Detailed geochemical map of Upper Silesia

1:25 000

Sheet **WOJKOWICE**

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Cover photo: Sheave wheel from the Andaluzja Mine next to the building of the Town Hall in Wojkowice (Fot. Angelika Szczypczyk)

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

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INTRODUCTION

The detailed geochemical map, scale 1:25,000, sheet Wojkowice M-34-51-C-c, is a continuation of mapping works initiated in 1996–1999 with the development of the pilot sheet Sławków M-34-63-B-b of the Detailed Geochemical Map of Upper Silesia (Lis, Pasieczna, 1999). By 2021, 21 sheets were compiled and published in the form of geochemical atlases. The works were 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 situated in the central part of the Silesian Voivodeship. It covers mostly the będziński district (poviat) area. The south-western part belongs to the cities of Siemianowice Śląskie and Piekary Śląskie. The main factor affecting the condition of natural environment is the geological structure including occurrence of hard coal and zinc-lead ore deposits. The area was dominated by the mining of raw materials for energy (hard coal), metals (zinc-lead ores) and construction industry (limestone, dolomites, and filling sands). Termination of mining activities has resulted in the formation of post-industrial areas in the surrounding landscape. Areas of anthropogenic transformations are located mainly in the southern, western and north-western parts of the map sheet.

The study area also shows natural values. In Wojkowice is a municipal park that functions as a large recreational complex. In Będzin and Siemianowice Śląskie, protected landscape areas – Wzgórze Doroty hill, Lasek Grodziecki wood, and Przełajka – are located. There is also the Brynicka Terasa ecological site in Siemianowice Śląskie. Monuments of animated nature are also located within the map sheet boundaries; these are mainly numerous trees (source: https://geoserwis.gdos.gov.pl/mapy/ [access: 31.12.2024]).

The results of the geochemical studies, presented in cartographic form and 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 condition of the environment), 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, aquatic sediments and waters can also be used to prepare various reports and assessments presenting the condition of the environment.

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:

- **A. Pasieczna** – project's concept and design;
- **A. Konon** – supervision and coordination;
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CHARACTERISTICS OF THE MAP SHEET AREA

Geographical and administrative location. According to the physico-geographical division, the entire Wojkowice map sheet area is located in the Silesian Upland within the lower-order units of Tarnowskie Góry Hummock and Katowice Upland (Richling *et al.*, 2021). It includes parts of the Dąbrowa Coal Basin and Upper Silesia that both form the Upper Silesian-Dąbrowa Metropolitan Area (Rozporządzenie..., 2017). A significant part of the study area is located in the będziński district. It includes the cities of Będzin (Grodziec quarter), Czeladź and Wojkowice, as well as the municipalities of Bobrowniki and Psary. The south-western part of the study area is occupied by parts of towns with poviat rights: Piekary Śląskie (Dąbrówka Wielka quarter) and Siemianowice Śląskie (Przełajka quarter).

Surface relief, geomorphology and hydrography. The surface relief of the area is varied and in places strongly transformed by human activity. The bedrock is represented by coal-bearing Carboniferous rocks, whose outcrops occur in the eastern part of the map sheet. Exposed Triassic formations occupy a large part of the area (Plate 1). Quaternary sediments occur in terrain depressions (Wilanowski, Żaba, 2016). The north-eastern part of the map sheet, included in the Tarnowskie Góry Hummock, is occupied by hills rising to 395 m a.s.l. The highest elevated point is Góra Siewierska hill. The remaining, predominant part of the study area belongs to the Katowice Upland. The hilly terrain rises to a maximum elevation of 382 m a.s.l. (Góra Świętej Doroty Mt. in Będzin). The lowest elevated regions (about 259 m a.s.l.) are located in the Brynica River valley at the point where the river leaves the map sheet area. The natural relief has been partly transformed by pits and dumps left over from many years of raw material extraction. Uplands in the map sheet are crossed by the Jaworznik, Brynica and Wielonka valleys (Richling *et al.*, 2021).

