon ironworks was located, established in 1823 on the site of a 15th century forge. During World War II, it produced products for the arms industry, and later on many grades of structural steel after the war. In 2016, the plant was decommissioned. The site of the Baildon steelworks has been earmarked for service, trade and office development.

In Milowice (currently a quarter of Sosnowiec), the Aleksander steelworks was opened in 1882 (Olszewicz, 1935), which changed its name and production profile many times in its history, and also underwent ownership transformations and in consequence was split into two plants. The main product over many years was high-pressure steel cylinders for technical gases, still manufactured today by the Vitkovice Milmet SA company (Vitkovice Milmet – https://www.vitkovice-milmet.pl/pl/ [access 18.10.2023]). Another equally important branch of industrial activity was the production of rolling bearings, which was initiated in the 1970s and is continued to date by the American Timken Co. (Gwosdz, 2013). In Siemianowice Śląskie (surroundings of Matejki, Głowackiego and Fitznerów streets), the Jedność steelworks, formerly Laurahütte, Laura, operated between 1839 and 2003 (Pomniki Organizacji...).

The north-western margin of the map sheet was the areas of mining of Zn-Pb ores from the Dąbrówka Wielka deposit in the 1970s and 1980s. Mining operations were carried out by the ZGH Orzeł Biały (Pradela, Solarski, 2013). Zinc metallurgy started developing in the mid-19th century in the quarters of Katowice: Dąbrówka Mała, Roździeń, Szopienice and Wełnowiec-Józefowiec. The following smelters operated in Dąbrówka Mała: Paweł, Walter Croneck (today the BATERPOL SA company is located there), Norma and Bernhardi (Muzeum...). The origins of the Szopienice non-ferrous metals smelter (Huta Metali Nieżelaznych – HMN) date back to 1834, when the Wilhelmina zinc smelter was opened near today's Krakowska Street, using calamine from the Szarlej mine as a raw material (Wilczok, 1984). In 1845, cadmium began to be produced at the smelter. In 1912, the Uthemann smelter was opened, along with a sphalerite roasting plant (https://pl.wikipedia.org/wiki/Uthyman [access 25.10.2021]).

At the beginning of the 20th century, the HMN Szopienice smelter was expanded and became the largest producer of non-ferrous metals in Silesia (the world's largest producer of cadmium as well). At the end of the 1940s, a copper refining division was established at the smelter, and in the 1950s, production of silver and liquid sulphur dioxide began. In 2008, the decision was taken to dissolve the company and to begin the process of liquidation. HMN Szopienice was the largest Polish manufacturer of rolled copper and brass products, including strips, metal sheets, blocks, plates, discs and thin-walled tubes from copper and its alloys (Huta...). Today, various companies and businesses operate on the smelter site, including: MISTAL sp. z o.o., BATERPOL SA (which recovers lead from used batteries), Elektrociepłownia Szopienice thermal power station, and the Zinc Rolling Mill Museum that is located in the former rolling mill building. The area between the Wilhelmina and Uthemann smelters was occupied by post-production heaps. Following the closure of the plants, the long and difficult process of reclamation of the 7-hectare tailings dump site was completed. About 120,000 tonnes of zinc-bearing sludge were removed (Boryszew SA...).

The history of zinc metallurgy in Wełnowiec-Józefów (Katowice) dates back to 1873, when the Hohenlohe zinc smelter was opened. From 1889, metal sheets for roofing, galvanography (zincography), lithography and other applications were produced there. As a result of ownership transformations and restructuring (in the 1960s and 1990s, and at the beginning of the 21st century) the plant operates as the ZM SILESIA SA company. Production includes four product groups: zinc-titanium sheet, zinc and zinc-aluminium wire, zinc casting alloys, and zinc anodes (ZM SILESIA...). Zinc smelters also operated in Siemianowice; these were the Jerzy (1818–1886) and Teresa (1840–1908) smelters.

In Bogucice (a quarter of Katowice city), a porcelain factory has been operating since 1925, originally under the name Porcelana Giesche and now as BGH Network SA (Porcelana Bogucice – https://porcelanabogucice.pl/index.php [access 25.10.2023]; Fabryka Porcelany – https://www.zabytkitechniki.pl/poi/153082 [access 15.11.2023]). The facility is on the list of the Industrial Monuments Route of the Silesian Voivodeship. In Czeladź, the Ceramic and Sanitary Products Factory "Józefów" operated from 1924 to 2008. After the demolition of the former production halls, the only remainder of the factory is a mosaic on one of the buildings in Katowicka Street (Miejsca...).

In addition to the mining and metallurgical industries, also trade and service, transport and construction activities (mainly in city centres) are developing in the study area. As a result of the restructuring carried out in recent years, the volume of production, the number of economic entities, and the proportion of industry in the employment structure show a decreasing trend.

GEOLOGICAL STRUCTURE AND MINERAL DEPOSITS

The Siemianowice Śląskie map sheet area is situated in the northern part of the Upper Silesian Coal Basin (USCB), within an anticlinal structure called the Main Saddle. This part of the USCB is composed of Paleozoic Variscan structures of Carboniferous formations, cut by numerous faults, with a very well-known geology owing to numerous drillings and mining operations associated with prospecting for and mining of hard coal deposits (Jureczka *et al.*, 2005).

The oldest formations found in the study area are **Cambrian** rocks which were encountered in the Sosnowiec IG 1 exploratory borehole at a depth of 3156 m. They are represented by sandstones, mudstones and subordinate conglomerates included in the Middle Cambrian. They are separated from the overlying complex of Devonian carbonates by a stratigraphic gap spanning the Ordovician and Silurian. The carbonate succession is more than a thousand metres thick and assigned to the Middle and Upper **Devonian**. It is represented by grey limestones overlain by marls, passing downward into dolomites containing inclusions and laminae of anhydrites (Wilanowski, 2016b).

The dominant stratigraphic formations of the study area are represented by (Lower and Middle) Carboniferous, Triassic and Quaternary rocks, locally also Paleogene–Neogene deposits (Buła, Kotas, 1994). The Lower **Carboniferous** succession is represented by a several-hundred-metre-thick complex of carbonates. These are dark grey and black limestones passing into clastic deposits (Culm facies): greywacke sandstones, mudstones and claystones (Malinowice Beds). The Culm facies also occurs at the bottom of the Upper Carboniferous succession (Namurian A). The facies underlies the Upper Carboniferous coal-bearing formations of the Upper Silesian Coal Basin (Wilanowski, 2016b).

The Upper Carboniferous coal-bearing deposits are found at various depths. In the southern and western parts of the map sheet, these rocks form outcrops on the ground surface or lie directly under a thin, up to 10 m, overburden of Quaternary sediments. In the northern and north-eastern parts of the sheet, they underlie mainly Triassic limestones and dolomites, while in the remaining area they occur under a cover of Pleistocene glacial tills and glaciofluvial sands and gravels (Biernat, Krysowska, 1956; updated by Wilanowski, 2016a; Wilanowski, 2016b).

The oldest Carboniferous coal-bearing deposits found on the surface represent the Carboniferous Paralic Series (Namurian A). Upper in the Carboniferous section there are terrigenous rocks of the Upper Namurian Silesian Sandstone Series (Namurian B and C) and the Lower Westphalian mudstone series (Westphalian A and B). The total thickness of both these series may be up to 1,700 m in the map sheet area (Jureczka *et al.*, 2005).

The Paralic Series is characterized by sedimentary cyclicity (Kotas, Malczyk, 1972b). Typically, the coal seams are overlain by claystones passing into mudstones, followed upward by coarse-clastic deposits: fine- and medium-grained sandstones and occasional coarse-grained sandstones. The sandstones again pass upward into mudstones and claystones that continue up to the base of the next coal seam. Numerous coal seams and strata containing marine, brackish and freshwater faunal fossils occur throughout the series. The thickness of the Paralic Series in the map sheet area has been estimated to be around 900–1100 m (Jureczka *et al.*, 2005). Their outcrops are small in area and occur in the central-western part of the sheet, in the Koszutka region (which is a quarter of Katowice) (Biernat, Krysowska, 1956; updated by Wilanowski, 2016a).

The Paralic Series is unconformably (stratigraphic gap) overlain by the Upper Silesian Sandstone Series. There is a marked change in the type of sedimentation from paralic to limnic, and the boundary is manifested by an abrupt change in floristic assemblages. The top of the Upper Silesian Sandstone Series is represented by the last horizon containing freshwater fauna, accompanying coal seams 408 and 407. It is one of the most important correlative levels in the USCB. The Upper Silesian Sandstone Series (Saddle and Ruda beds) consists mainly of grey fine- and medium-grained sandstones, as well as sporadic coarse-grained sandstones and conglomerates (Kotas, Malczyk, 1972a). The interbeds of claystone and mudstone occurring within the series are usually up to several metres thick. The Saddle Beds are conspicuous by the presence of coal seams, up to about 5 m in thickness, but locally exceeding 10 m (Wilanowski, 2016b). The series is found at the surface in the central-western part of the map sheet area and sporadically in its southern part. The outcropping deposits are represented predominantly by the Ruda Beds and locally by the Saddle Beds. The thickness of the Upper Silesian Sandstone Series varies from 100 m to 350–400 m (Jureczka *et al.*, 2005).

The mudstone series consists of the Załęże Beds, corresponding to the Westphalian A, and at the top also by the Orzesze Beds assigned to the Lower Westphalian B. The boundary between the Westphalian A and B is the marker tuffite horizon of coal seam 327. The deposits are characterized by a very monotonous lithology dominated by mudstones and claystones, with interbeds of fine-grained sandstones, usually a few metres or more thick. A characteristic feature of the whole series is the remarkable predominance of aleuritic-pelitic deposits over coarse-clastic ones, and a significant number of coal cyclothems. Most of them contain coal seams, usually of small thickness (mostly up to 1.5 m). The coal seams are variable and contain numerous overgrowths and only in the bottom part of the series do they reach a greater thickness (Wilanowski, 2016b). The claystones and mudstones contain numerous clayey siderites in the form of concretions, inserts and lenses. The upper boundary of the Orzesze Beds is clearly marked by a change in lithofacies type, whereas the lower boundary is a conventional boundary and is not manifested either in lithology or biostratigraphy. The thickness of the series reaches about 150–200 m. The above-described deposits (mainly the Orzesze Beds) occur at the surface or under a thin cover of Quaternary sediments only in the southern part of the map sheet (Wilanowski, 2016b).

The Upper Carboniferous deposits are erosionally overlain by Lower and Middle **Triassic** formations. On the ground surface, they occur in the northern (Siemianowice Śląskie, Czeladź and Sosnowiec regions) and central parts of the map sheet, where they form isolated "islands" in the sub-Quaternary or sub-Miocene basement. The thickness of the Triassic succession is variable and ranges from 40 m in the central to over 100 m in the northern part of the sheet, reaching a maximum of about 132 m in Czeladź (Biernat, Krysowska, 1956; updated by Wilanowski, 2016a; Wilanowski, 2016b).

The Lower Triassic (Scythian, spanning the Induan and Olenekian stages) Świerklaniec Beds are represented by sands, sandstones, clays, claystones and mudstones. Their stratotype section has been described from the Świerklaniec region, several kilometres north-west of the edge of the Siemianowice sheet. Their minor outcrops are found mainly in Milowice and Siemianowice Śląskie (north-western extreme of the sheet). These are terrestrial deposits showing a characteristic red colour. In places, they are accompanied by fine- and medium-grained sandstones, mudstones and subordinate conglomeratic sandstones. The thickness is variable, generally approximately 10 m and exceptionally around 20 m, locally reduced to 2–4 m (Wilanowski, 2016b).

The Świerklaniec Beds are unconformably overlain by dolomites, marls and limestones (cavernous limestones) of the lowermost Middle Triassic (Anisian), previously referred to as Röt deposits. They form minor outcrops at the foothills near Czeladź (Piaski quarter), Milowice (a quarter of Sosnowiec) and in Siemianowice Śląskie. Their lower part is represented mainly by grey dolomites interbedded with limestones and marls and locally marly dolomites and dolomitic limestones. The upper part is composed of light yellow and grey dolomites with increasing number of interbeds of grey or grey-brown, coarsely crystalline, compact limestone with small caverns. The thickness of the deposits is 25–35 m, reduced to several metres on outcrops (Biernat, Krysowska, 1956; updated by Wilanowski, 2016a; Wilanowski, 2016b).

These rocks are overlain by limestones of the Gogolin Beds that, in the study area, compose most of the hillslopes and hilltops ranging in elevation from about 280 to 324 m a.s.l. between Siemianowice Śląskie and Będzin. Their lower part is clearly dominated by platy limestones, while the upper part is dominated by wavy limestones, usually clayey and marly. The thickness of the Gogolin Beds outside the zone of outcrops is usually 30–38 m (Biernat, Krysowska, 1956; updated by Wilanowski, 2016a; Wilanowski, 2016b).

Ore-bearing dolomites compose the hillslopes and some hilltops from about 280 to 310 m a.s.l. in Siemianowice Śląskie, Czeladź and Będzin. The complex of medium-bedded, dark grey, finely crystalline, compact and cavernous-porous dolomites, locally silicified, usually rest on the Gogolin Beds. These rocks are overlain by thickly bedded and coarsely crystalline, highly porous grey dolomites. The top part of the ore-bearing dolomite complex contains grey and yellow cavernous-porous, finely to medium-crystalline and medium- to thick-bedded dolomites. The ore-bearing dolomites show mineralization with zinc and lead sulphides, especially abundant near the base of the complex. The thickness of the ore-bearing dolomites is about 25 m, but they have been significantly depleted in many places, including the extreme western part of Siemianowice Śląskie (Biernat, Krysowska, 1956; updated by Wilanowski, 2016a; Wilanowski, 2016b).

Upper in the Middle Triassic (Anisian) section are Diplopora dolomites of the Jemielnice Beds. They are exposed on the surface, forming the hilltops predominantly in the north of the map sheet area near Będzin and Czeladź. Their lower part is represented by medium- to thick-bedded, finely crystalline dolomites, while upper in the section there are thinly bedded marly dolomites with horizontal and wavy lamination, containing diverse faunal and floral fossils. The thickness of the Diplopora Beds is strongly reduced and generally does not exceed 10 m (Biernat, Krysowska, 1956; updated by Wilanowski, 2016a; Wilanowski, 2016b).

Paleogene–Neogene deposits, represented by loams, gravels, conglomerates and clay shales, occur over a very small area in the northern part of the map sheet near the boundary with the Wojkowice sheet (Wilanowski, 2016b). These deposits accumulated mainly in karst funnels developed at the top of Triassic carbonates, particularly in the outcrop zones of the Gogolin limestones and ore-bearing dolomites. These deposits were previously included in the Lower Jurassic. Refractory sands and clays are also locally found within these rocks. The chemical composition of clay minerals forming regoliths, and their similarity to "mouldering sands" of undoubtedly Oligocene–Miocene age, occurring in karst funnels on the outcrops of Upper Jurassic limestones, suggests they are mostly Miocene in age (Lewandowski, Ciesielczuk, 1997). The deposits reach 20 m in thickness (Wilanowski, 2016b).

Quaternary sediments cover about 65% of the map sheet area with a layer of highly variable thickness, ranging from a few metres on the uplands to more than 50 m in the fossil valleys, reaching 60 m in the south-eastern part of the study area (fossil valley of the Rawa River). Outside the fossil valleys, in terrain depressions, the thickness of the Quaternary sediments is commonly 20–30 m. On the surface, there are not only the sediments of fossil valleys, but also predominantly glacial tills of the San 1 Glaciation, glaciofluvial sands and gravels of the Odranian Glaciation, deluvial loams and sands (locally overlying Triassic and Carboniferous deposits), and weathering (eluvial) sands and loams (Biernat, Krysowska, 1956; updated by Wilanowski, 2016a; Wilanowski, 2016b).

The **South Polish Glaciation** (San 1) tills are exposed on the surface in the southern and central parts of the map sheet (environs of Bogucice and Milowice), or are overlain by a thin layer of glaciofluvial sediments of the Odranian Glaciation, or eluvial deposits, locally slope wash sediments. The tills are silty-sandy, yellow-brown and grey-yellow in colour. Their thickness is mostly 4–8 m, and about 2 m on the hillslopes composed of Carboniferous deposits (Biernat, Krysowska, 1956; updated by Wilanowski, 2016a; Wilanowski, 2016b).

South Polish glaciofluvial sands and gravels are preserved only locally under the cover of the Odranian glaciofluvial sediments. They overlie glacial tills or rest directly upon Carboniferous formations. These are fine-grained sands interbedded with medium-grained sands with gravels and single clasts of local rocks, and their thickness is 2–5 m. Fluvial sands, gravels and muds, dominated by fine-grained sands with an admixture of fine-grained gravels and lenses of gravels at the base, fill the fossil valley of the Brynica River (Biernat, Krysowska, 1956; updated by Wilanowski, 2016a; Wilanowski, 2016b).

Sediments **of the Middle Polish** (Odranian) **Glaciations** cover about 20% of the map sheet area. These are glaciofluvial sands and gravels occurring mainly in the southern and western parts of the study area. In the Brynica and Rawa valleys, they form a valley outwash plain, whose surface slopes gently towards the west, and locally occur on the uplands in the form of small patches. They are represented predominantly by yellow and light brown fine- to medium-grained sands with a variable, generally small admixture of fine-grained gravels. Their thickness in the valley is 5–10 m, elsewhere it is mostly 2–5 m, and occasionally – mainly on the uplands – it is reduced to about 1.5 m. Glacial lake clays and muds are common in the depression of the Przemsza River valley, in the southern part of the map sheet, under the cover of glaciofluvial or fluvial sediments. These are grey sandy clays and muds, 3–8 in thickness (Biernat, Krysowska, 1956; updated by Wilanowski, 2016a; Wilanowski, 2016b).

Undivided Quaternary sediments occupy a small part of the map sheet. These are sands and loams of weathering mantles (eluvial sediments), most often accompanying glacial tills of the San 1 Glaciation or other surface sediments mainly of Quaternary age. They cover a considerable area in the central part (surroundings of Dąbrówka Mała and Siemianowice Śląskie) and, to a lesser extent, in the southern part (Szopienice region) of the map sheet. These are mostly loamy sands or heavily sandy yellow and brown loams, with a thickness of about 1.5–2.0 m, locally reaching 3 m. Slope wash loams and sands occur at the foothills composed of Carboniferous rocks, mainly in the Katowice and Siemianowice Śląskie regions, or of Triassic rocks in the surroundings of Będzin and Sosnowiec. In places they occur on slopes, or partially fill poorly developed valleys. These are washed loamy-sandy sediments with single gravel grains. Their thickness is mostly 2–4 m and locally only about 1.5 m (Biernat, Krysowska, 1956; updated by Wilanowski, 2016a; Wilanowski, 2016b).

The Holocene is represented mainly by fluvial and swamp sediments of the modern valleys of the Brynica River and Rawa Stream. These are fluvial muds, sands and gravels of floodplain terraces and valley bottoms. The dominant sediments are fine- to medium-grained sands with an admixture of fine-grained gravels in the bottom part, and silty sands at the top. They attain a maximum thickness of 5–10 m, fill the oxbow lakes and riverbeds. Alluvial muds of the valley bottoms occur in the upper sections of the valleys of watercourses and fill drainless depressions in the relief. These are silty and fine-grained sands, about 3 m thick. Peats fill several small depressions in the Rawa Stream valley. They cover the fluvial muds, sands and gravels of floodplain terraces. The peats have been partly mined out or ditched during drainage operations and covered in places by anthropogenic deposits (Biernat, Krysowska, 1956; updated by Wilanowski, 2016a; Wilanowski, 2016b).

Mineral deposits. The Siemianowice map sheet area has a rich history of geological research because it hosts hard coal deposits and, of minor significance, rock raw materials – limestones, marls and sands.

The first records of hard coal mining and the establishment of coal mines in the study area date back to the 18th century. These were small mines that operated using the open-cast method, whose total production did not exceed several hundred tonnes per year until the 1880s. In 1788, the "Bergthal" mine was established in the Janów quarter of Katowice, located just beyond the southern boundary of the map sheet, which operated until 1823. The oldest mine in the study area is that later named "Wieczorek", located in the southern part of the map sheet. Its origins date back to 1823, when outcrops of thick (approx. 3 m) coal seams were discovered in the environs the Janów and Szopienice quarters, on which the "Morgenroth" („Jutrzenka") field was developed. Hard coal production in the southern and western parts of the study area, which were part of Germany at that time, developed rapidly in the 19th century. From 1823 on, the later „Katowice" mine started to operate, from 1837 – the "Mysłowice" mine, from 1845 – the "Kleofas" mine, and from 1855 – the "Siemianowice" mine. This was the result of the continuously increasing industrial demand for hard coal used in the iron and zinc smelters established in this region (KWK „Wieczorek").

In the north-eastern and eastern parts of the map sheet, belonging to Russia at that time, exploration and subsequent coal mining began in the late 19th century, due to the demand for coal in zinc production. Coal mining on an industrial scale started in 1887 and its intense development in the following decades was mainly due to the high activity of the Mining and Industrial Society "Saturn" that took over the "Saturn" mine in Czeladź in 1900 and opened the "Jowisz" mine in Wojkowice (to the north of the map sheet) in 1912. These mines operated until the end of the 20th century, when mining ceased due to depletion of resources and the consequent significant increase in production costs, but their activity was variable, depending, i.a., on the geopolitical situation (including two world wars) (Jaros, 1984).

Zinc, lead and iron ores are found in the Lower Muschelkalk dolomites of the Bytom Trough. In the Siemianowice map sheet area, deposits of these ores were known in the past from Gzichów (a quarter of Będzin), where a small zinc-lead ore mine was active. Signs of zinc-lead ore and iron ore mining are also known from several sites located north of Czeladź (Biernat, 1970).

In the study area, 19 mineral deposits are currently documented: hard coal, coal-bed methane, limestones and marls for the lime industry, and sands and gravels (Szuflicki *et al.*, 2023). Information on the parameters of the deposits and the quality parameters of the mineral products is quoted after geological documentations of the individual deposits, and the System of Management and Protecting of Polish Mineral Raw Materials (MIDAS).

Fifteen multi-seam hard coal deposits have been documented in the study area (Szuflicki *et al.*, 2023): "Wieczorek", "Kleofas", "Wujek", "Siemianowice-Szopienice I", "Polska-Wirek", "Sosnowiec", "Barbara-Chorzów", "Barbara Chorzów 2", "Katowice", "Rozalia", "Saturn", "Grodziec", "Siemianowice", "Paryż" and "Mysłowice", although each of them is partially, but to a different extent, located within the sheet area. Due to the depletion of hard coal reserves as a result of many years of mining and the development of minor deposits within the boundaries of those already documented, their number and boundaries have been subject to very frequent changes in recent years. According to *Bilans zasobów...* (Szuflicki *et al.*, 2023), currently the largest anticipated economic resources of hard coal are proved in the „Kleofas" (169.1 million tonnes) and „Polska-Wirek" (153.5 million tonnes) deposits, the anticipated economic resources of the „Wieczorek" and „Wujek" deposits are 105–110 million tonnes, and in the remaining deposits – from 27 to 61 million tonnes. Economic resources are proved only in the „Wieczorek" and „Wujek" deposits: 2.56 million tonnes and 11.07 million tonnes, respectively. Hard coal reserves have been documented to a depth of 700–720 m („Siemianowice" and „Kleofas" deposits) and to 1,000–1,250 m („Wieczorek", „Barbara-Chorzów", „Grodziec", „Rozalia", „Paryż", „Siemianowice-Szopienice I", and „Barbara-Chorzów 2" deposits) in categories A–C_2. The mineral deposit is represented by the Orzesze Beds (group 300), Ruda Beds (group 400), Saddle Beds (group 500) and Poręba Beds (group 600). The number of documented seams is highly variable, ranging from one in the "Barbara Chorzów" deposit, three in the "Rozalia" deposit, seven in the "Siemianowice-Szopienice I" deposit, to 29 in the "Wujek" deposit. The study area hosts mainly power coals of types 31+32, less common coking coals of types 33 and 34. The thickness of the individual economic coal seams varies from 1.0 to 10.4 m. The qualitative parameters of the power coals are highly variable. The calorific value of type 31+32 coals varies from 18,087 to 32,400 kJ/kg, the ash content ranges widely from 2.5 to 32%, and the sulphur content varies from 0.25 to 2.77%. The calorific value of type 33 and 34 coals ranges from 25,740 to 33,300 kJ/kg, the ash content is from 1.7 to 20%, and the sulphur content varies from 0.5 to 1.8%.

As part of the restructuring and reorganization of the mining industry, major changes in the mining structure have been taking place since the 1990s, involving the closure and/or merger of hard coal mines/operations into multi-operation mines. Towards the end of the 20th century (1994–1999), the following mines were closed: „Siemianowice", "Barbara-Chorzów", „Paryż", "Saturn", "Sosnowiec", "Katowice" and "Rozalia". Most of the mining plants and industrial infrastructure were decommissioned, and the post-industrial areas are being revitalized and given a new use. The „Kleofas", „Polska-Wirek", „Mysłowice" and „Wieczorek" mines were closed down between 2004 and 2021. The „Wujek-Śląsk" mine was merged with the „Murcki-Staszic" mine and has been operating as the „Staszic-Wujek" mine since 2021, but production from the „Wujek" deposit has been abandoned.

Hard coal deposits are accompanied by **methane**. It occurs in a sorbed form, i.e. physically and chemically bound to hard coal and to dispersed coal matter, and its content in coal increases with the depth to the seam. In the map sheet area, methane is documented to a depth of about 1,250 m as an associated mineral product in the "Barbara-Chorzów 2" (outside the area of coal mining) and "Wieczorek" deposits. It is neither being extracted nor economically used.

In the central part of the map sheet, the "Calcium Brynica-Czeladź" deposit has been documented within the outcrops **of limestones** of the Middle Triassic Gogolin Beds. Over an area of 3.6 hectares (two mineral deposit fields), limestones and marls for the lime industry, with an average thickness of 23.2 m, have been proved under an overburden of variable thickness ranging from 0.2 to 6.5 m. The average content of CaO in the mineral product is 53.0%, MgO is 1.6%, and SiO_2 is 4.88%. The deposit was exploited periodically from the 1920s to the 1960s.

The "Michałkowice" sand deposit has been documented within slope wash and glaciofluvial sediments in the northern part of the map sheet. It covers an area of 2.18 ha. The main mineral product is Quaternary sands, ranging in thickness from 10.5 to 13.2 m, under a 0.9–3.1 m thick overburden. The sand point averages 96.47%, and the mineral dust content is negligible, ranging from 0.09 to 0.82%. The deposit remains undeveloped and its geological resources are 465,000 tones.

HUMAN IMPACT (ANTHROPOPRESSION)

The map sheet area is highly anthropogenically altered. The main factors causing land transformation are the mining industry, iron and non-ferrous metal smelting industry, and industrial processing. In addition, strong urbanization and the linear infrastructure also contribute to the land transformation.

Areas transformed as a result of the activities of the mining industry are found all over the map sheet. Areas of non-ferrous and iron metallurgy are located in the south-eastern part of the sheet, in the Szopienice-Burowiec quarter of Katowice (zinc and lead metallurgy), in the southern (iron ore metallurgy) and central parts, and south of the central quarter of Siemianowice Śląskie (iron ore and zinc-lead ore metallurgy). Industrial activity in these areas has resulted in both continuous (subsidence troughs) and discontinuous deformation due to underground coal mining. The highest deformation risk occurs along the borders of the cities of Siemianowice Śląskie, Katowice and partly Czeladź. The map sheet area also includes grounds of historical shallow mining of raw materials, having connections with the surface. Heaps, dumps, and industrial and municipal landfills (including rehabilitated ones) are numerous, as well as post-industrial areas that arose as a result of the decommissioning of mining and metallurgical plants that have not yet been given new utility functions (Oszańcy *et al.*, 2014; Durka-Kamińska, 2020, 2021; Studium..., 2022), e.g. near the former Pipe Rolling Mill "Jedność" in Siemianowice Śląskie. Within the map sheet boundaries, there are also depressions and hollows left by the extraction of sands, loams and limestones. The largest ones occur in the south-eastern part of the map sheet on the borders of the cities of Katowice, Sosnowiec and Mysłowice, but also in the Borowa housing estate of Czeladź and in the Bytków quarter of Siemianowice Śląskie, in Michałkowice near the border with Chorzów, and in Bańgów near Rzęsa Pond and on a part of the Landeco municipal landfill (Głogowska *et al.*, 2018).

The artificial landforms created as a results of the functioning of linear infrastructure include mainly road and railway embankments, and areas occupied by a dense network of roads, and railway and tram lines. Strongly urbanized areas include, i.a., residential development covering most of the map sheet area, large-scale commercial development (e.g. near Kapicy and Kopalniana streets in Siemianowice Śląskie, and Nowy Roździeń in Katowice), warehouse areas (e.g. along the DK86 road in Sosnowiec), sports areas (e.g. Kresowa Street in Sosnowiec, Park Pszelnik Street in Siemianowice Śląskie), areas occupied by waste management installations (e.g. Waste Recovery and Neutralization Plant) near Milowicka Street in Katowice on the border with Sosnowiec, and GPSZOK local disposal facility at Szyb Jana Street in Czeladź) (Głogowska *et al.*, 2018; Cofałka *et al.*, 2019).

Atmospheric air. Anthropogenic factors play an important role in creating the aerosanitary conditions, including primarily the emission from individual heating of residential buildings, which is the main source of considerable concentrations of particulate matter (both PM10 and PM2.5) and benzo(a)pyrene contained in PM10 (Roczna ocena...). In addition to emissions from fuel combustion, also emissions from the transport sector (linear emissions) have an adverse impact on atmospheric air quality. It affects mainly the areas of heavy traffic roads (e.g. DK94, DK86, DK79) and their immediate surroundings, and manifests itself, i.a., by increased concentrations of nitrogen oxides emitted by motor vehicles. Contaminants emitted by industrial plants (point emissions), especially those released in an unorganized manner or through low emitters, are also of considerable importance for the status of the air (Roczna ocena...).

The air quality in the map sheet area is unsatisfactory because the permissible/target levels of concentrations of particulate matter, benzo(a)pyrene in PM10, and nitrogen dioxide are exceeded. The measures implemented to date to protect the air have resulted in a successive and noticeable improvement of the air quality, as confirmed by the results of national environmental monitoring (Roczna ocena...).

Surface waters. The hydrographic network of the study area is heavily anthropogenically transformed. Both the Brynica River and Rawa Stream flow in engineered, concreted and embanked channels without hydraulic connections to groundwater. In the Katowice region (Śródmieście – city centre), the Rawa's concrete channel is covered (Głogowska *et al.*, 2018; Orzechowski, 2023). The channels of the Rów Michałkowicki ditch and the Rów Śmiłowskiego ditch are uncovered only in their lower reaches, along the remaining sections they flow in an encased channel (Durka-Kamińska, 2020). The Bolina Stream in the south-eastern part of the map sheet is a channelized watercourse flowing in an earthen channel (Konieczny *et al.*, 2015). Additional elements of the hydrographic network of the study area are surface water bodies of anthropogenic nature. They formed predominantly as a result of land subsidence due to mining activities and extraction of aggregates (Konieczny *et al.*, 2015).

The quality status of surface waters flowing across the map sheet area is assessed as poor (Ocena..., 2016–2021). It is also confirmed by the environmental assessment carried out for the three Surface Water Bodies (fluvial) defined within the study area, where all the water bodies are considered to be at risk of failing to meet the environmental objectives set out in the Vistula River Basin Management Plan (Rozporządzenie..., 2023). The poor water quality status is due to discharges of municipal and industrial wastewater (the rivers flow across a highly urbanized and industrialized area), surface runoff of rainwater from industrial areas, roads, squares and roof surfaces, and discharges of mine water (from the former KWK "Siemianowice" mine – the Bańgów and Siemianowice III shafts).

Groundwater. The map sheet area is situated in the central macroregion and the Silesian-Cracow (XII) hydrogeological region (Paczyński, 1995), within the boundaries of GWB 111 and GWB 112 (north-eastern and south-eastern areas of the sheet), according to the characterization of Groundwater Bodies (CBDG Database – https://dm.pgi.gov.pl/ [access 19.12.2023]). Usable groundwater is found in sandy, sandy-gravelly and sandy-silty sediments of Quaternary age, Triassic marly-dolomitic and calcareous deposits represented by the Buntsandstein, Muschelkalk and Röt, and in sandstones of the Carboniferous Upper Silesian Sandstone Series (Nowicki, 2007). The water quality is assessed as poor due to pressure from urbanized and industrialized areas (including dewatering of mine workings). In the north-eastern and south-eastern regions, the overall groundwater condition is assessed as good (Karty charakterystyk, 2023).

In the north-eastern part of the map sheet, there is the Main Groundwater Reservoir MGR No. 329 Bytom, which is represented by Lower and Middle Triassic dolomitic and calcareous rocks (Muschelkalk and Röt), and this is a fracture-karst aquifer. The reservoir has no established protection zones. Most of the waters are categorized into classes II and III (locally class IV) and their chemical status is assessed as good. The potential threat to water quality is posed mainly by long-time mining of Zn and Pb ores and by surface contamination sources such as post-coal mining heaps and settling ponds (Mikołajków, Sadurski, 2017).

Treatment plants. Located in the northern area of Katowice, the Dąbrówka Mała – Centrum wastewater treatment plant is a mechanical-biological-chemical installation with enhanced nutrient removal, receiving wastewater from the Dąbrówka Mała quarter of Katowice, from Siemianowice Śląskie, Czeladź, and the Milowice quarter of Sosnowiec. The average capacity of the treatment plant is 18,000 m^3/day (Katowickie Wodociągi SA). The recipient of treated wastewater is the Brynica River (km 6+685) and the outlet is located near the Pekin housing estate (Uchwała..., 2021).

In the south of the map sheet, within the administrative boundaries of the city of Katowice, is the Gigablok Sewage Treatment Plant. This is the largest treatment plant in Katowice, which receives wastewater from the northern quarters of the city: Koszutka, Śródmieście and Paderewskiego, as well as from Załęże and the Osiedle Tysiąclecia, located outside the sheet area. In rainless seasons, the average throughput of the plant reaches 40,000 m^3/day. The wastewater treatment process is based on the activated sludge method with nutrients removal (nitrogen and phosphorus). The resulting sludge is stabilized by anaerobic digestion, and the biogas obtained is used to generate electricity and heat (Katowickie Wodociągi SA). Treated wastewater is discharged to the Rawa Stream (km 4+880) and the outlet is located in close proximity to the treatment plant (Uchwała..., 2021).

Soils. The dominant soil types in the map sheet area are brown soils developed on glacial tills and weathered carbonates, as well as podzolic soils developed on sandy or loamy bedrock (Aktualizacja..., 2020; Program..., 2021, Studium..., 2022). The soil cover has been strongly transformed by anthropogenic processes, including the current and historical activities of the mining and processing industries and the development of urban functions and infrastructure. The impact of industry and urbanization manifests itself through mechanical transformation (removal and/or mixing of the natural soil cover with other allochthonous materials), heavy metal pollution (e.g.: deposition of mining and industrial waste, emissions from transport, low emissions), drainage and waterlogging (as a result of, i.a., changes in water relations), or salinization and acidification (e.g. as a result of industrial emissions, the impact of coal mining waste heaps and dumps, and atmospheric precipitation) (Program..., 2017a; Program..., 2017b; Oszańcy *et al.*, 2014; Durka-Kamińska, 2020, 2021).

Soils in the areas of historical mining and processing of zinc and lead ores show significant concentrations of Zn, Pb, Cd, Tl and Mn, while in the regions of coal mining and processing may demonstrate increased salinization and sulphidation, as well as contamination as a result of dust fallout from wind erosion of fine-grained material from heaps (Fajfer *et al.*, 2010). In addition, the soil quality status is also directly influenced by precipitation chemistry. In the study area, the dominant pH of precipitation (59%) is below 5.6 (i.e. acidic). However, between 2013 and 2017, there was a decrease in its proportion of approximately 6% (Liana *et al.*, 2014, 2018). The deposition of sulphates and metals, such as cadmium, lead and nickel, also decreased over the same time interval, while the deposition of chlorides, sodium and heavy metals, i.e.: zinc, copper and chromium, slightly increased.

Landslides. Within the map sheet boundaries, five landslides have been documented in Siemianowice Śląskie, of which four developed in anthropogenic formations, e.g. in an mound created as a result of deposition of waste from zinc ore processing, and in the slope of a railway cutting. Of the inventoried landslides, three are still active, one is periodically active, and one is considered inactive and its intra-landslide relief is obliterated and shows no fresh cracks, fissures or swells. All of them are below 0.5 ha in area (Piotrowski, Ziomek, 2022). A small active landslide (below 0.5 ha in area) is also reported from Czeladź in the immediate vicinity of the historic church of St. Stanislaus the Bishop and Martyr (SOPO Database – https://geoportal.pgi.gov.pl/portal/page/portal/SOPO/ [access 12.01.2024]).

Waste dumps, spoil tips and landfills. The numerous spoil tips and industrial dumps distributed in the map sheet area were associated in the past with the mining and processing industries. Coal mining waste was deposited on heaps that occupied large areas close to the mining plants. Also industrial (post-smelting and power generation) waste was deposited on heaps and dumps near production facilities. Due to the high industrialization level of the study area, industrial dumps, spoil tips and landfills were located next to each other and even (some of them) at sites of previously mined waste. The highest concentration of industrial dumps, heaps and landfills (now rehabilitated, including partially demolished ones) was in the central part of the map sheet, on the border of Czeladź, Siemianowice Śląskie, Katowice and Sosnowiec. These included area dumps (e.g. near Węglowa Street in Czeladź), depression dumps (e.g. Hieronim in Czeladź) and tailings ponds (e.g. Alfred) belonging to the former KWK "Saturn" coal mine (Studium..., 2005). In this region (in Srokowiec in Siemianowice Śląskie), heaps and dumps of industrial waste were also located between the heaps of mining waste, including that coming from the former Jedność SA smelter (e.g. a smelter waste heap near Konopnickiej and Stara Katowicka streets) and the former Silesia zinc smelter (e.g. a dismantled heap on the border of Siemianowice Śląskie and Katowice near Plebiscytowa and Konduktorska Street), as well as the energy waste dump of the former PKE SA – EC "Katowice", currently TAURON Ciepło SA – Zakład Wytwarzania Katowice (Franiel, 2001; Studium..., 2016; Durka-Kamińska, 2021; TAURON Ciepło SA – https://cieplo.tauron.pl/o-nas/obszary-wytwarzania [access 12.12.2023]).

Between 1996 and 2006, in the fully exploited part of the metallurgical waste heap of the former Jedność SA smelter, near Konopnickiej and Stara Katowicka streets, a landfill site for hazardous waste was in operation (currently rehabilitated area). The total area of the landfill was 1.6 ha and the area of the landfill basin for hazardous waste storage was 0.8 ha. The landfill was designed and made as a sealed earthen tank. There were two layers of HDPE sealing film, as well as a leachate collection system, preventing from contamination of the soil and water environments. Originally, the landfill received post-neutralization sludge and sludge from the cooling water treatment plant of the former Jedność SA smelter. In December 1999, in accordance with the decision of the Silesian Voivode, the list of hazardous waste deposited at the site was extended. The waste was deposited in an unselective manner (Stańczyk *et al.*, 2003). A total of 36,000 Mg of hazardous waste was stored (Plan..., 2003).