The study area belongs to the Vistula River basin. Its predominant part lies within the 4th order catchment of the Brynica River. The eastern margin of the map sheet belongs to the 4th order catchment of the Czarna Przemsza River from the Przeczyce reservoir dam to the Brynica River. The hydrographic network consists mainly of the Brynica River and its tributaries: Wielonka and Jaworznik streams. The Wielonka's headwaters are located within the map sheet area (Uchwała, 2021a) in the Strzyżowice region (Studium, 2021), and the headwaters of the Jaworznik are occur beyond its northern boundary near Twardowice and "Srocza Góra" in the municipality of Psary (Uchwała, 2021a, b). In the Wojkowice municipality (at the border with the municipality of Psary, near Strzyżowice), the Wielonka is fed by a small right-bank tributary locally known as the Graniczny stream (Uchwała, 2021b). The hydrographic network consists also of surface water bodies of anthropogenic origin (*e.g.*: in the Bobrowniki and Wojkowice municipalities, of small areas, located in the Wielonka valley, in the Żychcice quarry, and near the border with Psary), as well as smaller watercourses and ditches draining agricultural and forest areas (Piotrkiewicz, Wojciechowska, 2016; Uchwała, 2021b). Swamps are locally present as well.

In the northern part of the map sheet, there are water bodies located in the former workings of the Siemonia sand mine. They were created in several stages. In 1959–1961, the Jaworznik mining field was rehabilitated for forestry, which is now the Rogoźnik III reservoir (1 ha in area) and its surroundings. Between 1961 and 1976, the area of the present-day Rogoźnik II reservoir was rehabilitated, and the waters of the Jaworznik stream were diverted into a newly prepared post-mining basin. In 1969–1972, the Rogoźnik I reservoir was built. Since the 1970s, Rogoźnik I and II (under the name Rogoźnik Lake) have performed recreational functions. During the highest water level, the areas of these reservoirs are 25 ha (Rogoźnik II) and 13 ha (Rogoźnik I), respectively (Woźnica *et al.*, 2018).

Land development and land use. The housing type and land use varies between different parts of the study area. Low-rise single-family housing predominates in the north. Urban development, which occupies about 20% of the map sheet, occurs in Wojkowice, Piekary Śląskie, Siemianowice Śląskie and Będzin. Industrial and post-industrial facilities are located in the southern part of the study area. Scattered forests (19% of the map sheet) are owned by State Forests and managed by the Świerklaniec and Katowice forest districts. Agricultural areas predominate in the north and south, whereas wasteland in the centre and west. Agricultural areas (arable fields and meadows) cover about 30% and wasteland about 37% of the map sheet area (Plates 2–3). The Wojkowice sheet is crossed by the A1 motorway, connecting southern Poland with the Tricity, and by the provincial road 913 from Gródków to the Pyrzowice airport.

Economy. The map sheet area is located in the north-eastern part of the Upper Silesian Coal Basin. Of key importance for the economic development of this region was industrial activity of the mining sector, including hard coal mining. The region of Psary, Strzyżowice and Gródków is considered to be its cradle. It is also referred to as the Strzyżowicki (or Strzyżowski or Psarski) Basin that continues beyond the eastern boundary of the map sheet towards Malinowice and Sarnowo (Ciepiela, 2016b).

Over many years, six coal mines operated in Psary. Because of the lack of archival materials about one of them, the "Hoym" (later "Lubecki" and "Tadeusz") mine, which was opened in 1797, is formally considered the oldest. This mine ceased operations in 1862, when exploitation was halted due to high groundwater inflow rate (Ciepiela, 2016c). Hard coal was also mined at the "Barbara" mine, which was originally named "Maria" (1874–1882), at "Tadeusz I" (1919–1924), "Psary" (1920–1921) and "Rudokoks" (1928–1930) (Ciepiela, 2016c). In Strzyżowice, hard coal was exploited for almost 100 years in five mines: "Strzyżowic" (1833–1922), "Andrzej II" (1833–1922), "Teodor" (1878–1884), "Jan II" (1901–1902) and an unnamed mine also referred to as "Private" (1885–?) (Ciepiela, 2016b; Ciepiela, Trzcionka, 2017). The "Wanda" mine (1910–1924) operated in Gródków (Ciepiela, 2016b).

In the south-eastern part of the map sheet, in Grodziec (which is now a quarter of Będzin), there were four coal mines. The first one, "Barbara", was opened in 1823 and operated until 1893. Initially, it extracted hard coal using the open-cast method, and then the seams were accessed via shallow shafts and adits (Ciepiela, 2016a). It supplied, among others, the zinc smelter built in 1845 in Grodziec near the road to Łagisza and closed several years later (source: http://ceko.com.pl/s_bedzin_grodziec.php [access: 07.02.20204]). Another mine was "Maria", opened in 1894, often called "Grodziec I". In 1899, the "Grodziec II" mine was opened and commonly referred to as "Grodziec Towarzystwo", and from 1938 (after the liquidation of "Grodziec I") known as "Grodziec". The mine operated until 1998 (Ciepiela, 2006). A shallow mine called "Bory" also functioned in this area between 1917 and 1926 (Jaros, 1984).

In Wojkowice, the "Jowisz" mine (called "Jupiter" during the German occupation) was opened in 1910 and extracted coal until 2000 with short interruptions. From 1997, it operated under the name Zakład Górniczy "Wojkowice", which was established as a new organizational and capital structure on the basis of the assets of the KWK "Jowisz" mine (source: https://www.wojkowice.pl/miasto/dzieje_przemyslu [access: 22.01.2024]). Depleted mine workings of KWK "Jowisz" were filled with, i.a., sand from the "Siemonia" mine. The mine was located in Rogoźnik (Bobrowniki municipality) and operated from the mid-1920s to the late 1950s, supplying aggregates for backfilling purposes. After depletion of the resources, the mine site was rehabilitated to create, i.a., a cascade of artificial reservoirs (Machowski, Rzętała, 2023). In addition to the KWK Jowisz, hard coal was exploited for four years (1918–1922) in Wojkowice in the "Aleksandra" mine located on mining fields leased from Towarzystwo Saturn (the Saturn Society) (Jaros, 1984).

In addition to hard coal, the south-western part of the map sheet was also an area of intensive mining of zinc and lead ores, which was most intense at the turn of the 19th and 20th centuries. Evidence of this activity includes the Przełajka shafts in Siemianowice Śląskie (Durka-Kamińska, 2020). The Kacper mine, located in the western part of Wojkowice, was in operation between 1824 and 1825, but ore was also mined in the area extending to the east of Krzyżówka, where the sports stadium is now located, and in the area of the so-called "Drożdżowizna" between the two bridges of the railway from Brzeziny to Ząbkowice and the bridge leading to the "Jowisz" mine, which is currently decommissioned, but at that time did not exist yet (source: https://www.wojkowice.pl/miasto/dzieje_przemyslu [access: 22.01.2024]). In Dąbrówka Wielka (part of Piekary Śląskie), the "Rozalia" zinc mine was opened in 1855. Due to mine drainage problems preventing mining activities, it was finally decided in 1893 to convert the mine infrastructure into a water intake (sources: https://wodociagi.eu/baza-wiedzy/wodociagi-woj-slaskiego-rewolucja-przemyslowa [access: 30.01.2024]). From 1968 to 1989, zinc and lead ores were extracted in Dąbrówka Wielka in the "Dąbrówka" mine, which was part of the "Orzeł Biały" Mining and Smelting Combine (in Polish: Kombinat Górniczo--Hutniczy "Orzeł Biały") (Majorczyk, 1985).