The presence of mining waste dumps is also marked in the relief of anthropogenically transformed areas located in the north-western part of the map sheet (in the Michałkowice quarter of Siemianowice Śląskie (a partly eliminated dump in Michałkowicka Street, of the former KWK "Siemianowice" mine) and at its south-eastern edges (on the border of Katowice, Mysłowice and Sosnowiec). In the landscape of the Siemianowice Śląskie sheet there are also landfills of municipal non-hazardous and inert waste. In the Dąbrówka Mała quarter of Katowice (at Leopolda Street), there is a reclaimed municipal waste landfill. An active municipal waste landfill operates near Żwirowa Street (in the same quarter). The landfill's third quarter is currently in operation (the first and second ones have been closed and rehabilitated). In 2023, a 1 MW photovoltaic power plant has been built in the area of the rehabilitated first quarter (MPGK – https://www.mpgk.com.pl [access 14.12.2023]). In the Bańgów quarter of Siemianowice Śląskie (Zwycięstwa Street), a landfill for non-hazardous and inert waste was in operation from 1992 to 2014, where municipal waste was deposited (Stańczyk *et al.*, 2003). The landfill has been closed and its area rehabilitated.

RESEARCH SCOPE AND METHODS

The research carried out between 2021 and 2024 included the study of published and archival materials, delineation of the soil sampling grid on topographic maps at a scale of 1:10,000, sampling and determination of geographical coordinates at their locations, measurements of pH and specific electrolytic conductivity of surface water in the field, chemical analyses of the samples, creation of field and laboratory databases, statistical calculations of the results of chemical analyses, development of a topographic base, development of a geological map and geochemical maps, and interpretation of the results. The workflow sequence is illustrated in the schematic diagram below (Fig. 1).

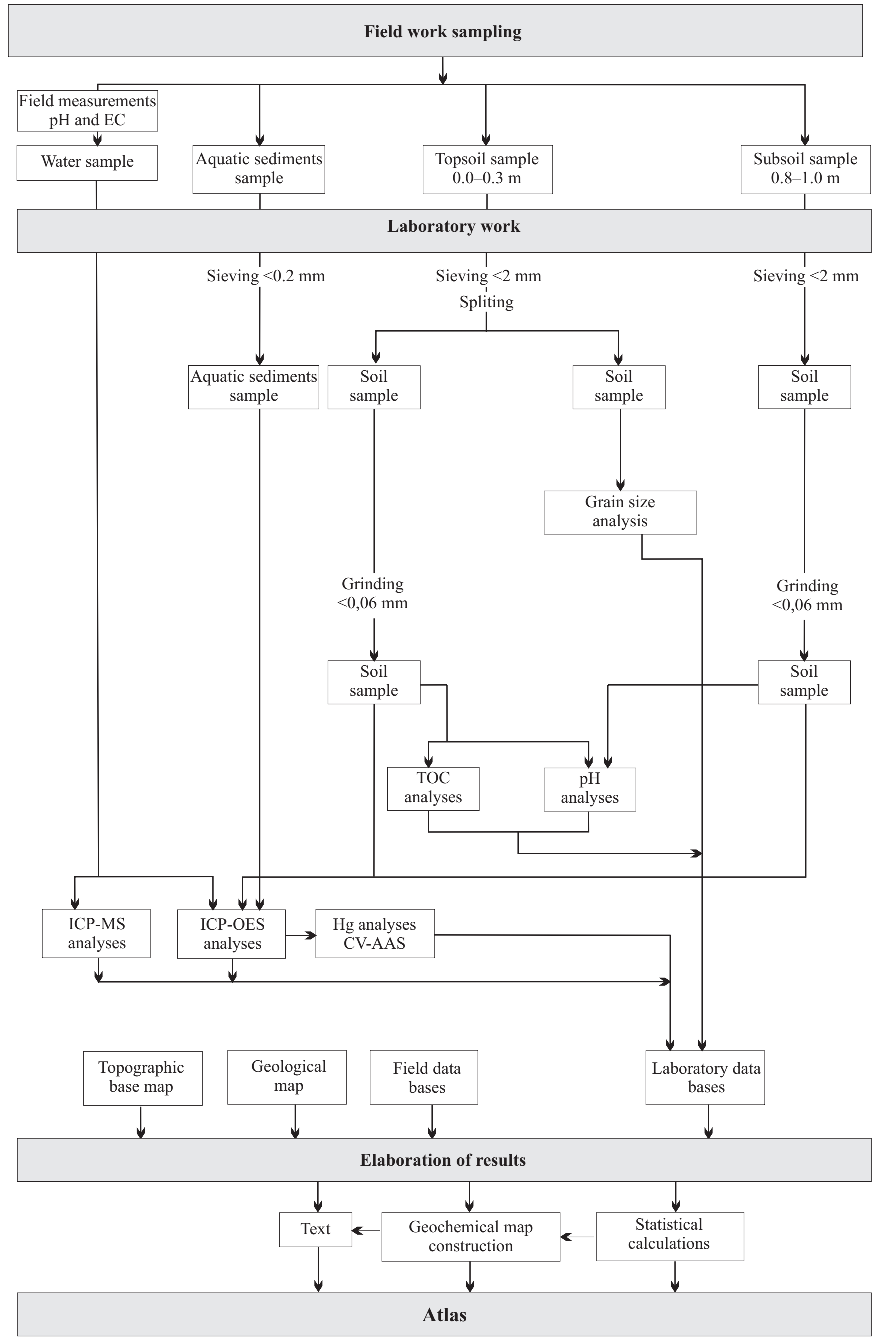

Fig. 1. Scheme of the work performed

FIELDWORK

Soils were sampled using a 60 mm diameter hand auger in a regular 250×250 m grid (16 samples/km^2). The location of sampling sites is documented by maps showing both the housing type and land use (Pls. 2, 3). A total of 1,297 samples were collected from a depth of 0.0–0.3 m, and 1163 samples from a depth of 0.8–1.0 m (or from a shallower depth in case of shallower-seated bedrock). Each sample (weighing approximately 500 g) was placed in a linen bag labelled with the appropriate number, and pre-dried on wooden pallets in a field storage facility.

Samples of surface waters and aquatic sediments (251 and 225 samples, respectively) were taken at the same locations from rivers, streams, ditches, canals, lakes, and settling and natural ponds. The differences in the number of samples collected were dependent on the possibility to sample them (lack of material resulting, for example, from the periodic drying up of watercourses or the concreting of their channels). The distance between the sampling sites in the watercourses and water bodies was approximately 250 m. The locations of the sampling sites corresponds to those presented in the plates (starting with Plates 7 and 9, respectively), showing the content of individual elements in surface waters and aquatic sediments.

Surface water samples were taken directly from the water body/watercourse using a syringe. In cases where there was no safe approach, waters were collected using a bucket. The electrical conductivity (EC) and pH of the waters were measured in the field using a pH meter/conductivity meter (Elmetron CPC-105) with automatic temperature compensation, assuming a reference temperature of 25°C. After collection, the waters were filtered in the field through Milipore 0.45 µm filters, poured into 30 cm^3 bottles, and acidified with nitric acid to pH <2. The bottles were labelled with the appropriate numbers. Sediment samples of approximately 500 g (grain size as fine as possible) were collected from the banks of water bodies and watercourses using a bucket, and then placed in 500 cm^3 plastic containers labelled with the appropriate numbers.

All sampling sites were marked on topographic maps at a scale of 1:10,000, and their locations were determined using GPS technology, with an accuracy of ±2–5 m. The device used allows recording additional information (e.g. sample number, pH and EC values of the waters, data on housing types and land use, and lithology of the samples), as well as results of geographical coordinate measurements. Prior to the field trips, the sampling grid had been uploaded into the memory of the GPS device in the form of shapefile spatial data. For added security, all field data were also recorded on specially prepared field sheets (Fig. 2).

LABORATORY WORK

Sample preparation for testing, determinations of physico-chemical parameters, and chemical analyses were carried out at the chemical laboratory of PGI-NRI.

Sample preparation. After transport to the laboratory, soil samples were dried at room temperature and sieved through 2 mm mesh nylon sieves. Each soil sample from a depth of 0.0–0.3 m (topsoil), after sieving and quartering, was divided into two subsamples: one for chemical analysis and the other for grain size analysis. Each soil sample from a depth of 0.8–1.0 m (subsoil), after sieving and quartering, was destined for chemical analysis (Fig. 1). Soil samples prepared for chemical analysis were grinded to a <0.06 mm fraction in agate ball mills. Aquatic sediment samples were dried at room temperature and then sieved through 0.2 mm mesh nylon sieves. The <0.2 mm fraction, after quartering, was destined for chemical analysis (Fig. 1).

Chemical analyses. Samples of soils and aquatic sediments were dissolved using aqua regia (1 g sample to a final mineralizate of 50 g) for 1 hour at a temperature of 95°C in a thermostated heating block. Determinations of Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Ni, P, Pb, S, Sr, Ti, V and Zn in soils and aquatic sediments were performed by inductively coupled plasma optical emission spectrometry (ICP-OES). Analyses of Hg content in soil and aquatic sediment samples were carried out by cold vapour atomic absorption spectrometry (CV-AAS) in a flow-injection system. The pH was determined by a potentiometric method in 1:5 (weight fraction) suspension of soil in water (pH-H_2O), and the total organic carbon (TOC) content of soils was determined by high-temperature combustion with IR detection. Determinations of B, Ba, Ca, Cr, Fe, K, Mg, Mn, Na, P, Si, S, Sr, Ti and Zn in surface waters were carried out by inductively coupled plasma atomic emission spectrometry (ICP-OES), while the contents of Ag, Al, As, Be, Cd, Co, Cu, Li, Mo, Ni, Pb, Sb, Se, Tl, U and V by inductively coupled plasma mass spectrometry (ICP-MS). A summary of the analytical methods and the determination limits of the elements are shown in Table 1.

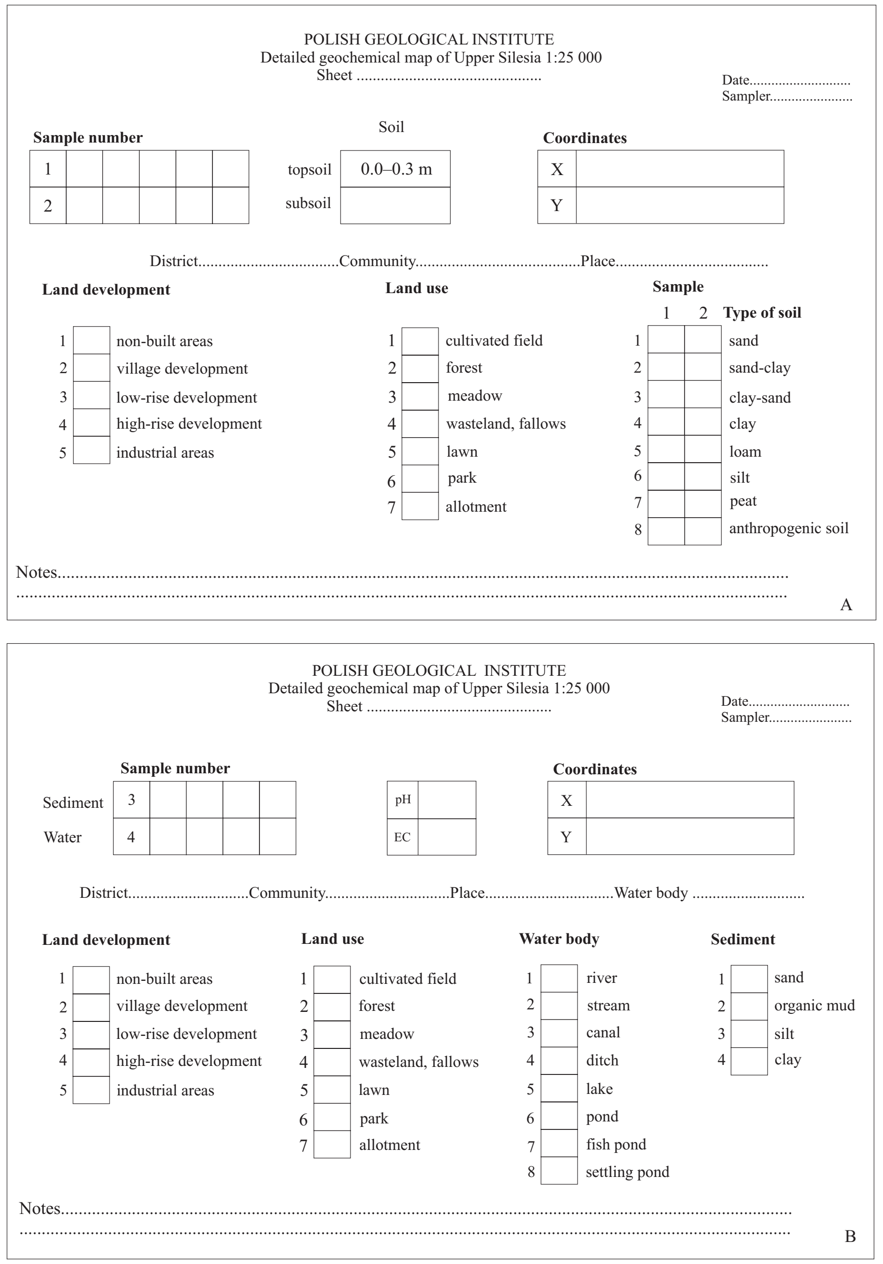

Fig. 2. Field sampling sheets for soils (A) and sediments and surface waters (B)

Metody analityczne i granice oznaczalności — **Tabela 1** / *Table*

Analytical methods and determination limits

Pierwiastek/związek *Element/compound*	Metoda analityczna *Analytical method*	Granica oznaczalności *Determination limit*	Jednostka *Unit*	Metoda analityczna *Analytical method*	Granica oznaczalności *Determination limit*	Jednostka *Unit*
	Gleby, osady wodne *Soils, aquatic sediments*			Wody powierzchniowe *Surface water*		
Ag	ICP-OES	1	[mg/kg]	ICP-MS	0,05	[µg/dm^3]
Al	ICP-OES	0,01	[%]	ICP-MS	0,5	[µg/dm^3]
As	ICP-OES	3	[mg/kg]	ICP-MS	2	[µg/dm^3]
B	nie oznaczono/ *not indicated*			ICP-OES	0,01	[mg/dm^3]
Ba	ICP-OES	1	[mg/kg]	ICP-OES	0,001	[mg/dm^3]
Be	nie oznaczono/ *not indicated*			ICP-MS	0,05	[µg/dm^3]
C_{org} (TOC)	*	0,02	[%]	nie oznaczono/ *not indicated*		
Ca	ICP-OES	0,01	[%]	ICP-OES	0,1	[mg/dm^3]
Cd	ICP-OES	0,5	[mg/kg]	ICP-MS	0,05	[µg/dm^3]
Co	ICP-OES	1	[mg/kg]	ICP-MS	0,05	[µg/dm^3]
Cr	ICP-OES	1	[mg/kg]	ICP-OES	0,003	[mg/dm^3]
Cu	ICP-OES	1	[mg/kg]	ICP-MS	0,05	[µg/dm^3]
Fe	ICP-OES	0,01	[%]	ICP-OES	0,01	[mg/dm^3]
Hg	CV-AAS	0,02	[mg/kg]	nie oznaczono/ *not indicated*		
K	nie oznaczono/ *not indicated*			ICP-OES	0,5	[mg/dm^3]
Li				ICP-MS	0,3	[µg/dm^3]
Mg	ICP-OES	0,01	[%]	ICP-OES	0,1	[mg/dm^3]
Mn	ICP-OES	2	[mg/kg]	ICP-OES	0,001	[mg/dm^3]
Mo	nie oznaczono/ *not indicated*			ICP-MS	0,05	[µg/dm^3]
Na				ICP-OES	0,5	[mg/dm^3]
Ni	ICP-OES	1	[mg/kg]	ICP-MS	0,5	[µg/dm^3]
P	ICP-OES	0,002	[%]	ICP-OES	0,05	[mg/dm^3]
Pb	ICP-OES	2	[mg/kg]	ICP-MS	0,05	[µg/dm^3]
S	ICP-OES	0,003	[%]	ICP-OES	1	[mg/dm^3]
Sb	nie oznaczono/ *not indicated*			ICP-MS	0,05	[µg/dm^3]
Se				ICP-MS	2	[µg/dm^3]
Si				ICP-OES	0,1	[mg/dm^3]
Sr	ICP-OES	1	[mg/kg]	ICP-OES	0,002	[mg/dm^3]
Ti	ICP-OES	5	[mg/kg]	ICP-OES	0,002	[mg/dm^3]
Tl	nie oznaczono/ *not indicated*			ICP-MS	0,05	[µg/dm^3]
U				ICP-MS	0,05	[µg/dm^3]
V	ICP-OES	1	[mg/kg]	ICP-MS	1	[µg/dm^3]
Zn	ICP-OES	1	[mg/kg]	ICP-OES	0,003	[mg/dm^3]

ICP-OES – emisyjna spektrometria atomowa ze wzbudzeniem w plazmie indukcyjnie sprzężonej
Inductively Coupled Plasma Optical 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

Quality control of the determinations was performed by analysis of duplicate samples (5% of the total number of samples), analysis of reference materials with certified content of the elements tested (2% of the total number of samples), and analysis of internal control samples confirming correct instrumental measurements (5% of the total number of samples). The purity of reagents and vessels was controlled by "reagent blanks" and "procedural blanks".

The expanded uncertainty of the research results (assuming the probability level of 95% and the coverage factor k = 2) of water, soil and sediment samples does not exceed 25%, except for the expanded uncertainty of the results of boron concentration in water samples in the range of 0.01–0.10 mg/dm^3, mercury content in soil and sediment samples, and organic carbon content in soil samples, which is 30%.

Grain size analyses of soils sampled from a depth of 0.0–0.3 m were carried out at the Soil and Rock Laboratory Testing Centre, Department of Engineering Geology, PGI-NRI, Warsaw. Determination of grain composition was performed by sieve (granulometric) analysis according to an in-house procedure developed on the basis of Standard PN-B-04481: 1988. After oxidation of organic matter (using 30% solution of hydrogen peroxide – perhydrol), the samples were washed through a 0.02 mm sieve and the residue was sieved dry through a column of sieves with mesh sizes of 1 mm, 0.10 and 0.02 mm, and then the resulting fractions of 2–1 mm, 1.0–0.1 mm and <0.02 mm were weighed.

The results of the grain size analyses (after conversion to percentages) are presented in the grain class maps: 1.0–0.1 mm – sand fraction, 0.10–0.02 mm – silt fraction, and <0.02 mm – clay fraction (Pls. 4–6).

DATABASES AND GEOCHEMICAL MAP CONSTRUCTION

Databases. Separate datasets (spreadsheets) have been created for:
- soils from a depth of 0.0–0.3 m,
- soils from a depth of 0.8–1.0 m,
- aquatic sediments,
- surface waters.

The datasets for soils, sediments and surface waters include: numbers of samples, results of measurements of geographic coordinates at sampling sites, field observations (type of housing, land use, soil types – for sampled soils, type of water body, type of sediment – for sampled sediments and surface waters), administrative location of sampling sites – district, municipality, locality, date of sampling, the name of sampler, and results of chemical analyses.

The data were placed in separate tables (for soils, aquatic sediments and surface waters) of a special geodatabase in the Central Geological Database (CBDG) running in the Oracle environment. These tables were used to develop mono-elemental geochemical maps. The geodatabase stores descriptive data (metadata), results of chemical analyses of samples, and geometrical data comprising the graphical part of the study.

Statistical calculations. The research results stored in the databases were used to separate subsets for statistical calculations according to different environmental criteria, for example in terms of elemental content of industrial soils, forest soils, urban soils, and sediments and waters of individual watercourses and water bodies, as well as for the construction of geochemical maps. Calculations of statistical parameters were performed (using *Statistica* software) for both entire sets and subsets of soils, sediments, and surface waters provided they numbered 10 or more samples. If the contents of elements were lower than their limits of quantification of the analytical method, a value equal to half of this limit was taken for statistical calculations. The arithmetic mean, geometric mean, and median were calculated and the minimum and maximum values were presented. In case of elements for which the percentage of results below the limit of quantification exceeded 50%, the calculation of selected measures of descriptive statistics was abandoned and only the minimum and maximum values were presented. Statistical parameters for individual elements and indices are summarized in Tables 2–5 and shown in the geochemical maps (Pls. 7–62).

When interpreting the results, the median values were used as a measure of the geochemical background for the 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 with an undefined distribution.

Topographic base. VMap L2 data (vector format) at a scale of 1:50,000 in the PL-1992 rectangular coordinate system and other auxiliary materials were used to develop the topographic base of the 1:25,000 geochemical maps. The topographic map includes the following vector information layers:
- relief,
- hydrography (rivers, streams, ditches, and bodies of stagnant water),
- road network (with breakdown by class),
- railway network,
- built-up area type (rural, urban and industrial),
- forests,
- industrial areas (industrial facilities, mine workings, spoil heaps, and settling ponds).

Geological map. The Detailed Geological Map of Poland 1:50,000 sheet Katowice (Biernat, Krysowska, 1956; updated by Wilanowski, 2016a) was used to present the geological structure of the study area. The vector images of the map sheet, created as a result of digitization, were combined with the topographic base to construct the geological map at the scale of 1:25,000 (Pl. 1).

Map construction. The following maps were produced for the Siemianowice Śląskie sheet (Pls. 2–63):
- land development,
- land use
- content of total organic carbon, and of the sand, silt and clay fractions in soils at a depth of 0.0–0.3 m,
- pH in soils at depths of 0.0–0.3 and 0.8–1.0 m,
- 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 at depths of 0.0–0.3 and 0.8–1.0 m, and in aquatic sediments,
- pH and EC and the 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^{2-}, Sb, Se, SiO_2, Sr, Ti, Tl, U, V and Zn in surface waters,
- assessment of topsoil (0.0–0.3 m) contamination according to the permissible cadmium content.

The maps were developed in *ArcGIS 10.8*, which is a software package from ESRI for working with maps and spatial data. The software enables to create new or modify existing maps, and to analyse, visualize and manage spatial data in geodatabases. The housing type and land use, as well as the distribution of elements in sediments and surface waters, are presented as point maps.

An isoline (areal) method of mapping was chosen to represent the distribution of grain size classes in soils, their pH and the content of chemical elements, due to its clarity and legibility. The geochemical isoline maps were constructed using the deterministic Inverse Distance Weighted method (IDW). This method produces a result for a given grid by averaging the values from the nearest points, with closer points having a greater influence on the interpolated value. This influence is the inverse of the distance of a given point raised to a power set by the mapper. The advantage of the method is the possibility to determine the distance and location of the points used in the interpolation process.

Maps of distribution of grain size classes, soil pH, and elemental contents in soils were constructed for a set of results of chemical analyses for the Pyrzowice, Siewierz, Wojkowice and Siemianowice Śląskie sheets at a scale of 1:25,000. One spatial analysis of the above-mentioned map sheets was made for each map to prevent discrepancies at their boundaries. The resulting monoelemental maps were combined with the topographic base within the boundaries of the respective sheet.

Soil's pH is presented according to the scale adopted in soil science, with a subdivision into very acidic (pH <5.0), acidic (pH 5.0–6.0), slightly acidic (pH 6.1–6.7), neutral (pH 6.8–7.4) and alkaline (pH >7.4) soils (Bednarek *et al.*, 2004). The spatial distribution of selected elements in soils is presented using a geometric progression to determine distribution classes.

Geochemical maps of sediments and surface waters in the Siemianowice Śląskie sheet were compiled separately. They were constructed as circular cartodiagrams, assigning their respective diameters to individual content classes, arranged mostly in geometric progression.

In drawing up an example map of topsoil contamination assessment (Pl. 63), according to the permissible content of cadmium, the results of geochemical tests are related to permissible contents of risk-causing substances, with regard to soil groups specified in the Regulation of the Minister of Environment (Rozporządzenie..., 2016).

For the purpose of publishing, the geochemical maps are combined in pairs, i.e. the geochemical map of soils from 0.0–0.3 m depth and the geochemical map of sediments are presented on the same plate, and the adjacent plate presents the geochemical map of soils from 0.8–1.0 m depth and the geochemical map of surface waters. This method of presentation allows direct comparison of geochemical images of different environments. For the convenience of use, the maps (annotated with a linear scale) are printed in a reduced format (A3) and the scale of the print is 1:35,000. This procedure did not result in omission of any detail of the content of the maps.

STUDY RESULTS

SOILS

As in the neighbouring areas (Chorzów sheet to the west, and Dąbrowa Górnicza sheet to the east), the original soil cover in many places of the Siemianowice Śląskie sheet area has been greatly altered by the impact of a number of anthropogenic factors, including the current and historical mining and processing activities and the development of urban functions and infrastructure.

Grain size composition is defined as the fineness of the mineral part of soil's solid phase and is expressed in terms of the particle size and the percentage of each fraction (Bednarek *et al.*, 2004). Grain size composition remains constant in the presence of soil processes. Moreover, it is regarded as one of the fundamental physical characteristics of soils, with numerous soil properties being associated with it (Mocek *et al.*, 2000; Ryżak *et al.*, 2009).

The study adopted the division of particles into grain size fractions according to the standard BN-78/9180-11, which was in force until 2008, as it is a continuation of the serial project carried out permanently for several years in accordance with the instructions for the geochemical map at a scale of 1:25,000. The results of grain size analyses are presented for the following grain size groups: 1.0–0.1 mm – sand fraction, 0.10–0.02 mm – silt fraction, and <0.02 mm – clay fraction (Pls. 4–6). Changing the ranges of grain size groups in accordance with the guidelines of the

Tabela 2
Table

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)

Gleby *Soils*	Parametry *Parameters*	Ag	Al	As	Ba	C_{org}	Ca	Cd	Co	Cr	Cu	Fe	Hg	Mg	Mn	Ni	P	Pb	S	Sr	Ti	V	Zn	pH
		[mg/kg]	[%]	[mg/kg]		[%]		[mg/kg]				[%]	[mg/kg]	[%]	[mg/kg]		[%]	[mg/kg]	[%]	[mg/kg]				[–]
	Granica oznaczalności *Determination 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	2,00
Gleby ogółem	a	<1	0,08	<3	14	0,05	0,01	<0,5	<1	2	2	0,10	<0,02	0,02	16	2	0,004	7	<0,003	1	6	2	22	4,66
Total soils	b	69	2,00	3910	1203	47,20	13,92	761,4	147	1420	8861	16,58	10,98	6,19	8721	605	1,594	17 240	4,301	322	2467	223	36 510	9,83
n = 1297	c	–	0,60	32	158	4,29	1,00	11,3	6	20	65	1,61	0,15	0,29	644	15	0,052	420	0,063	34	124	18	1426	7,52
	d	–	0,56	13	124	3,10	0,59	5,7	5	14	30	1,33	0,09	0,19	477	12	0,041	214	0,037	24	104	16	773	7,49
	e	–	0,58	11	120	3,04	0,63	5,6	5	14	26	1,29	0,08	0,18	486	12	0,041	181	0,035	23	98	16	707	7,64
Tereny bez zabudowy	a	<1	0,08	<3	14	0,05	0,01	<0,5	<1	2	2	0,10	<0,02	0,02	16	2	0,004	7	<0,003	1	20	2	22	4,75
Non-built-up areas	b	69	1,85	3910	997	47,20	9,50	761,4	147	275	3055	11,54	2,66	5,03	8721	72	1,594	17 240	4,301	322	693	223	36 510	9,78
n = 520	c	–	0,63	31	141	4,09	0,75	12,7	6	16	50	1,53	0,13	0,26	651	14	0,049	416	0,064	27	108	18	1375	7,24
	d	–	0,57	12	109	2,74	0,39	6,0	5	13	25	1,27	0,08	0,16	451	11	0,035	203	0,031	18	93	16	729	7,20
	e	–	0,61	11	110	2,69	0,37	6,0	5	13	21	1,26	0,08	0,14	491	11	0,037	179	0,028	17	88	17	703	7,32
Tereny z zabudową wiejską	a	<1	0,27	5	59	0,81	0,09	2,6	2	6	8	0,57	0,03	0,04	236	4	0,026	92	0,008	6	51	6	315	5,96
Village areas	b	<1	0,76	13	153	3,70	7,85	9,2	6	18	38	1,72	0,10	0,49	1522	14	0,094	321	0,042	144	136	20	970	7,96
n = 14	c	–	0,53	9	93	2,25	0,93	5,8	4	10	17	1,03	0,06	0,13	524	9	0,047	181	0,025	24	82	14	542	7,10
	d	–	0,51	9	90	2,08	0,33	5,4	4	10	16	0,99	0,06	0,11	469	8	0,044	171	0,023	16	79	13	511	7,08
	e	–	0,52	9	91	2,16	0,25	5,6	4	10	14	0,96	0,06	0,11	462	8	0,042	169	0,024	13	79	14	465	7,13
Tereny z zabudową miejską	a	<1	0,17	<3	28	0,21	0,06	<0,5	<1	3	6	0,25	<0,02	0,03	30	2	0,008	17	0,005	4	6	4	76	4,66
Urban areas	b	27	2,00	833	923	31,29	13,92	98,8	44	1420	2617	12,83	10,98	6,19	6793	605	0,509	8497	1,732	229	1447	148	17 600	9,83
n = 538	c	–	0,58	27	173	4,14	1,16	7,8	5	22	47	1,53	0,16	0,31	637	15	0,057	367	0,056	37	124	18	1180	7,73
	d	–	0,54	13	139	3,27	0,81	5,2	4	15	30	1,31	0,09	0,21	494	12	0,048	208	0,039	28	106	16	759	7,71
	e	–	0,55	11	135	3,13	0,84	4,9	4	14	27	1,29	0,08	0,19	481	12	0,045	177	0,037	28	101	16	690	7,81
Tereny przemysłowe	a	<1	0,21	<3	24	0,18	0,03	<0,5	<1	4	4	0,35	<0,02	0,02	35	2	0,005	23	0,003	3	35	5	70	5,87
Industrial areas	b	37	1,88	1719	1203	30,06	7,24	391,1	131	205	8861	16,58	3,16	2,02	6334	111	0,425	6994	1,477	318	2467	199	35 470	9,78
n = 225	c	–	0,62	49	169	5,25	1,17	16,7	7	25	146	1,99	0,19	0,32	650	20	0,048	571	0,078	43	163	21	2185	7,68
	d	–	0,57	17	133	3,70	0,76	6,6	5	18	46	1,58	0,10	0,23	500	15	0,038	266	0,048	30	128	17	954	7,66
	e	–	0,58	13	122	3,52	0,86	6,0	5	17	39	1,55	0,09	0,25	494	15	0,037	229	0,047	29	114	17	865	7,75
Pola uprawne	a	<1	0,25	<3	23	0,28	0,05	0,8	2	5	5	0,41	<0,02	0,03	56	3	0,013	32	0,004	4	47	6	80	6,21
Cultivated fields	b	2	1,35	262	242	7,44	2,91	30,4	8	39	37	3,95	1,00	1,71	3211	23	0,126	722	0,057	60	177	33	3530	8,47
n = 107	c	–	0,65	15	106	1,96	0,53	8,8	4	11	15	1,33	0,08	0,25	838	10	0,047	180	0,022	14	90	17	867	7,26
	d	–	0,63	11	99	1,76	0,33	7,3	4	11	14	1,22	0,06	0,16	691	9	0,044	159	0,020	13	87	16	711	7,24
	e	–	0,69	10	105	1,79	0,27	6,4	4	12	15	1,17	0,07	0,12	623	10	0,044	160	0,019	13	86	16	625	7,29
Lasy	a	<1	0,14	<3	16	0,26	0,03	<0,5	1	3	3	0,22	<0,02	0,02	61	2	0,005	17	0,005	2	20	3	48	4,75
Forests	b	11	1,61	108	997	37,40	3,11	75,4	17	56	227	5,75	1,42	1,51	1679	41	0,115	4039	0,349	231	675	66	12 650	8,51
n = 90	c	–	0,58	14	156	4,88	0,50	7,5	5	14	34	1,44	0,12	0,18	402	13	0,031	339	0,045	26	103	17	963	6,79
	d	–	0,51	10	107	3,05	0,26	4,5	4	12	24	1,17	0,07	0,12	305	10	0,025	203	0,030	16	87	15	551	6,73
	e	–	0,55	10	104	2,86	0,23	5,1	4	12	22	1,21	0,08	0,11	353	11	0,024	221	0,029	15	81	16	575	6,77
Łąki	a	<1	0,23	6	42	1,35	0,09	4,0	1	5	8	0,46	0,03	0,05	170	5	0,016	110	0,014	5	40	6	471	6,17
Meadows	b	7	1,41	319	340	10,44	1,47	32,4	17	30	185	4,24	0,20	0,78	1005	51	0,104	1986	0,139	80	469	40	6348	7,76
n = 15	c	–	0,60	35	128	3,55	0,49	12,1	5	13	38	1,23	0,09	0,22	475	12	0,049	529	0,037	20	114	16	1344	7,03
	d	–	0,55	14	104	2,91	0,33	8,6	4	11	23	1,04	0,08	0,15	431	9	0,041	340	0,029	16	94	14	913	7,01
	e	–	0,57	9	95	3,02	0,26	5,8	5	11	15	1,05	0,08	0,12	438	8	0,043	272	0,024	15	87	14	615	6,97
Nieużytki, ugory	a	<1	0,08	<3	14	0,05	0,01	<0,5	<1	2	2	0,10	<0,02	0,02	16	2	0,004	7	<0,003	1	22	2	22	5,60
Barren lands	b	69	1,88	3910	1203	47,20	8,43	761,4	147	344	8861	16,58	10,98	2,66	8721	111	1,594	17 240	4,301	322	2467	223	36 510	9,78
n = 461	c	–	0,63	47	166	5,21	1,11	16,9	7	24	108	1,89	0,20	0,31	743	18	0,056	567	0,087	40	141	21	1906	7,55
	d	–	0,58	15	127	3,39	0,62	6,4	5	16	38	1,49	0,10	0,21	504	14	0,040	237	0,043	26	111	17	869	7,53
	e	–	0,59	12	124	3,39	0,67	6,0	5	15	33	1,46	0,09	0,21	504	14	0,040	187	0,044	26	99	17	794	7,58
Ogródki działkowe	a	<1	0,27	3	45	0,63	0,07	1,4	2	6	11	0,51	<0,02	0,04	88	4	0,017	89	0,008	6	51	6	129	5,78
Allotments	b	9	1,34	164	484	10,05	9,50	62,7	12	180	168	3,82	0,52	5,03	1974	39	0,142	6440	0,241	104	348	38	11 360	8,80
n = 46	c	–	0,69	20	179	4,46	1,09	9,9	6	20	39	1,66	0,12	0,39	584	15	0,053	469	0,046	34	122	20	1403	7,42
	d	–	0,65	13	154	3,80	0,69	6,9	5	16	32	1,52	0,10	0,22	524	14	0,047	240	0,038	27	112	19	911	7,40
	e	–	0,69	11	145	3,86	0,80	6,5	5	15	29	1,54	0,10	0,18	509	14	0,045	207	0,036	27	109	20	855	7,36

Tabela 2 cd.
Table 2 cont.

Gleby *Soils*	Parametry *Parameters*	Ag	Al	As	Ba	C_{org}	Ca	Cd	Co	Cr	Cu	Fe	Hg	Mg	Mn	Ni	P	Pb	S	Sr	Ti	V	Zn	pH
		[mg/kg]	[%]	[mg/kg]		[%]		[mg/kg]				[%]	[mg/kg]	[%]	[mg/kg]		[%]	[mg/kg]	[%]	[mg/kg]				[–]
	Granica oznaczalności *Determination 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	2,00
	a	<1	0,12	<3	16	0,06	0,02	<0,5	<1	3	3	0,20	<0,02	0,02	24	2	0,006	10	0,004	2	25	3	41	5,23
Parki	b	5	2,00	824	673	15,11	11,51	98,8	10	44	407	4,70	0,99	5,23	2131	36	0,167	3860	1,732	99	776	55	15 680	8,80
Parks	c	–	0,61	29	153	3,61	0,74	10,7	5	14	40	1,40	0,13	0,24	516	12	0,044	368	0,058	25	108	17	1350	7,19
n = 94	d	–	0,55	13	122	2,89	0,40	6,9	4	13	28	1,22	0,09	0,14	410	11	0,036	237	0,033	20	95	15	813	7,15
	e	–	0,57	12	130	2,92	0,41	6,8	5	13	27	1,21	0,09	0,14	477	10	0,036	232	0,033	18	93	17	738	7,20
	a	<1	0,17	<3	20	0,10	0,03	<0,5	<1	3	5	0,25	<0,02	0,03	30	2	0,006	17	<0,003	2	6	4	52	4,66
Trawniki	b	37	1,62	1254	908	20,19	13,92	87,0	44	1420	1288	12,83	4,55	6,19	6793	605	0,509	8497	1,384	223	624	148	19 600	9,83
Lawns	c	–	0,56	28	163	3,97	1,14	7,4	5	21	48	1,47	0,13	0,30	587	15	0,054	351	0,056	36	122	17	1197	7,77
n = 484	d	–	0,53	13	131	3,21	0,80	4,8	4	15	30	1,27	0,09	0,21	464	12	0,045	201	0,039	28	106	16	728	7,75
	e	–	0,54	11	124	3,17	0,84	4,6	4	14	27	1,25	0,08	0,20	458	11	0,044	174	0,037	28	102	16	643	7,83
	a	<1	0,14	<3	14	0,05	0,01	<0,5	<1	2	2	0,10	<0,02	0,02	16	2	0,004	7	<0,003	1	20	2	22	4,71
Gleby piaszczyste	b	16	1,38	262	923	18,53	7,85	82,1	33	43	2617	4,97	1,08	2,41	4540	49	0,197	4029	0,704	144	280	38	8051	8,53
Sandy soils	c	–	0,54	14	118	2,79	0,53	8,7	4	11	31	1,20	0,09	0,17	596	10	0,042	273	0,030	19	86	15	909	7,15
n = 362	d	–	0,50	10	95	2,14	0,29	6,0	4	10	19	1,04	0,07	0,12	417	9	0,036	186	0,023	14	80	13	636	7,12
	e	–	0,54	10	96	2,17	0,27	5,9	4	10	17	1,05	0,07	0,11	468	9	0,039	168	0,023	13	80	15	608	7,21
	a	<1	0,41	3	54	0,65	0,07	0,9	2	8	7	0,64	<0,02	0,08	87	5	0,012	40	0,006	6	34	10	126	5,67
Gleby gliniaste	b	5	1,48	132	250	10,05	3,90	61,9	13	40	168	4,64	0,52	1,71	4312	37	0,261	4246	0,126	46	145	33	8009	8,26
Clay soils	c	–	0,78	17	119	2,26	0,61	10,2	5	14	21	1,66	0,09	0,31	975	12	0,049	258	0,026	17	98	20	1081	7,16
n = 80	d	–	0,77	13	113	1,97	0,39	7,5	5	14	18	1,54	0,07	0,21	739	12	0,043	185	0,023	15	95	20	803	7,13
	e	–	0,76	12	113	1,90	0,34	7,1	5	14	16	1,43	0,07	0,16	670	11	0,044	172	0,022	15	99	20	781	7,32
	a	<1	0,08	<3	16	0,14	0,02	<0,5	<1	3	3	0,17	<0,02	0,02	27	2	0,004	13	0,003	2	6	3	37	4,66
Gleby antropogeniczne	b	69	2,00	3910	1203	47,20	13,92	761,4	147	1420	8861	16,58	10,98	6,19	8721	605	1,594	17 240	4,301	322	2467	223	36 510	9,83
Anthropogenic soils	c	–	0,61	41	179	5,11	1,23	12,4	6	24	83	1,77	0,18	0,33	633	18	0,056	495	0,080	42	142	20	1663	7,71
n = 853	d	–	0,57	15	141	3,77	0,82	5,5	5	17	38	1,46	0,10	0,23	484	14	0,043	230	0,047	31	117	17	834	7,68
	e	–	0,57	12	139	3,63	0,87	5,1	5	15	34	1,45	0,09	0,23	474	14	0,041	190	0,044	31	111	17	749	7,78
Tło geochemiczne / *Geochemical background*																								
Gleby Europy [1] *Soils of Europe*	e	0,27 n = 840	5,82 n = 845	6,00 n = 837*	65,0 n = 837*	1,73 n = 819	0,659 n = 845	0,145 n = 840	7,00 n = 837*	22,00 n = 837*	12,0 n = 837*	1,96 n = 837*	0,037 n = 833	0,46 n = 845	382 n = 837*	14,0 n = 837*	0,056 n = 845	15,0 n = 837*	0,023 n = 837*	89,0 n = 845	3426 n = 845	33,0 n = 837*	48,0 n = 837*	5,51 n = 818
Gleby Polski [2] *Soils of Poland* n = 10 840**	e	<1	nd.	<5	32	nd.	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	nd.	<5	54	nd.	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 z podziałem na grupy gruntów [4] / *Permissible contents of risk-causing substances by land groups* [4]																								
I grupa *Group I*		nd.	nd.	25	400	nd.	nd.	2	50	200	200	nd.	5	nd.	nd.	150	nd.	200	nd.	nd.	nd.	nd.	500	nd.
II grupa *Group II*		nd.	nd.	10–50	200–600	nd.	nd.	2–5	20–50	150–500	100–300	nd.	2–5	nd.	nd.	100–300	nd.	100–500	nd.	nd.	nd.	nd.	300–1000	nd.
III grupa *Group III*		nd.	nd.	50	1000	nd.	nd.	10	100	500	300	nd.	10	nd.	nd.	300	nd.	500	nd.	nd.	nd.	nd.	1000	nd.
IV grupa *Group IV*		nd.	nd.	100	1500	nd.	nd.	15	200	1000	600	nd.	30	nd.	nd.	500	nd.	600	nd.	nd.	nd.	nd.	2000	nd.