Another key economic sector of mining activities in the map sheet area was the cement industry that used Triassic limestones and marls. The "Grodziec" cement plant (Cementownia Grodziec), which was in operation since 1857, was first supplied with raw material from the quarry in Grodziec, located in its vicinity and active since the beginning of the plant's existence, and then (from 1949) from the Rogoźnik quarry (Górecka, 1962). The cement plant ceased its activity in 1979 as a result of ground subsidence caused by the exploitation of the protective pillar of the Grodziec coal deposit (Wierzchoń, 2015). In 2021, the complex of buildings of the "Grodziec" cement plant, together with the traditional name "Cementownia Grodziec", was entered in the register of monuments (Gminny program...). In turn, limestone raw material for the "Saturn" cement plant (Cementownia "Saturn") located in Wojkowice was derived from open pits in Gawczyce and Żychcice (Górecka, 1962; Jochemczyk, 2004). The cement plant was in operation since 1930, but between 1972 and 1973 it was a single multi-plant enterprise together with the Grodziec cement plant. Since 1974, the plant was part of the Silesian Cement and Limestone Combine (Śląski Kombinat Cementowo-Wapienniczy) in Rudniki and Ogrodzieniec. The plant became independent again in 1982 and ceased producing cement clinker in 1991. In 2000, the Wojkowice cement plant was sold to the German company Dyckerhoff (source: https://www.wojkowice.pl/miasto/dzieje_przemyslu [access: 22.01.2024]).

The engineering industry was also important for the economy of the study area beginning from 1924, when Wytwórnia Wyrobów Żelaznych Stefana Unierzyskiego (Stefan Unierzyski iron factory) was established in Wojkowice. This enterprise, nationalized in 1948, became part of a Silesian company for mechanization of the construction industry (Śląskie Zakłady Mechanizacji Budownictwa) as Plant No. 2 (Zakład nr 2). In 1998, was transformed into the ZREMB Wojkowice company as a result of privatization. Eventually, the company was purchased by Profil NR, a manufacturer of steel profiles and pipes and reinforcements for PVC windows and doors, which is in operation to date (https://www.wojkowice.pl/miasto/dzieje_przemyslu [access: 22.01.2024]; Orzeczenie...).

In the course of economic and environmental changes, the share of entities of the mining and mineral processing sector in the map sheet area has been significantly reduced. Today, the economic structure is dominated by companies from the trade and services sector.

GEOLOGICAL STRUCTURE AND MINERAL DEPOSITS

The Wojkowice map sheet area is situated in the northern part of the Upper Silesian Coal Basin (USCB), mostly within the structural unit called the Bytom Trough. It is included in the Paleozoic Variscan structure, cut by numerous faults, with a very well explored geological structure because of numerous boreholes and mining works. The succession consists of Carboniferous, Permian, Triassic, Paleogene–Neogene and Quaternary formations (Buła, Kotas, 1994).

The oldest deposits in the map sheet area are Lower Carboniferous (Visean) rocks included in the Malinowice Beds, also referred to as the Culm facies. These are clastic terrigenous, non-coal deposits accumulated in marine environments, containing numerous horizons containing marine fossils. They consist mainly of claystones and mudstones with interbeds of fine-grained sandstones. The Culm deposits occur throughout the map sheet and are approximately 800 m thick. They are not exposed on the surface (Biernat, 1955; updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

The Culm deposits are overlain by Upper Carboniferous coal-bearing rocks found at depths of approximately 200 to 800 m a.s.l. They comprise a thick complex of claystones, mudstones and sandstones included in the Paralic Series (Namurian A) and in the Upper Silesian Sandstone Series (Namurian B and C) (Jureczka *et al.*, 2005).