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..., 2016

„–" nie obliczono w przypadku, gdy odsetek wyników poniżej granicy oznaczalności przekraczał 50% *not calculated in the case when the percentage of the results below determination limit exceeded 50%*; nd. – nie dotyczy *not applicable*; * ekstrakcja wodą królewską *aqua regia digestion*; ** ekstrakcja kwasem solnym *hydrochloric acid digestion*

Tabela 3
Table

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)

Gleby *Soils*	Parametry *Parameters*	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	Hg	Mg	Mn	Ni	P	Pb	S	Sr	Ti	V	Zn	pH
		[mg/kg]	[%]	[mg/kg]		[%]	[mg/kg]				[%]	[mg/kg]	[%]	[mg/kg]		[%]	[mg/kg]	[%]	[mg/kg]				[–]
	Granica oznaczalności *Determination 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	2,00
	a	<1	0,08	<3	8	<0,01	<0,5	<1	1	<1	0,05	<0,02	<0,01	5	<1	<0,002	<2	<0,003	1	15	2	12	3,97
Gleby ogółem	b	73	4,00	2195	1455	19,58	2373,9	546	324	15 590	31,63	15,78	9,87	19 525	198	1,199	21 600	3,670	499	2069	683	43 640	12,38
Total soils	c	–	0,62	33	138	1,19	13,1	6	15	66	1,63	0,13	0,36	661	15	0,033	382	0,056	35	129	18	1311	7,77
n = 1163	d	–	0,54	8	83	0,39	2,2	4	11	17	1,11	0,05	0,16	316	10	0,021	86	0,016	17	106	14	347	7,73
	e	–	0,58	7	86	0,48	2,4	4	11	16	1,15	0,05	0,15	355	10	0,023	86	0,018	18	104	15	362	7,89
	a	<1	0,08	<3	8	<0,01	<0,5	<1	1	<1	0,05	<0,02	<0,01	5	<1	<0,002	<2	<0,003	1	15	2	12	4,80
Tereny bez zabudowy	b	73	3,91	1854	1379	19,12	2373,9	546	273	5962	31,63	6,88	9,87	13 554	185	1,199	21 600	3,670	499	2069	683	43 640	9,77
Non-built-up areas	c	–	0,63	28	106	1,10	13,3	6	14	55	1,57	0,10	0,43	660	14	0,032	346	0,047	27	120	19	1160	7,52
n = 481	d	–	0,53	6	63	0,24	1,6	4	10	12	0,98	0,04	0,14	262	9	0,017	57	0,011	11	93	13	244	7,47
	e	–	0,58	5	60	0,16	1,4	4	11	11	1,05	0,03	0,13	270	9	0,017	49	0,010	10	91	15	201	7,65
	a	<1	0,23	<3	16	0,03	<0,5	<1	3	2	0,15	<0,02	0,03	12	3	0,004	7	<0,003	2	38	5	18	6,34
Tereny z zabudową wiejską	b	<1	1,37	14	98	3,59	7,9	10	20	15	2,03	0,05	2,20	1305	20	0,023	324	0,009	23	228	33	1601	8,28
Village areas	c	–	0,51	–	33	0,36	–	3	8	7	0,75	–	0,25	298	7	0,011	42	–	6	96	11	208	7,48
n = 12	d	–	0,43	–	27	0,08	–	2	6	5	0,57	–	0,08	160	5	0,010	19	–	5	83	9	69	7,46
	e	–	0,35	–	21	0,06	–	2	6	5	0,44	–	0,05	153	4	0,011	15	–	4	69	7	46	7,60
	a	<1	0,11	<3	12	0,02	<0,5	<1	2	1	0,14	<0,02	0,02	22	2	0,003	3	<0,003	2	26	2	18	4,35
Tereny z zabudową miejską	b	26	4,00	1366	1455	19,58	155,7	67	324	1006	17,18	3,84	8,88	19 525	68	0,319	8018	1,307	321	698	134	16 390	12,38
Urban areas	c	–	0,61	26	162	1,29	6,0	5	15	33	1,56	0,12	0,31	664	14	0,034	294	0,047	40	130	17	989	8,00
n = 481	d	–	0,54	9	101	0,56	2,4	4	11	18	1,15	0,06	0,17	352	10	0,026	99	0,020	22	112	14	392	7,97
	e	–	0,56	8	103	0,77	2,7	4	12	19	1,15	0,06	0,16	392	11	0,027	108	0,023	24	111	15	438	8,03
	a	<1	0,11	<3	11	0,01	<0,5	<1	2	2	0,12	<0,02	0,02	17	1	<0,002	3	<0,003	2	32	2	13	3,97
Tereny przemysłowe	b	51	1,89	2195	1179	8,55	1821,1	25	208	15 590	10,70	15,78	4,70	10 042	198	0,237	9391	2,240	263	732	125	43 240	9,44
Industrial areas	c	–	0,63	69	168	1,23	31,9	6	19	179	2,00	0,23	0,33	677	20	0,033	717	0,103	44	153	20	2585	7,84
n = 189	d	–	0,57	14	111	0,59	4,7	5	14	29	1,45	0,08	0,19	398	14	0,025	182	0,032	25	127	16	688	7,80
	e	–	0,59	10	114	0,69	4,3	5	13	26	1,50	0,08	0,19	449	14	0,025	167	0,034	29	119	17	606	7,92
	a	<1	0,10	<3	11	0,01	<0,5	<1	2	2	0,13	<0,02	0,01	11	1	0,003	4	<0,003	1	27	3	12	6,64
Pola uprawne	b	4	2,87	185	443	16,59	61,8	11	48	49	10,60	2,51	9,87	10 717	67	0,056	444	0,052	89	240	115	7639	8,75
Cultivated fields	c	–	0,69	14	67	1,39	6,5	4	11	11	1,64	–	0,74	998	12	0,017	73	0,007	12	92	17	767	7,71
n = 105	d	–	0,57	5	44	0,20	1,3	3	9	8	0,98	–	0,15	341	8	0,013	34	0,004	7	85	13	183	7,70
	e	–	0,59	4	36	0,09	0,5	3	9	7	0,86	–	0,09	268	7	0,012	20	0,004	6	86	12	126	7,71
	a	<1	0,08	<3	12	<0,01	<0,5	<1	1	2	0,10	<0,02	0,01	9	1	<0,002	<2	<0,003	1	23	2	12	4,80
Lasy	b	27	1,53	153	937	15,28	214,2	86	37	119	31,63	0,54	8,02	2616	70	0,131	9005	0,351	265	2069	354	37 820	8,86
Forests	c	–	0,61	12	126	0,77	7,7	6	12	20	1,79	0,06	0,30	393	14	0,022	344	0,039	25	144	20	1474	7,17
n = 85	d	–	0,51	5	71	0,19	1,3	4	10	12	1,07	0,04	0,14	220	10	0,016	59	0,014	12	98	14	221	7,08
	e	–	0,60	5	61	0,15	1,2	4	11	9	1,12	0,04	0,14	246	9	0,017	44	0,012	10	102	16	146	7,37
	a	<1	0,28	<3	16	0,03	<0,5	1	3	2	0,32	<0,02	0,04	44	3	0,006	7	<0,003	2	55	5	18	5,59
Łąki	b	2	1,43	50	605	6,55	16,4	16	81	126	5,01	0,12	1,47	1004	48	0,206	12 740	0,117	276	621	41	1856	8,51
Meadows	c	–	0,63	10	98	0,91	–	5	16	25	1,25	0,04	0,26	274	14	0,029	1052	0,023	32	139	14	457	7,43
n = 14	d	–	0,54	4	53	0,19	–	3	10	10	0,86	0,03	0,13	171	8	0,015	60	0,008	10	107	12	132	7,39
	e	–	0,40	4	48	0,13	–	3	9	10	0,63	0,03	0,12	138	8	0,012	16	0,006	8	89	12	50	7,59
	a	<1	0,08	<3	8	<0,01	<0,5	<1	1	<1	0,05	<0,02	<0,01	5	<1	<0,002	<2	<0,003	1	15	2	12	3,97
Nieużytki, ugory	b	73	3,91	2195	1379	19,12	2373,9	546	324	15 590	17,18	15,78	5,89	19 525	198	1,199	21 600	3,670	499	1634	683	43 640	9,77
Barren lands	c	–	0,64	53	151	1,23	26,4	7	18	119	1,90	0,21	0,37	865	18	0,041	580	0,087	41	136	21	1894	7,73
n = 395	d	–	0,54	9	87	0,39	2,8	4	11	20	1,19	0,06	0,17	332	11	0,022	101	0,020	18	106	15	417	7,69
	e	–	0,59	8	96	0,53	2,8	5	12	20	1,34	0,06	0,18	367	13	0,023	101	0,023	22	100	16	421	7,82
	a	<1	0,23	<3	14	0,03	<0,5	1	4	3	0,35	<0,02	0,04	30	3	0,005	9	<0,003	3	43	5	26	6,34
Ogródki działkowe	b	2	1,89	186	662	14,9	34,5	26	38	85	6,68	0,73	8,88	2966	76	0,103	848	0,096	373	531	54	5550	8,92
Allotments	c	–	0,74	12	107	1,58	3,6	5	13	19	1,43	0,07	0,76	455	13	0,025	123	0,018	32	146	20	518	7,71
n = 44	d	–	0,67	6	71	0,34	1,2	4	11	13	1,14	0,03	0,20	293	10	0,020	51	0,009	15	122	17	192	7,69
	e	–	0,74	5	61	0,20	1,1	5	13	13	1,19	0,04	0,16	339	10	0,019	36	0,010	13	110	18	141	7,72

Tabela 3 cd.
Table 3 cont.

Gleby *Soils*	Parametry *Parameters*	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	Hg	Mg	Mn	Ni	P	Pb	S	Sr	Ti	V	Zn	pH
		[mg/kg]	[%]	[mg/kg]		[%]	[mg/kg]				[%]	[mg/kg]	[%]	[mg/kg]		[%]	[mg/kg]	[%]	[mg/kg]				[–]
	Granica oznaczalności *Determination 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	2,00
Parki *Parks* n = 91	a	<1	0,12	<3	11	0,02	<0,5	<1	2	1	0,07	<0,02	0,01	10	<1	0,002	5	<0,003	2	24	2	17	4,98
	b	4	2,01	234	1455	19,58	32,1	9	121	692	4,10	0,86	1,12	9820	34	0,104	1779	0,374	228	698	34	10 822	12,38
	c	–	0,60	15	131	0,82	4,5	4	12	36	1,18	0,09	0,17	461	11	0,026	192	0,031	25	122	14	745	7,41
	d	–	0,52	6	74	0,23	1,8	3	9	14	0,91	0,04	0,11	230	8	0,019	69	0,013	12	99	12	257	7,35
	e	–	0,55	5	66	0,15	1,9	4	11	12	1,03	0,04	0,12	279	9	0,018	72	0,012	10	103	14	235	7,65
Trawniki *Lawns* n = 429	a	<1	0,11	<3	12	0,01	<0,5	<1	2	1	0,12	<0,02	0,02	11	1	0,003	3	<0,003	2	26	2	18	4,49
	b	17	4,00	1366	1245	11,54	224,3	24	94	7356	8,64	3,45	6,91	6929	68	0,319	8018	2,240	321	542	61	22 650	9 ,92
	c	–	0,58	30	152	1,24	6,8	5	15	51	1,47	0,11	0,28	519	14	0,033	328	0,052	40	129	16	1103	8,03
	d	–	0,53	9	101	0,60	2,7	4	12	19	1,14	0,06	0,17	349	11	0,025	112	0,022	23	112	14	437	8,01
	e	–	0,55	8	103	0,79	2,9	4	12	20	1,15	0,06	0,17	396	11	0,026	114	0,026	27	112	15	438	8,09
Gleby piaszczyste *Sandy soils* n = 316	a	<1	0,08	<3	8	<0,01	<0,5	<1	1	<1	0,05	<0,02	<0,01	5	<1	<0,002	<2	<0,003	1	15	2	12	5,21
	b	2	2,01	185	662	13,07	53,5	17	52	89	11,18	0,74	7,83	12 807	46	0,477	722	0,251	173	698	70	4412	8,86
	c	–	0,42	–	48	0,40	–	3	7	7	0,75	–	0,20	359	6	0,016	52	0,009	8	82	10	263	7,58
	d	–	0,36	–	32	0,09	–	2	6	5	0,51	–	0,06	126	5	0,010	23	0,004	5	69	8	99	7,55
	e	–	0,36	–	27	0,07	–	2	5	5	0,52	–	0,05	110	4	0,010	17	0,003	4	68	8	79	7,64
Gleby gliniaste *Clay soils* n = 215	a	<1	0,21	<3	14	0,02	<0,5	<1	3	1	0,26	<0,02	0,03	23	3	0,003	3	<0,003	2	28	4	14	4,80
	b	4	2,87	327	552	19,12	178,6	18	48	2963	17,18	2,51	9,87	19 525	67	0,160	12 740	0,432	342	324	115	10 344	8,84
	c	–	0,82	15	92	1,41	8,3	5	14	27	1,93	0,07	0,66	1147	14	0,023	167	0,015	19	114	20	874	7,44
	d	–	0,75	7	67	0,28	1,5	4	12	11	1,36	0,03	0,20	381	11	0,019	50	0,007	12	104	18	241	7,38
	e	–	0,76	6	59	0,17	1,1	5	12	11	1,23	0,03	0,14	307	9	0,018	38	0,007	10	104	18	171	7,68
Gleby antropogeniczne *Anthropogenic soils* n = 631	a	<1	0,11	<3	15	0,02	<0,5	<1	2	3	0,16	<0,02	0,02	23	2	0,003	9	<0,003	2	25	2	43	3,97
	b	73	4,00	2195	1455	19,58	2373,9	546	324	15 590	31,63	15,78	4,04	6929	198	1,199	21 600	3,670	499	2069	683	43 640	12,38
	c	–	0,65	54	199	1,51	20,3	7	19	108	1,97	0,21	0,35	647	19	0,044	619	0,093	54	159	22	1983	7,98
	d	–	0,59	14	143	0,93	4,5	5	15	34	1,53	0,09	0,23	469	15	0,031	199	0,043	36	131	18	732	7,95
	e	–	0,61	12	143	1,00	4,1	5	15	31	1,53	0,09	0,23	483	15	0,030	167	0,040	36	125	18	634	8,04

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*; „–” nie obliczono w przypadku, gdy odsetek wyników poniżej granicy oznaczalności przekraczał 50% *not calculated in the case when the percentage of the results below determination limit exceeded 50%*

Tabela 4
Table

Parametry statystyczne zawartości pierwiastków chemicznych w osadach wodnych

Statistical parameters of chemical elements contents in aquatic sediments

Osady wodne *Aquatic sediments*	Parametry *Parameters*	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	Hg	Mg	Mn	Ni	P	Pb	S	Sr	Ti	V	Zn
		[mg/kg]	[%]	[mg/kg]		[%]	[mg/kg]				[%]	[mg/kg]	[%]	[mg/kg]		[%]	[mg/kg]	[%]	[mg/kg]			
	Granica oznaczalności *Determination 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	0,03	<3	6	0,03	<0,5	<1	2	2	0,14	<0,02	0,02	14	1	0,003	6	0,005	2	8	3	31
Osady wodne (wszystkie próbki)	b	52	1,80	638	485	17,19	155,0	70	537	1817	36,30	7,85	1,74	13 460	348	1,344	7394	5,453	814	674	61	37 856
Aquatic sediments (all samples)	c	–	0,62	33	142	1,97	13,8	10	40	145	2,99	0,49	0,47	1040	34	0,188	458	0,404	76	123	20	3076
n = 225	d	–	0,52	16	106	1,02	7,8	7	24	69	1,87	0,17	0,31	504	22	0,078	252	0,211	41	104	17	1373
	e	–	0,65	20	135	1,60	8,8	8	27	82	2,04	0,25	0,43	594	26	0,078	314	0,236	51	96	20	1534
	a	<1	0,32	7	35	0,23	3,8	3	9	14	0,90	<0,02	0,11	144	10	0,016	108	0,037	15	60	11	414
Rowy (bez nazwy)	b	2	1,49	53	309	3,83	29,7	30	85	226	3,40	0,53	1,36	1979	58	0,119	689	2,276	94	309	35	2309
Ditches (no name)	c	–	0,68	25	151	1,57	9,14	13	38	63	2,17	0,24	0,51	885	30	0,060	243	0,339	53	156	22	1325
n = 12	d	–	0,62	20	130	1,12	7,28	10	30	48	2,00	0,16	0,40	635	25	0,052	208	0,167	46	135	21	1176
	e	–	0,68	26	138	1,35	6,10	10	29	49	2,22	0,29	0,40	672	22	0,049	193	0,151	54	131	21	1184
	a	<1	0,07	<3	6	0,03	<0,5	<1	2	2	0,14	<0,02	0,02	14	1	0,003	6	0,005	2	26	3	31
Stawy	b	3	1,61	137	360	15,52	65,7	70	89	734	10,65	0,38	1,74	9524	82	0,216	1524	5,453	814	546	59	7114
Ponds	c	–	0,39	13	73	1,54	8,1	6	14	80	1,53	0,07	0,25	497	16	0,041	226	0,379	63	105	13	1046
n = 69	d	–	0,31	7	49	0,43	3,9	3	9	27	0,92	0,03	0,13	175	9	0,023	125	0,133	20	87	10	520
	e	–	0,32	6	43	0,28	3,8	3	9	19	0,88	0,03	0,11	137	9	0,020	108	0,106	14	78	10	449
Zlewnia Brynicy	a	<1	0,03	<3	6	0,03	<0,5	<1	2	2	0,14	<0,02	0,02	14	1	0,003	6	0,005	2	8	3	31
od Wielonki do Rawy	b	52	1,80	597	374	17,19	88,0	41	117	769	36,30	3,08	1,74	13 460	348	1,340	2928	4,820	424	674	41	17 171
Catchment of the Brynica River from	c	–	0,66	24	138	2,17	12,1	8	31	98	3,01	0,36	0,51	1107	31	0,245	349	0,392	71	113	19	3339
Wielonka Stream to the Rawa Stream	d	–	0,53	14	103	1,14	6,7	6	23	58	1,74	0,15	0,33	504	20	0,094	225	0,213	39	94	16	1337
n = 138	e	–	0,72	18	135	2,06	6,7	7	29	78	2,01	0,27	0,53	587	25	0,094	281	0,272	47	88	20	1228
	a	<1	0,31	7	54	0,39	5,0	5	12	48	0,84	0,06	0,14	223	10	0,032	228	0,060	14	59	13	881
Brynica	b	12	1,20	51	309	4,00	54,6	23	74	302	6,64	1,55	1,18	6938	61	1,344	883	1,926	170	127	31	17 171
Brynica River	c	3	0,88	32	205	2,54	22,6	10	43	143	2,89	0,61	0,74	1587	37	0,613	559	0,565	98	83	22	7668
n = 46	d	2	0,86	31	193	2,44	20,3	10	41	127	2,72	0,55	0,71	1259	35	0,505	533	0,481	89	81	22	6527
	e	3	0,89	31	214	2,63	19,6	10	42	134	2,72	0,60	0,74	1286	36	0,549	564	0,462	91	81	22	6767
	a	<1	0,10	<3	12	0,04	0,6	<1	3	4	0,30	<0,02	0,04	24	3	0,006	30	0,010	3	45	3	88
Zlewnia Rawy	b	20	1,61	638	485	15,52	155,0	70	207	1212	10,65	7,85	1,20	9524	133	0,323	7394	5,453	814	546	61	37 856
Catchment of the Rawa Stream	c	–	0,55	48	149	1,66	16,3	12	46	165	3,05	0,70	0,40	935	38	0,094	652	0,407	76	140	22	2625
n = 78	d	–	0,48	20	110	0,82	9,4	8	24	78	2,08	0,18	0,27	498	24	0,054	289	0,196	41	120	18	1324
	e	–	0,60	25	135	1,27	12,4	9	20	108	2,33	0,17	0,32	638	28	0,052	329	0,214	53	120	21	1645
	a	2	0,31	24	85	1,46	11,9	14	85	145	3,59	0,94	0,46	966	55	0,074	314	0,121	52	93	25	1628
Rawa	b	7	0,85	53	359	2,50	25,9	25	207	197	10,44	3,54	0,89	2787	133	0,323	792	1,072	76	262	43	2468
Rawa Stream	c	3	0,64	37	232	1,81	18,7	19	125	166	5,42	1,84	0,74	1555	86	0,222	465	0,304	64	162	32	2071
n = 18	d	3	0,63	36	224	1,79	18,2	18	121	165	5,23	1,74	0,72	1491	84	0,212	449	0,256	63	158	31	2057
	e	3	0,64	35	232	1,69	18,8	19	115	160	5,03	1,61	0,74	1539	83	0,218	419	0,237	64	161	32	2079

Tabela 4 cd.
Table 4 cont.

Tło geochemiczne / *Geochemical background*																						
Osady strumieniowe Europy[1] *Stream sediments of Europe*[1]	e	nd.	5,50 n = 799	6,00 n = 794*	87,5 n = 794*	1,74 n = 801	0,29 n = 797	8,00 n = 794*	22,0 n = 794*	15,0 n = 794*	1,97 n = 794*	0,038 n = 797	0,72 n = 801	453 n = 794*	17,0 n = 794*	0,057 n = 801	14,0 n = 794*	0,0502 n = 794	124 n = 801	3798 n = 801	29,0 n = 794*	59,5 n = 794*
Osady Polski[2] *Sediments of Poland*[2] n = 12 778**	e	<1	nd.	<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*[3] n = 1459**	e	1	nd.	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

„–” nie obliczono w przypadku, gdy odsetek wyników poniżej granicy oznaczalności przekraczał 50% *not calculated in the case when the percentage of the results below determination limit exceeded 50%*; nd. – nie dotyczy *not applicable*; * ekstrakcja wodą królewską *aqua regia digestion*; ** ekstrakcja kwasem solnym *hydrochloric acid digestion*

Tabela 5
Table

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

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

Wody powierzchniowe *Surface water*	Parametry *Paramters*	EC	pH	Ag	Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn	Mo	Na	Ni	P	Pb	SO_4^{2-}	Sb	Se	SiO_2	Sr	Ti	Tl	U	V	Zn
		[mS/cm]	[–]	[µg/dm³]			[mg/dm³]		[µg/dm³]	[mg/dm³]	[µg/dm³]		[mg/dm³]	[µg/dm³]	[mg/dm³]		[µg/dm³]	[mg/dm³]		[µg/dm³]	[mg/dm³]	[µg/dm³]	[mg/dm³]	[µg/dm³]	[mg/dm³]	[µg/dm³]		[mg/dm³]			[µg/dm³]			[mg/dm³]
	Granica oznaczalności *Determination limit*	brak *none*	brak *none*	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	0,002	0,002	0,05	0,05	1	0,003
Wody powierzchniowe	a	0,15	4,94	<0,05	<0,5	<2	<0,01	0,007	<0,05	10,3	<0,05	<0,05	<0,003	<0,05	<0,01	1,3	0,3	0,9	0,001	<0,05	1,6	<0,5	<0,05	<0,05	2	<0,05	<2	0,1	0,027	<0,002	<0,05	<0,05	<1	<0,003
(wszystkie próbki)	b	30,90	9,99	0,07	194,7	41	1,48	1,075	0,09	523,8	9,02	7,58	0,020	62,32	4,51	170,0	744,1	355,7	4,165	25,74	4948,7	294,6	1,59	6,10	661	14,91	153	18,3	15,902	0,004	1,30	2,46	41	2,627
Surface water (all samples)	c	2,03	8,20	–	20,1	–	0,26	0,089	–	96,4	–	0,81	–	2,56	0,11	16,5	35,4	43,9	0,320	2,94	190,0	9,3	–	0,61	224	1,47	–	6,0	0,674	–	0,22	0,64	–	0,064
n = 251	d	1,20	8,17	–	12,2	–	0,20	0,061	–	74,3	–	0,22	–	1,56	0,03	11,6	15,6	29,1	0,082	1,36	71,5	4,0	–	0,35	111	0,85	–	3,4	0,357	–	0,11	0,37	–	0,021
	e	1,48	8,24	–	12,8	–	0,22	0,053	–	74,6	–	0,34	–	1,81	0,03	13,2	21,3	34,4	0,122	1,33	103,1	5,0	–	0,35	148	1,05	–	5,9	0,402	–	0,13	0,64	–	0,022
	a	0,33	7,53	<0,05	6,6	<2	0,02	0,014	<0,05	12,1	<0,05	<0,05	<0,003	0,60	<0,01	1,9	1,1	0,9	0,015	0,14	7,7	0,7	<0,05	0,29	5	0,28	<2	0,5	0,036	<0,002	<0,05	<0,05	<1	<0,003
Rowy (bez nazwy)	b	1,53	9,09	<0,05	194,7	4	0,21	0,150	<0,05	103,5	0,53	0,62	0,005	16,49	1,17	25,7	33,9	54,9	0,434	4,91	119,4	6,0	0,06	6,10	352	3,82	3	6,8	0,515	0,004	0,13	1,47	2	0,132
Ditches (no name)	c	0,73	7,91	–	60,9	–	0,13	0,067	–	43,9	0,17	0,35	–	5,15	0,19	9,0	17,6	17,3	0,127	3,15	54,3	3,0	–	1,91	94	2,31	–	3,8	0,300	–	–	0,45	1	0,034
n = 10	d	0,64	7,90	–	34,4	–	0,11	0,054	–	37,6	0,10	0,27	–	2,90	0,06	7,2	12,4	11,0	0,066	2,14	35,5	2,5	–	1,21	53	1,74	–	2,9	0,240	–	–	0,26	1	0,019
	e	0,53	7,73	–	45,8	–	0,12	0,059	–	45,3	0,12	0,30	–	2,88	0,09	8,4	13,7	9,9	0,058	4,23	43,4	3,1	–	1,03	57	2,52	–	4,0	0,259	–	–	0,27	1	0,020
	a	0,15	4,94	<0,05	<0,5	<2	0,04	0,026	<0,05	16,6	<0,05	<0,05	<0,003	0,34	<0,01	3,5	1,8	3,6	0,001	0,12	2,9	0,8	<0,05	0,06	8	<0,05	<2	0,1	0,038	<0,002	<0,05	<0,05	<1	<0,003
Stawy	b	2,63	9,41	<0,05	59,6	16	0,40	0,512	0,07	202,6	0,06	2,78	<0,003	3,52	2,08	16,1	41,0	84,1	1,289	2,17	194,9	50,9	0,33	4,51	540	6,94	6	10,5	0,702	0,002	0,31	2,46	2	0,045
Ponds	c	0,88	8,34	–	23,6	5	0,22	0,120	–	58,5	–	–	–	0,94	–	8,3	12,3	28,8	0,057	1,08	62,7	2,9	–	0,50	114	2,18	–	1,6	0,277	–	–	0,69	–	0,009
n = 72	d	0,73	8,29	–	17,5	3	0,20	0,103	–	50,3	–	–	–	0,79	–	7,4	7,9	23,5	0,012	0,89	41,8	1,8	–	0,34	56	1,38	–	0,9	0,248	–	–	0,45	–	0,007
	e	0,71	8,57	–	21,9	3	0,22	0,113	–	44,6	–	–	–	0,68	–	7,8	6,3	22,7	0,011	1,08	48,2	1,5	–	0,38	31	1,73	–	1,1	0,245	–	–	0,63	–	0,006
Zlewnia Brynicy	a	0,15	6,71	<0,05	<0,5	<2	<0,01	0,007	<0,05	11,7	<0,05	<0,05	<0,003	0,30	<0,01	1,3	0,3	1,1	0,002	0,11	1,6	<0,5	<0,05	<0,05	2	<0,05	<2	0,1	0,027	<0,002	<0,05	<0,05	<1	<0,003
od Wielonki do Rawy	b	15,02	9,99	0,07	146,2	12	0,97	0,287	0,09	202,6	9,02	7,58	0,020	62,32	4,51	170,0	84,4	104,4	4,165	25,74	1907,9	294,6	1,59	4,76	661	14,91	6	16,4	1,315	0,003	0,76	2,46	41	2,627
Catchment of the Brynica River from	c	1,97	8,42	–	18,4	–	0,26	0,068	–	106,7	–	0,84	–	3,06	0,15	15,9	24,0	45,1	0,349	2,05	135,6	10,7	0,18	0,57	267	1,16	–	6,2	0,468	–	0,20	0,78	–	0,089
Wielonka Stream to the Rawa Stream	d	1,38	8,40	–	10,6	–	0,20	0,057	–	85,6	–	0,25	–	1,77	0,03	10,9	13,3	31,5	0,106	1,00	72,0	4,5	0,08	0,30	133	0,61	–	3,5	0,350	–	0,12	0,47	–	0,024
n = 142	e	1,76	8,51	–	9,7	–	0,23	0,053	–	133,7	–	0,37	–	1,98	0,03	13,7	24,5	55,0	0,186	0,89	108,6	6,7	0,06	0,27	351	0,59	–	6,8	0,450	–	0,21	0,92	–	0,022
	a	1,16	7,30	<0,05	1,0	<2	0,13	0,041	<0,05	130,1	<0,05	<0,05	<0,003	1,55	0,01	12,4	15,7	50,1	0,063	0,60	73,8	6,2	0,09	0,08	328	0,23	<2	5,4	0,416	<0,002	0,18	0,77	<1	0,016
Brynica	b	2,57	9,10	<0,05	81,5	2	0,42	0,068	0,09	174,7	0,18	1,28	<0,003	4,82	0,98	17,6	39,3	76,4	0,592	3,10	238,8	78,7	0,37	1,32	504	3,68	3	11,5	0,964	<0,002	0,76	1,33	1	0,522
Brynica River	c	1,83	8,41	–	11,5	–	0,29	0,051	–	154,9	–	0,55	–	2,37	0,04	14,9	30,7	65,6	0,264	1,13	127,7	13,8	0,24	0,30	422	0,84	–	8,8	0,668	–	0,34	1,03	–	0,115
n = 50	d	1,81	8,40	–	8,5	–	0,27	0,050	–	154,4	–	0,43	–	2,26	0,02	14,9	29,9	65,2	0,223	1,05	123,1	10,2	0,22	0,25	419	0,60	–	8,6	0,654	–	0,32	1,02	–	0,056
	e	1,88	8,53	–	8,9	–	0,29	0,049	–	154,0	–	0,52	–	2,07	0,02	14,9	33,7	66,2	0,253	1,02	122,2	8,0	0,26	0,23	415	0,42	–	9,1	0,649	–	0,31	1,01	–	0,033
	a	0,18	4,94	<0,05	<0,5	<2	0,02	0,014	<0,05	10,3	<0,05	<0,05	<0,003	0,27	<0,01	1,6	1,4	0,9	0,001	0,07	1,6	<0,5	<0,05	0,06	3	0,16	<2	0,1	0,036	<0,002	<0,05	<0,05	<1	<0,003
Zlewnia Rawy	b	2,55	8,91	<0,05	194,7	16	0,50	0,512	<0,05	185,0	1,27	3,10	0,008	16,49	1,00	30,0	99,8	100,7	1,530	24,01	301,9	26,8	0,64	6,10	633	6,94	11	18,3	1,471	0,004	1,30	1,73	2	0,132
Catchment of the Rawa Stream	c	1,07	7,89	–	23,3	4	0,21	0,083	–	68,4	–	0,79	–	1,79	0,06	15,0	25,7	31,6	0,288	4,33	93,4	6,9	–	0,68	163	1,94	–	5,6	0,417	–	0,22	0,46	–	0,031
n = 101	d	0,90	7,85	–	16,0	3	0,18	0,060	–	58,4	–	0,19	–	1,30	0,02	11,9	17,1	24,4	0,058	2,21	61,0	3,6	–	0,45	88	1,41	–	3,0	0,331	–	0,09	0,30	–	0,018
	e	0,90	7,92	–	15,7	3	0,21	0,067	–	68,6	–	0,08	–	1,42	0,03	8,7	17,8	25,2	0,038	1,70	64,6	3,2	–	0,40	127	1,32	–	2,1	0,296	–	0,06	0,30	–	0,017
	a	0,70	6,99	<0,05	8,5	<2	0,09	0,015	<0,05	39,7	<0,05	1,23	<0,003	1,51	0,02	15,3	13,2	9,6	0,215	2,70	58,8	6,0	0,06	0,21	72	0,70	<2	7,5	0,169	<0,002	0,12	0,07	<1	0,029
Rawa	b	2,55	8,44	<0,05	23,8	4	0,50	0,084	<0,05–	185,0	1,27	3,10	0,008	3,59	0,11	30,0	99,8	100,7	1,393	24,01	301,9	26,8	0,64	1,50	633	1,99	11	14,9	1,471	<0,002	1,30	0,35	2	0,095
Rawa Stream	c	1,60	7,64	–	14,0	3	0,26	0,034	–	103,1	0,32	1,91	–	2,17	0,05	26,1	45,7	47,7	0,629	8,73	159,1	14,5	0,29	0,56	320	1,28	4	11,3	0,672	–	0,53	0,21	–	0,059
n = 37	d	1,53	7,63	–	13,6	2	0,24	0,030	–	97,2	0,12	1,88	–	2,14	0,04	25,8	41,0	42,1	0,577	6,05	147,4	12,8	0,24	0,48	286	1,25	3	11,2	0,599	–	0,33	0,19	–	0,057
	e	1,71	7,63	–	12,9	3	0,26	0,029		102,0	0,07	1,91	–	2,14	0,04	27,2	42,1	49,3	0,562	4,30	155,4	10,9	0,31	0,43	292	1,19	3	10,9	0,692	–	0,19	0,19	–	0,062
Wartości graniczne wskaźników jakości wód powierzchniowych z grupy specyficznych substancji zanieczyszczających[1] *Limit values for surface water quality indicators from the group of specific pollutants [1]*																																		
I i II klasa[1] *Classes I and II [1]*		nd.	nd.	≤5	≤400	≤50	≤2	≤0,5	≤0,8	nd.	nd.	≤50	≤0,05	≤50	nd.	nd.	nd.	nd.	nd.	≤40	nd.	nd.	nd.	nd.	nd.	≤2	≤20	nd.	nd.	≤0,05	≤2	nd.	≤50	≤1

Tabela 5 cd.
Table 5 cont.

Środowiskowe normy jakości dla wskaźników stanu chemicznego jednolitych części wód powierzchniowych[2)] *Environmental quality standards for chemical status indicators of uniform part of the surface water[2)]*																																	
Maksymalne dopuszczalne stężenie[2)] *Maximum allowable concentration[2)]*	nd.	nd.	nd.	nd.	nd.	nd.	nd.	nd.	nd.	0,45 (klasy 1 i 2) *(class 1 and 2)*; 0,6 (klasa 3) *(class 3)*; 0,9 (klasa 4) *(class 4)*; 1,5 (klasa 5) *(class 5)*	nd.	nd.	nd.	nd.	nd.	nd.	nd.	nd.	nd.	nd.	34	nd.	14	nd.	nd.	nd.	nd.	nd.	nd.	nd.	nd.	nd.	nd.

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* „–” nie obliczono w przypadku, gdy odsetek wyników poniżej granicy oznaczalności przekraczał 50% *not calculated in the case when the percentage of the results below determination limit exceeded 50%* nd. – nie dotyczy *not applicable*

[1)] Zgodnie z załącznikiem nr 26 do rozporządzenia Ministra Infrastruktury (Rozporządzenie…, 2021)
In accordance with Annex 26 of the Regulation of the Minister of Infrastructure

[2)] Zgodnie z załącznikiem nr 14 do rozporządzenia Ministra Infrastruktury (Rozporządzenie…, 2021)
In accordance with Annex 14 of the Regulation of the Minister of Infrastructure

Polish Soil Association (Klasyfikacja..., 2008) would make it difficult to compare the grain size composition with data from map sheets developed previously.