The Paralic Series is composed of fine- to medium-grained sandstones and claystones-mudstones interbedded with coal seams and layers, coal-shales, and occasional sapropelic shales. These deposits accumulated in terrestrial and nearshore environments, with periodic marine inundations, which is confirmed by the presence of faunal fossils of marine species in the section; there are also numerous intercalations containing freshwater species. A characteristic feature of the series is its sedimentary cyclicity. Its basal surface coincides with the top of the so-called Štur marine horizon (XVI), characterized by abundant marine faunal fossils in clastic rocks, while its top surface – with the base of the coal seam 510 (Wilanowski, Żaba, 2016). Deposits of the Paralic Series form extensive, dismembered outcrops in the eastern part of the map sheet between Strzyżowice, Grodziec and Psary. Minor outcrops occur also in the north-western part of the map sheet, near Rogoźnik and Dobieszowice (Biernat, 1955; reambulacja Wilanowski, Żaba, 2010). Between the outcrops, the Paralic Series is covered by thin (about 5–15 m) Quaternary sediments, in the south-western part by the Upper Silesian Sandstone Series, and in the southern and north-eastern parts by Triassic rocks. The greatest thickness of the Paralic Series (about 500 m) is found in the south-western part of the map sheet; it thins north-eastwards wedging out completely in the Brzękowice region (Jureczka *et al.*, 2005).

The Upper Silesian Sandstone Series is composed of sandstones, conglomerates, mudstones and claystones with coal seams. In the map sheet area, it consists of two lithostratigraphic units – the Saddle Beds and the Ruda Beds, which overlie unconformably (stratigraphic gap) the Paralic Series (Kotas, Malczyk, 1972). The base of the Upper Silesian Sandstone Series coincides with the base of the first coal seam of the Saddle Beds, which is the coal seam 510. They represent limnic and deltaic environments. The top of the deposits is marked by the last horizon with freshwater fauna, accompanying coal seams 407 and 408, which is one of the most important correlative levels in the USCB (Dybová, Jachowicz, 1957). This series, attaining a thickness of 250–300 m, underlies Triassic deposits in the south-western part of the map sheet area, filling the Bytom Trough in the Wojkowice region (Jureczka *et al.*, 2005). It is dominated by grey fine- to medium-grained sandstones, with a smaller proportion of coarse-grained sandstones and subordinate conglomerates. Interbeds of claystones and mudstones are usually up to several metres thick. A characteristic feature is the fairly widespread occurrence of relatively thick (about 2–4 m, in places exceeding 10 m) coal seams, which locally may merge or are separated by thin beds of carbonaceous shales (Wilanowski, Żaba, 2016).

Permian deposits are represented by sandstones, conglomerates, claystones and mudstones of the Bolesław Formation, stratigraphically included in the Zechstein (Kiersnowski, 1991). They are dominated by red clays with green patches, subordinately by conglomeratic sandstones and conglomerates at the top, and red-green conglomerates composed of clasts of various rock types, with sparse interbeds of sandstones, mudstones and claystones. The Permian rocks are covered by Triassic deposits. In the map sheet area, the Permian is found in the Sławków Graben, which is called here the Podwarpie Trough, trending ESE–WNW in the extreme north-east of the map sheet. These deposits have been drilled at Podwarpie (*ca.* 7.5 km north-east of the map sheet boundary) at a depth of 139–608 m (Wilanowski, Żaba, 2016).

The Triassic deposits overlie the Lower and Upper Carboniferous or Permian succession over most of the sheet area, forming extensive, highly dismembered outcrops. Their thickness is variable, constrained by both tectonics and surface relief of the top of the Carboniferous succession. Their thickness is mostly 70–80 m, but in the north-eastern and south-western parts of the map sheet it can be up to about 150 m (Wilanowski, Żaba, 2016).

The Lower Triassic (Scythian, spanning the Induan and Olenekian stages) Świerklaniec Beds erosionally overlie Upper Carboniferous rocks. These are terrestrial deposits showing a characteristic red colour, included in the Lower and Middle Buntsandstein. They are represented by sands, clays, sandstones and subordinate conglomerates, passing at the top into mudstones and claystones. Over most of the study area, the Świerklaniec Beds underlie Middle Triassic carbonates. Their minor outcrops, locally covered by a thin Quaternary succession, are found mostly at the foothills in the surroundings of Dobieszowice, Rogoźnik, Góra Siewierska and Grodziec (Biernat, 1955; updated by Wilanowski, Żaba, 2010). The thickness of the Świerklaniec Beds is generally *ca.* 20 m, but locally, along the axes of then-existing valleys, it often exceeds 30 m (Wilanowski, Żaba, 2016).