Grain size composition of the investigated soils is dominated by the sand fraction (1.0–0.1 mm). Its highest content (>75%) was found mainly in the south-eastern part of the map sheet in areas of Pleistocene glaciofluvial sands and gravels (Pl. 4). In contrast, the soils that developed mainly on Quaternary tills and slope wash sands and on the outcrops of Triassic carbonates are enriched in the silt (0.10–0.02 mm) and clay (<0.02 mm) fractions, whose proportion is above 25% in some areas (Pls. 5, 6). Within the clay fraction, colloidal clay plays the most significant role and comprises mainly clay minerals and secondary oxide minerals. The presence of this fraction is a factor determining many significant soil properties, with the sorption capacity being predominantly affected (Bednarek *et al.*, 2004).

The pH. Both the topsoil (0.0–0.3 m) and subsoil (0.8–1.0 m) layers are characterized predominantly by alkaline pH (pH >7.4). In the topsoil layer, the proportion of pH >7.4 soils is 63%, while in the subsoil layer it is 77%. Very acidic to acidic soils (pH <6.0) are found in small areas mainly in the forests of the north-western part of the map sheet (Pls. 7, 8).

Geochemistry. Anthropogenic transformations have led to significant changes in the chemical composition of the soils in relation to the parent rocks. The spatial distributions of the chemical elements analysed in the soils allow the presence of contaminants from various industrial activities to be identified.

The median concentrations of the elements studied in the topsoil layer exceed to varying degrees the values defined as geochemical background levels of the Silesian-Cracow region (with the exception of mercury). The median content of phosphorus is slightly higher than the geochemical background level. The median concentrations of arsenic, barium, cobalt, iron, magnesium, manganese, nickel, sulphur, strontium and vanadium are significantly higher (about double), of calcium, chromium and titanium are three times higher, and of cadmium, copper and lead are about four times higher. The median concentration of zinc exceeds the geochemical background level by as much as about seven times (Tab. 2; Lis, Pasieczna 1995b).

Soils in the northern and north-eastern parts of the map sheet area, which developed on Triassic carbonates and glaciofluvial sands and gravels, are the least rich in organic carbon (<3.00%). Concentrations of Corg above 12.00% (Pl. 19) are found in anthropogenic soils, including those around reclaimed and partially dismantled post-mining coal heaps and dumps. The high concentrations of this component in soils may be due, among other things, to the storage of coal mining waste. The maximum content of organic carbon (47.20%) is recorded in Katowice (south-western part of the study area) in soils near the railway tracks.

Soils from both depth ranges contain mostly between 0.40 and 0.80% aluminium. Only locally, in areas of Quaternary tills and slope wash sands, as well as Triassic carbonates, the content of this element is above 0.80% (Pl. 12). The spatial distributions of calcium (>2.00%; Pls. 20, 21), magnesium (>0.50%; Pls. 36, 37) and manganese (>800 mg/kg; Pls. 38, 39), reflecting the relationship with the chemistry of the bedrock, are more pronounced in the deeper layers and coincide with the outcrops of Triassic carbonates, particularly limestones and dolomites. These areas occur mainly in the northern and north-eastern parts of the map sheet. The soils are also locally rich in cadmium, iron, nickel and zinc, which probably indicates that the bedrock was the primary source of the elements. In contrast, the geochemical anomalies of these elements in the topsoil layer may be due to the large-scale transformation of the land surface.

Most of the investigated soils contain less than 0.080% sulphur. Concentrations above 0.640% (Pls. 48, 49) of this element are found in anthropogenic soils, including those around reclaimed partially demolished post-mining coal heaps and dumps and embankments. The maximum sulphur content (4.301%) was recorded in a topsoil sample collected from a wasteland area in Czeladź. High contents of cadmium (761.4 mg/kg), lead (2,371 mg/kg) and zinc (7,940 mg/kg) are also observed at that site.

In topsoil, the median phosphorus content (0.041%) is almost twice as high as that measured in the subsoil layer (0.023%). In soils from a depth of 0.0–0.3 m, elevated contents of this element in relation to the geochemical background level of the Silesian-Cracow region are typically found in urban areas (median 0.045%). The highest concentration of phosphorus in both soil horizons was measured in an anthropogenic soil sample from the industrial area of the former Tube Rolling Mill "Jedność" in Siemianowice Śląskie. At this site, the topsoil and subsoil layers contain 1.594 and 1.199% phosphorus, respectively.

In the soils of Upper Silesia, the barium content exceeds 100 mg/kg, mainly in the outcrops of Carboniferous ore-bearing clay-sand deposits (Lis, Pasieczna 1995a, b). The distribution of the content of this element in samples from both depth ranges is similar. Larger areas of soils containing anomalous levels of barium (120–480 mg/kg) occur in the 0.0–0.3 m depth layer (Pls. 16, 17), indicating an anthropogenic factor as a major source of contamination. The sources of barium may include dust from coal combustion. Research conducted by Różkowska and Ptak (1995) has demonstrated that the geometric mean concentration of this element in Upper Silesian coal is 176 mg/kg, while in ashes, it reaches 1,274 mg/kg. The maximum concentration of barium (1,203 mg/kg) in the topsoil layer was found in a heavily anthropogenically transformed area in the western part of the map sheet, on the border between the cities of Katowice and Siemianowice Śląskie. The highest level of barium (1,455 mg/kg) in subsoil was measured in a sample from a park in Katowice (Śródmieście).

Clear geochemical anomalies of metals and arsenic have been found in the areas of mineral exploitation and current and historical non-ferrous metal smelters, near reclaimed and partially dismantled tailings heaps, dumps and industrial sites. High concentrations of arsenic (>80 mg/kg; Pls. 13, 14), copper (>80 mg/kg; Pls. 28, 29), cadmium (>16.0 mg/kg; Pls. 22, 23), lead (>500 mg/kg; Pls. 46, 47), zinc (>1,000 mg/kg; Pls. 61, 62) and silver (>4 mg/kg; Pls. 9, 10) in soils from both depth ranges are observed mainly in the western, south-eastern and southern parts of the map sheet. At the border between the cities of Siemianowice Śląskie and Katowice, maximum levels of arsenic (3,910 mg/kg), cadmium (2,373.9 mg/kg), copper (15,590 mg/kg), lead (21,600 mg/kg) and mercury (15.78 mg/kg), as well as high concentrations of zinc (up to 36,510 mg/kg), silver (up to 69 mg/kg) and sulphur (up to 3.670%), are recorded in anthropogenic soils. These soils locally also show significant levels of chromium, manganese, nickel and strontium. In this area, coal mining was carried out and zinc smelters operated, including the former smelters Jedność SA, Jerzy, Hohenlohe (currently ZM SILESIA SA). There were also industrial waste heaps and dumps in this area between the spoil tips, including the metallurgical waste heap of the former "Jedność SA" smelter and the dismantled waste heap of the former Silesia zinc smelter.

Distinct geochemical anomalies of metals and arsenic also occur in the soils of the north-eastern part of Katowice (Dąbrówka Mała, Zawodzie, Roździeń, Szopienice-Burowiec). Maximum levels of zinc (43,640 mg/kg) and silver (73 mg/kg) and high concentrations of copper, cadmium, lead, mercury and arsenic were found here in anthropogenic soils. Soil contamination by these elements is probably related to non-ferrous and ferrous smelting activities in the area. In various periods, the following smelters, which are no longer in operation, were active in this region: Dietrich, Paweł, Walter Croneck, Bernhardi, Wilhelmina, Uthemann, and Szopienice Non-ferrous Metal Works (HMN). The HMN was the largest producer of non-ferrous metals in Silesia, and of cadmium in the world. The plant also operated a copper refining division, producing also silver and liquid sulphur dioxide. In addition, the area between the Wilhelmina and Uthemann smelters was occupied by tailings piles, the reclamation process of which has been completed. At the southern border of the map sheet, the FERRUM SA ironworks operates in the Zawodzie district of Katowice.

Anthropogenic contamination of soils with metals and arsenic was found locally, among others, in the central part of the map sheet area, on the border between the cities of Czeladź and Siemianowice Śląskie. In the samples collected from a road embankment, there are distinct anomalies of copper concentrations in both sampling levels (1,550 mg/kg in topsoil, and 5,962 mg/kg in subsoil). High concentrations of cobalt, strontium, chromium, nickel, lead, titanium, vanadium and zinc are recorded also at that site. In Katowice, high concentrations of arsenic (>640 mg/kg), cadmium (>30.0 mg/kg), lead (>3,000 mg/kg) and zinc (>8,000 mg/kg) were found in soil samples collected near a road embankment. In the southern part of the area, close to a trackway, the soils are characterized by significant concentrations of mercury, silver, arsenic, lead and zinc, which are [mg/kg]: 10.98 and 3.84; 24 and 26; 833 and 453; 6,617 and 5,579; and 15,810 and 10,026 in topsoil and subsoil, respectively.

Point anomalies in the concentrations of some metals in the topsoil layer are observed in the Sosnowiec urban area. Near the Kalety residential area, maximum concentrations of chromium (1,420 mg/kg) and nickel (605 mg/kg) were recorded in a sample taken from a lawn. This area was anthropogenically modified in the past by coal mining, while to the east of the study area, there was historical iron ore smelting. A high copper content (2,617 mg/kg) was found in anthropogenic soils near the eastern boundary of the map sheet.

In Czeladź, close to the border with Siemianowice Śląskie, near the mouth of the Rów Michałowicki ditch into the Brynica River, high concentrations of lead, copper, zinc, mercury and arsenic are observed in soils. The highest concentrations of these elements in the topsoil and subsoil layers of this area are as follows [mg/kg]: for lead 2,523 and 12,740, for copper 555 and 2,963, for zinc 13,780 and 5,329, for mercury 2.57 and 2.41, and for arsenic 367 and 327, respectively.

Distinct geochemical anomalies of cadmium (>8 mg/kg; Pls. 22, 23) and zinc (>1,000 mg/kg; Pls. 61, 62) in soils from both depth ranges occur also in the areas of Triassic outcrops, including Diplopora and ore-bearing dolomites (northern and north-eastern parts of the map sheet). These soils are also rich, among others, in calcium, magnesium, manganese and iron, which may indicate a relationship between these elements and the geology of the underlying rocks.

Because of the ease of accumulation in soils and the harmful effects of excess arsenic, cadmium, lead and zinc on plants and soil microorganisms, the amounts of the map sheet area occupied by soils contaminated by each of these elements were estimated (Tab. 6). A high arsenic concentration (>100 mg/kg) was found in 4.09% of the topsoil layer and in 4.90% of the subsoil layer. In the 0.0–0.3 m depth layer, the area of soils contaminated with cadmium (>15 mg/kg) is 14.41%, lead (>600 mg/kg) 13.42%, and zinc (>2,000 mg/kg) 14.80%. At a depth of 0.8–1.0 m, the proportion of soils contaminated with these metals decreases, being 11.53% for cadmium, 9.72% for lead, and 12.56% for zinc.

In order to assess the degree of contamination of soils from the 0.0–0.3 m depth layer with potentially toxic elements, reference was made to the limit values provided in the Regulation of the Minister of the Environment on the manner of conducting the assessment of contamination of the Earth surface (Rozporządzenie..., 2016). According to the contents of barium, chromium, cobalt, copper, nickel and mercury, the requirements for group I (residential areas, other built-up areas, urbanized undeveloped areas, built-up agricultural land, recreational and leisure areas) were met by 95.61 to 99.92% of the analysed soil samples. Cadmium is notable by the fact that only 12.49% of the soil samples met its requirements for group I. This is important because the study area is largely an urban agglomeration. According to the contents of most elements, the requirements for group II (arable land, orchards, meadows and permanent pastures, land under ponds and ditches, allotment gardens)

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)

Tabela 6
Table

Pierwiastek *Element*	Zawartość *Content* [mg/kg]	Gleba *Soil* 0,0–0,3 m [km²]	[%]*	0,8–1,0 m [km²]	[%]*
As	<10	38,67	46,87	51,22	62,08
	10–25	28,50	34,55	17,81	21,59
	25–50	8,27	10,02	6,03	7,31
	50–100	3,69	4,47	3,40	4,12
	>100	3,37	4,09	4,04	4,90
Cd	<2	10,30	12,49	37,95	46,00
	2–5	26,27	31,85	19,44	23,56
	5–10	25,83	31,30	11,70	14,18
	10–15	8,21	9,95	3,90	4,73
	>15	11,89	14,41	9,51	11,53
Pb	<100	14,82	17,96	44,12	53,48
	100–200	30,40	36,85	15,68	19,01
	200–500	23,22	28,15	13,19	15,98
	500–600	2,99	3,62	1,49	1,81
	>600	11,07	13,42	8,02	9,72
Zn	<300	10,62	12,87	38,02	46,08
	300–500	16,28	19,73	10,36	12,56
	500–1000	26,72	32,39	13,62	16,51
	1000–2000	16,67	20,21	10,14	12,29
	>2000	12,21	14,80	10,36	12,56

* 82,5 km² = 100%

Ocena zanieczyszczenia gleb z głębokości 0,0–0,3 m ze względu na zawartości wybranych pierwiastków potencjalnie toksycznych

Assessment of topsoil (0.0–0.3 m) contamination according to the content of selected potentially toxic elements

Tabela 7
Table

Pierwiastek *Element*		Grupa I *Group I*	Grupa II* *Group II*	Grupa III *Group III*	Grupa IV *Group IV*	Pozostałe** *Other*
As	1	<25	<10	<50	<100	>100
	2	1056	608	1186	1244	53
	3	81,42%	46,88%	91,44%	95,91%	4,09%
Ba	1	<400	<200	<1000	<1500	>1500
	2	1240	1003	1296	1297	0
	3	95,61%	77,33%	99,92%	100,00%	0,00%
Cr	1	<200	<150	<500	<1000	>1000
	2	1292	1287	1296	1296	1
	3	99,61%	99,23%	99,92%	99,92%	0,08%
Zn	1	<500	<300	<1000	<2000	>2000
	2	423	167	843	1105	192
	3	32,61%	12,88%	65,00%	85,20%	14,80%
Cd	1	<2	<2	<10	<15	>15
	2	162	162	981	1110	187
	3	12,49%	12,49%	75,64%	85,58%	14,42%
Co	1	<50	<20	<100	<200	>200
	2	1295	1286	1295	1297	0
	3	99,85%	99,15%	99,85%	100,00%	0,00%
Cu	1	<200	<100	<300	<600	>600
	2	1248	1182	1260	1283	14
	3	96,22%	91,13%	97,15%	98,92%	1,08%
Ni	1	<150	<100	<300	<500	>500
	2	1296	1294	1296	1296	1
	3	99,92%	99,77%	99,92%	99,92%	0,08%
Pb	1	<200	<100	<500	<600	>600
	2	711	233	1076	1123	174
	3	54,82%	17,96%	82,96%	86,58%	13,42%
Hg	1	<5	<2	<10	<30	>30
	2	1296	1291	1296	1297	0
	3	99,92%	99,54%	99,92%	100,00%	0,00%

1 – dopuszczalne zawartości substancji powodujących ryzyko z podziałem na grupy gruntów przyjęte za Rozporządzeniem Ministra Środowiska z dnia 1 września 2016 r.
permissible contents of substances causing risk, divided into soil groups, adopted according to the Regulation of the Minister of Environment of September 1, 2016

2 – liczba próbek spełniających kryteria dla poszczególnych grup gruntów
number of samples meeting the criteria for individual soil groups

3 – udział procentowy próbek (w stosunku do całkowitej liczby *n*) spełniających kryteria dla poszczególnych grup gruntów
percentage of samples (in relation to the total number n) meeting the criteria for individual soil groups

* – wartości przyjęte dla grupy II-1 (wartości najniższe)
values adopted for group II-1 (lowest values)

** – nie spełniające wymogów dla żadnej z grup
not meeting the requirements for any of the groups

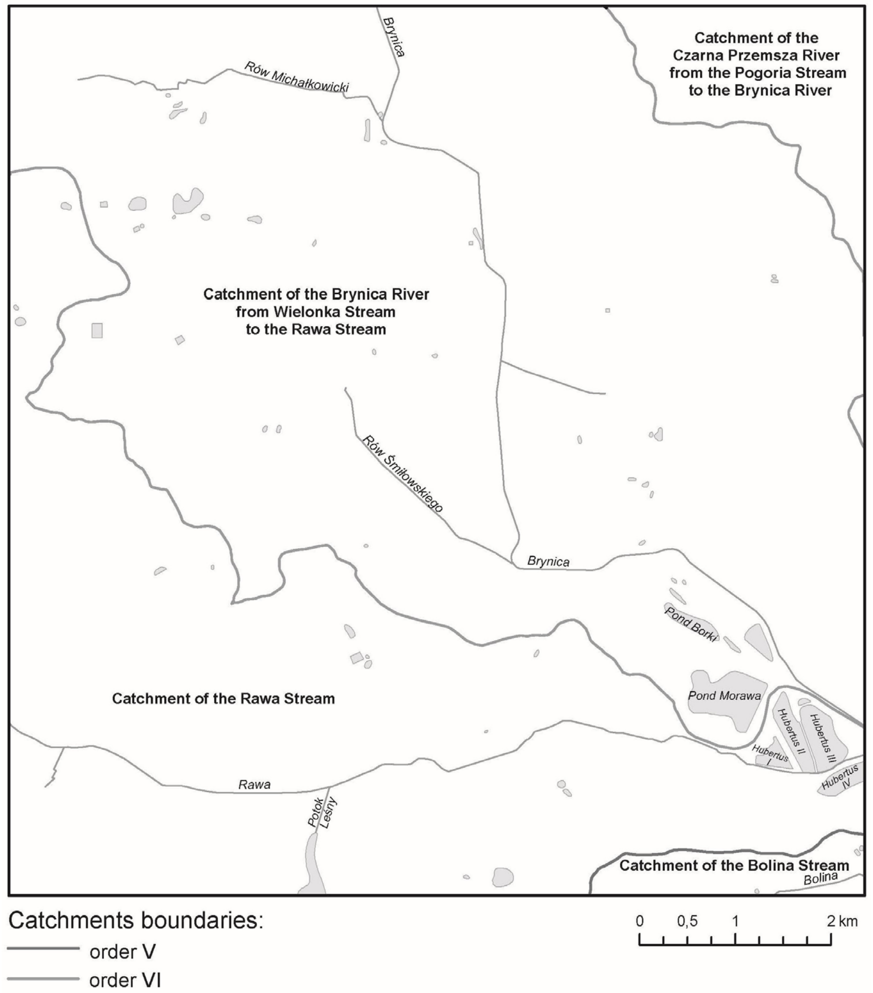

Fig. 3. Location of watercourses and catchments (after Hydroportal – https://wody.isok.gov.pl/imap_kzgw/ [access 12.09.2024])

were met by 77.33–99.77% of the soil samples. The exceptions were arsenic, zinc, cadmium and lead, for which the percentage of samples meeting the requirements for group II was much lower (12.49– 46.88%). Between 65.00 and 99.92% of the soil samples were found to meet the requirements for group III (forests, wooded and shrubby land including agricultural land, wasteland, recreational and leisure areas, ecological sites, miscellaneous land), with the lowest percentage of samples referencing cadmium (Tab. 7). An example of the assessment of soil contamination (in cartographic form) according to the permissible cadmium content (Rozporządzenie..., 2016) is presented in the map of the distribution of the content of this element (Pl. 63). The analysis carried out does not take into account the stages and method of soil and land contamination testing, set out in Rozporządzenie (2016).

AQUATIC SEDIMENTS

Within the map sheet boundaries, sediments taken from watercourses and standing water bodies (termed “sediments” in the maps) were tested from the following catchments: Brynica River from the Wielonka to Rawa streams, Rawa Stream, and Bolina Stream (Fig. 3). The ranges and statistical parameters of the elemental contents in the individual catchments are presented in Tab. 4. In characterizing the study results, reference was made to the geochemical background values for the Silesian-Cracow region (according to Lis, Pasieczna, 1995b), and to the values of the ecotoxicological risk indicator PEC (*Probable Effect Concentration*; MacDonald *et al.*, 2000), above which harmful effects of a given element on aquatic organisms is observed. The PEC index takes on the following values: arsenic – 33 mg/kg, cadmium – 4.98 mg/kg, chromium – 111 mg/kg, copper – 149 mg/kg, lead – 128 mg/kg, mercury – 1.06 mg/kg, nickel – 48.6 mg/kg, and zinc – 459 mg/kg.

Catchment of the Brynica River from the Wielonka Stream to the Rawa Stream covers most of the study area, including the Brynica River with its tributaries, and standing water bodies. Within the map sheet boundaries, the Brynica River flows in a regulated, concreted and embanked channel. It is one of the watercourses that have lost their natural character as a result of human economic activity. It flows through highly urbanized and industrialized areas, which are the main source of its contamination, especially in the section from Piekary Śląskie downstream to the mouth of the Przemsza River – outside the map sheet area (Uchwała.., 2016). In the analysed catchment area, the Brynica River is fed by the Rów Michałkowicki and Rów Śmiłowski ditches. The channels of these watercourses are not covered only in their lower reaches, while along the remaining sections they flow in encased channels. The Rów Michałkowicki ditch receives water from, among others, dewatering of the former KWK “Siemianowice” coal mine.

The median contents of the chemical elements analysed in aquatic sediments of the catchment area exceed to various degrees the values defined as geochemical background levels of the Silesian-Cracow region. The median concentrations of barium and phosphorus are slightly higher. The median concentrations of cobalt, iron, manganese, nickel, strontium, titanium, vanadium are significantly higher (about double); the contents of arsenic, calcium, cadmium, chromium are three times higher, and those of mercury and magnesium are about four times higher. The median concentrations of copper, lead, sulphur and zinc are about five times the geochemical background level (Tab. 4; Lis, Pasieczna, 1995b).

High contents of potentially toxic metals (cadmium, copper, lead and zinc) in the sediments of the Brynica River are particularly pronounced downstream of the mouth of the Rów z Orła Białego ditch – beyond the north-western boundary of the map sheet (Pasieczna *et al.*, 2021). The present investigations of the Brynica River sediments in the Siemianowice Śląskie sheet area shows variations in metal concentrations, which fall within the following ranges [mg/kg]: <1–12 for silver (Pl. 9), 5.0–54.6 for cadmium (Pl. 22), 48–302 for copper (Pl. 28), 228–883 for lead (Pl. 46), and 881–17,171 for zinc (Pl. 61; Tab. 4). Moreover, the Brynica River alluvial deposits are also distinguished from all aquatic sediments in the map sheet area by their high levels of mercury (often >0.20 mg/kg; Pl. 32), sulphur (>0.300%; Pl. 48) and phosphorus (>0.320%; Pl. 44). Near the Pekin residential area, downstream of the Dąbrówka Mała – Centrum sewage treatment plant, discharges of treated sewage are an additional source of phosphorus.

An artificial watercourse flows through the city of Czeladź in the central part of the catchment area. This canal drains the workings of coal mines that are no longer in use. The flows of water in the canal are steady and depend on the amount of pumped water (Uchwała..., 2016). Sediments taken from the canal are characterized by high concentrations of some elements. The following records have been obtained: 30–52 mg/kg silver (Pl. 9), 306–374 mg/kg barium (Pl. 16), 24–41 mg/kg cobalt (Pl. 24), 198–289 mg/kg copper (Pl. 28), 32.94–36.30% iron (Pl. 30), 0.63–0.84 mg/kg mercury (Pl. 32), 7,206–13,460 mg/kg manganese (Pl. 38), 144–348 mg/kg nickel (Pl. 42) and 352–424 mg/kg strontium (Pl. 53). Sediment taken from the pond located at the mouth of the Rów Michałkowicki ditch into the Brynica River (northern part of the catchment area) contain high levels of arsenic (597 mg/kg), cadmium (88 mg/kg), copper (108 mg/kg), iron (3.91%), mercury (1.01 mg/kg), lead (2,928 mg/kg) and zinc (12,720 mg/kg). Geochemical anomalies of these elements are also observed in soil samples collected in this region.

In the south-eastern part of the study area, on the border between Katowice, Sosnowiec and Mysłowice, there are water reservoirs of anthropogenic origin, created at sites of former sand mining. The ponds and their surroundings fulfill important recreational functions and are of great natural significance (Orzechowski, 2023). The following ponds are located within the catchment area: Stawiki, Borki and Morawa. In the sediment samples from these water bodies, the levels of silver and mercury are often below the limit of quantification. Most of the samples also contain arsenic (<3–7 mg/kg), chromium (2–8 mg/kg), copper (2–16 mg/kg) and nickel (1–9 mg/kg), as well as barium (6–69 mg/kg), calcium (0.03–0.58%), cobalt (<1–4 mg/kg), iron (0.14–1.07%), magnesium (0.02–0.13%), manganese (14–236 mg/kg), phosphorus (0.003–0.052%), strontium (2–15 mg/kg) and vanadium (3–12 mg/kg) in ranges close to the geochemical background level of the region. The concentrations of cadmium, lead and zinc in the sediments are varied. Maximum levels of cadmium (14 mg/kg) and lead (551 mg/kg) were determined in a sediment sample from the Stawiki pond. Fine-grained sediments rich in organic matter in Morawa Pond (in its north-eastern part) are characterized by significant concentrations of most of the elements studied, including 54 mg/kg arsenic, 226 mg/kg barium, 7.1 mg/kg cadmium, 43 mg/kg chromium, 121 mg/kg copper, 2.27% iron, 38 mg/kg nickel, 280 mg/kg titanium, 41 mg/kg vanadium, and 1,652 mg/kg zinc.

Some of the aquatic sediment samples from the catchment area are characterized by higher contents of the elements analysed relative to the PEC values. The highest number of samples for which this indicator was exceeded was found for cadmium (65%), lead (73%) and zinc (75%). For nickel, arsenic and copper, the percentage of samples with exceedances is lower: 14, 19 and 22%, respectively. Chromium and mercury concentrations were higher than the PEC threshold values for these metals only in a few sediment samples.

The south-western and southern parts of the map sheet belong to the **Rawa Stream catchment** basin. In this area, the Rawa Stream flows in a regulated, concreted and embanked channel. In the area of Katowice (Śródmieście quarter), its significant section is encased. The Rawa Stream receives treated effluents from the Klimzowiec Wastewater Treatment Plant in Chorzów (outside the western boundary of the map sheet) and from the Gigablok WWTP in Katowice. The median contents of the chemical elements analysed in the aquatic sediments of this catchment area exceed to varying degrees the values defined as the geochemical background level of the Silesian-Cracow region, with the exception of phosphorus. The median concentrations of calcium, cobalt, chromium, iron, magnesium, manganese, nickel, strontium and vanadium are about twice the background levels, of mercury and titanium are three times the background levels, and of arsenic and sulphur are about four times the background levels. The median concentrations of cadmium and lead exceed the geochemical background levels by about five times, of zinc by six times, and of copper by as much as seven times (Tab. 4; Lis, Pasieczna, 1995b).

Significant concentrations of arsenic and metals are observed in most of the samples taken downstream of the Gigablok Wastewater Treatment Plant from sediments of the Rawa Stream. Up to 53 mg/kg arsenic, 7 mg/kg silver, 25.9 mg/kg cadmium, 197 mg/kg copper, 10.44% iron, 2,787 mg/kg manganese, 133 mg/kg nickel, 792 mg/kg lead and 2,468 mg/kg zinc have been measured there. Alluvial deposits of the Rawa Stream also distinguished by high levels of mercury (0.94–3.54 mg/kg) and chromium (85–207 mg/kg).

At the eastern boundary of the area, in the valley of the Brynica River and Rawa Stream, in the vicinity of the former non-ferrous metal smelters, there are water reservoirs of anthropogenic origin: Hubertus I, II, III and IV. These ponds were created as a result of sand exploitation for coal mining. Aquatic sediments of these water bodies are characterized by varying chemical composition. Maximum levels of silver (3 mg/kg), arsenic (137 mg/kg), cadmium (65.7 mg/kg) and lead (1,524 mg/kg) were found in a sediment sample taken from Hubertus I Pond. In this pond, significant concentrations of aluminium (up to 1.61%) and titanium (up to 546 mg/kg) were also determined. Maximum levels of chromium (89 mg/kg), copper (734 mg/kg), iron (10.65%), magnesium (1.20%), vanadium (59 mg/kg) and zinc (7,114 mg/kg) were observed in Hubertus II Pond. The aquatic sediment sample taken from Hubertus IV Pond stands out by the highest concentrations of barium (360 mg/kg), cobalt (70 mg/kg), mercury (0.37 mg/kg), manganese (9,524 mg/kg) and nickel (82 mg/kg). In addition, the water body contains calcium up to 15.52%, sulphur up to 5.453%, and strontium up to 814 mg/kg.

High concentrations of arsenic and metals are found in sediment samples taken from the Łąka reservoir (near the southern boundary of the map sheet). The maximum elemental concentrations in the water body were as follows: 638 mg/kg of arsenic, 14 mg/kg of silver, 70.2 mg/kg of cadmium, 1,212 mg/kg of copper, 7.85 mg/kg of mercury, 7,394 mg/kg of lead, and 25,912 mg/kg of zinc.

Analysis of the results shows that the largest number of samples exceeding the PEC threshold was for cadmium (72%), lead (76%) and zinc (79%). For mercury, nickel, arsenic and copper, the percentage of samples with exceedances is lower: 26, 32, 36 and 40%, respectively. Chromium concentrations were above the PEC threshold only in several sediment samples.

In the south-western part of the map sheet, there is a small sector of the **Bolina Stream catchment** area. The concentrations of arsenic, cadmium, cobalt, chromium, copper, iron, mercury, magnesium, nickel, lead, sulphur, strontium, titanium, vanadium and zinc in the catchment's sediments are above their geochemical background values in the Silesian-Cracow region. In the case of barium, calcium, manganese and phosphorus, higher concentrations than their background levels (Lis, Pasieczna, 1995b) are recorded mainly in samples collected from the anthropogenically heavily modified Bolina Stream. Sediments of this watercourse are characterized in the section studied by the chromium concentrations ranging from 106 to 537 mg/kg and the copper concentrations ranging from 595 to 1,817 mg/kg. There are also significant concentrations of cadmium (10.3-19.5 mg/kg), nickel (51–83 mg/kg), lead (246–537 mg/kg), zinc (2,021–3,276 mg/kg) and mercury (0.92–1.39 mg/kg). Exceedances of the PEC threshold in sediments of the catchment area were recorded for arsenic, cadmium, chromium, copper, nickel, mercury, lead and zinc. However, concentrations above the PEC value for chromium, nickel and mercury were found mainly in alluvial deposits of the Bolina Stream, and for arsenic in a reed-covered reservoir.

SURFACE WATERS

The studies of surface waters were preformed to assess the contents of selected chemical components, specific electrolytic conductivity, and pH. In order to compare and facilitate the assessment of the quality of the waters, the content ranges for individual components in the study area and the results of calculations of statistical parameters are presented in Table 5. It also includes the limit values of water quality indicators from the group of specific synthetic and non-synthetic contaminants, and the environmental quality standards for chemical condition indicators of Surface Water Bodies (Rozporządzenie..., 2021).

Catchment of the Brynica River from the Wielonka Stream to the Rawa Stream. The pH of the waters of the catchment area varies between 6.71 and 9.99 and the specific electrolytic conductivity is between 0.15 and 15.02 mS/cm. What is striking are the EC values between 10.52 and 15.05 mS/cm that were measured in the open rainwater reservoirs located, among others, near the Czeladź logistics centre. High antimony concentrations (2.63–14.91 µg/dm^3) were also found at these locations.

The concentrations of silver, aluminium, arsenic, boron, barium, beryllium, cobalt, chromium, molybdenum, selenium, titanium, thallium and vanadium in the catchment waters are below the limits set for surface water quality classes I and II for indicators from the group of specific contaminants (Rozporządzenie..., 2021; Tab. 5). As for copper and zinc, higher concentrations are observed only in a few cases (62.32 µg/dm^3 and 2.627 mg/dm^3, respectively). Antimony concentrations in excess of the limit are recorded in about 18% of the samples, a significant proportion of which come from Morawa Pond and the Rów Śmiłowski ditch. Taking into account the environmental quality standards for chemical status indicators, the permissible concentrations of lead are not exceeded in the samples analysed. Concentrations of nickel and cadmium exceed the normative values in only a few samples, reaching maximum values of 294.6 µg/dm^3 and 9.02 µg/dm^3, respectively. The highest nickel concentrations were found in a water sample taken from a canal in Czeladź, which drains the workings of coal mines that are no longer in operation. High concentrations of copper (62.32 µg/dm^3) and cadmium (0.72 µg/dm^3) were also determined at this location. The maximum concentration of cadmium was found in a water sample from the Rów Śmiłowski ditch, upstream of its confluence with the Brynica River. In this sample, 0.287 mg/dm^3 of barium, 7.58 µg/dm^3 of cobalt, 2.58 µg/dm^3 of antimony, and 2.627 mg/dm^3 of zinc were also measured.

The Brynica River water is characterized by a specific electrolytic conductivity value ranging from 1.16 to 2.57 mS/cm. The elevated EC value (>1 mS/cm) is mainly due to the concentrations of sodium (73.8–238.8 mg/dm^3), calcium (130.1–174.7 mg/dm^3), magnesium (50.1–76.4 mg/dm^3) and sulphate (328–504 mg/dm^3). Levels of arsenic and metals are relatively low in the water. The concentrations of copper and lead do not exceed 4.82 µg/dm^3 and 1.32 µg/dm^3, respectively. The cadmium and chromium levels are generally below the limit of quantification. Elevated concentrations of nickel (up to 54.3–78.7 µg/dm^3) and antimony (2.36–3.68 µg/dm^3) were recorded in several samples downstream of the wastewater treatment plant. The concentrations of some of the constituents in the Brynica River water depend also on their levels in its tributaries. This is most evident in the case of sodium, the source of which is the water flowing from the Rów Michałkowicki ditch. Upstream and downstream of the confluence with the ditch, the sodium concentrations in the Brynica River water are 73.8–77.6 mg/dm^3 and 96.2–238.8 mg/dm^3, respectively. The Rów Michałkowicki ditch receives mine waters from the former KWK "Siemianowice" mine. Downstream of the discharge point, concentrations of boron (0.36–0.60 mg/dm^3), lithium (62.7–84.4 µg/dm^3), magnesium (25.9–104.4 mg/dm^3), sulphate (137–661 mg/dm^3) and strontium (0.337–1.020 mg/dm^3) increase in the watercourse.

The pH of the water in Stawiki, Borki and Morawa ponds ranges from 8.07 to 8.97, and the specific electrolytic conductivity from 0.41 to 0.99 mS/cm. It contains relatively low concentrations of the constituents tested, including metals that are potentially toxic to living organisms. The concentrations of the analysed elements do not exceed the normative values (Rozporządzenie..., 2021). The exception is antimony, whose higher concentrations (2.99–3.82 µg/dm^3) were found in most samples from Morawa Pond.

Catchment of the Rawa Stream. The pH of the catchment waters varies within a wide range of 4.94–8.91, and the specific electrolytic conductivity within a range of 0.18–2.55 mS/cm. Thy are characterized by lower concentrations of most of the elements in relation to the limits defined for surface water quality classes I and II (Rozporządzenie..., 2021; Tab. 5). Antimony concentrations above the limit values are found in about 30% of the samples, a significant proportion of which come from Hubertus I, II and III ponds. Taking into account the environmental quality standards for chemical status indicators, the permissible concentrations of nickel and lead are not exceeded in the samples analysed in the catchment area. Cadmium concentrations above the normative values (max. 1.27 µg/dm^3) were found in several samples mainly from the Rawa Stream. They are clearly evident in the waters of the industrial area near Roździeń in Katowice. The samples also show elevated concentrations of thallium and selenium compared to the average in the catchment area.

Water samples taken from Hubertus I, II, III and IV ponds are characterized by the pH values varying over a wide range from 4.94 to 8.91, and the EC values ranging from 0.44 to 1.57 mS/cm. Water with EC values above 1 mS/cm is found in Hubertus I Pond. The water body also has significant levels of calcium (68.5–69.1 mg/dm^3), potassium (15.9–16,1 mg/dm^3), magnesium (43.3–44.0 mg/dm^3), sodium (141.3–144.4 mg/dm^3), sulphate (148–149 mg/dm^3), antimony (6.33–6.94 µg/dm^3) and uranium (1.44–1.73 µg /dm^3). Concentrations of most of the elements analysed do not exceed the normative values (Rozporządzenie..., 2021). The exception is antimony, whose concentrations above 2 µg/dm^3 classify the water quality of Hubertus I, II, and III ponds as substandard. The significant sources of antimony are emissions from the copper ore processing industry and the combustion of some coals and municipal waste (Kabata-Pendias, Pendias, 1999; Jabłońska-Czapla, 2014).

Catchment of the Bolina Stream. The pH of the catchment waters varies between 7.49 and 9.05, and the specific electrolytic conductivity ranges between 0.29 and 30.90 mS/cm. What is striking are the EC values measured in the Bolina Stream waters, ranging from 27.20 to 30.90 mS/cm, and the high concentrations of elements characteristic of mine waters. The following values were recorded: 0.922–1.075 mg/dm^3 for barium, 81.3–89.9 mg/dm^3 for potassium, 322.1–355.7 mg/dm^3 for magnesium, 4,223.5–4,948.7 mg/dm^3 for sodium, 645.9–744.1 µg/dm^3 for lithium, 13.563–15.802 mg/dm^3 for strontium, and 431–466 mg/dm^3 for sulphate. The Bolina Stream waters also show significant concentrations of calcium (459.5–523.8 mg/dm^3), aluminium (12.9–24.8 µg/dm^3) and selenium (135–153 µg/dm^3).

SUMMARY AND CONCLUSIONS

1. In the study area, the main anthropogenic sources of contamination of the natural environment are mining, ferrous and non-ferrous metallurgy, deposition of mining and processing wastes in spoil tips and dumpsites of large areas, urbanization (e.g. residential, industrial and commercial development), and transport infrastructure.
2. The median contents of the elements analysed in the topsoil layer are higher than the geochemical background values for the Silesian-Cracow region. The only exception is mercury. The elements with the highest exceedance of the background levels are cadmium, copper, lead and zinc.
3. The prevalence of alkaline soils is observed at both depth ranges (topsoil and subsoil). Very acidic to acidic soils are found in small areas predominantly in the north-western forested part of the map sheet area.
4. Numerous geochemical anomalies of silver, arsenic, cadmium, chromium, copper, iron, mercury, nickel, lead and zinc in the soils are observed in the areas of historical and contemporary metal smelters, as well as in the surroundings of reclaimed and partially demolished spoil tips and dumps.
5. The relationship between the chemical composition of the bedrock and the soils is evident only in the outcrops of Triassic carbonates, where soils rich in calcium, magnesium, iron, manganese, cadmium and zinc are found.
6. Exceedances of the PEC threshold for arsenic, cadmium, lead, zinc, nickel, copper and chromium were found in aquatic sediments of all catchment areas in the map sheet.
7. Surface waters are characterized by variability in terms of chemical element content, pH, and specific electrolytic conductivity. They are mainly neutral and alkaline in pH. High EC values (>1 mS/cm) are found in the waters of the Bolina Stream, the Brynica River and its tributaries, and some water reservoirs. The water quality status is influenced mainly by discharges of municipal and industrial wastewater, surface runoff of rainwater from industrial and communication areas, and mine water discharges.

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