The terrigenous Świerklaniec Beds are unconformably overlain by Middle Triassic (Anisian) rocks, previously referred to as Röt deposits (Wagner, 2008), represented by marly dolomitic facies with subordinate limestones. These are largely thickly bedded dolomitic limestones, marly dolomites, dolomitic and sandy marls, and occasional cavernous limestones. Their outcrops compose the slopes and ridges of hills almost throughout the sheet area, except in its south-western part. The thickness of these rocks is variable and ranges from 40 to 60 m (Wilanowski, Żaba, 2016). The stratigraphic position of the deposits has been under discussion. According to the proposal of Kotlicki (1995), this succession should be given the name Lędziny Formation and included in the Upper Buntsandstein (Röt).

These rocks are overlain by limestones referred to as the Gogolin Beds. They compose most of the slopes and hilltops in the surroundings of Gołąsza Górna, Góra Siewierska, Rogoźnik and Wojkowice (Biernat, 1955; updated by Wilanowski, Żaba, 2010). In the lower part of the Gogolin Beds, platy limestones clearly predominate, while the upper part is dominated by wavy limestones, mostly silty and marly, locally with conglomerates and laminated marly dolomites containing crinoids. The thickness of the Gogolin Beds ranges from 35 to 60 m (Wilanowski, Żaba, 2016).

The Gogolin Beds are overlain by an approximately 20–40 m thick (even 60 m in the area of Piekary Śląskie) succession of ore-bearing dolomites. These are epigenetic rocks that formed as a result of hydrothermal alteration (metasomatosis) of limestones, mainly of the Górażdże Beds, as well as of the Terebratula and Karchowice beds. The succession is represented by dolomites commonly forming nests, less frequently by limestones. The dolomites are mostly medium-layered, grey and yellow-grey, and variably crystalline. They are characterized by dense fracturing, mainly vertical, and the presence of irregular caverns, many filled with lead, zinc and iron minerals (galena, sphalerite, wurtzite, pyrite, markasite). Zinc and lead sulphide mineralization is particularly abundant near the base of the complex. On the outcrops of ore-bearing dolomites, metal sulphides are oxidized and concentrate in calamines and in nests of iron ore (limonites). The vertical distribution of the deposits is highly variable. The area of ore-bearing dolomites has been mined since the early 16th century. Their minor outcrops occur in the south-western part of the study area (Biernat, 1955; updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

The limestones and marls (Górażdże Beds, Terebratula Beds and Karchowice Beds) have been almost completely dolomitized. The ore-bearing dolomite complex locally contains sporadic undolomitized or not fully dolomitized layers of primary limestones. These beds may have originally been about 50 m in thickness, but in the preserved portions they are much thinner, 10.0–30.0 m. These deposits do not occur on the ground surface in the map sheet area (Wilanowski, Żaba, 2016).

Upper in the section, the Middle Triassic (Anisian) successsion is represented by Diplopora dolomites of the Jemielnice Beds and dolomites of the Tarnowice Beds. The Diplopora dolomites occur in the southern part of the map sheet and are exposed on the surface in the Grodziec and Piekary Śląskie regions (Biernat, 1955; updated by Wilanowski, Żaba, 2010). Their lower part is represented by yellow and grey-yellow, medium- to thick-bedded, finely crystalline dolomites containing sparse fragments of crinoids. These are overlain by thinly bedded marly dolomites with horizontal and wavy lamination, containing fossils of diverse, indeterminate fauna and flora. Manganese and limonite dendrites are common, and some fissures and minor caverns are filled with calcite crystals. The Diplopora Beds reach about 35 m in thickness (Wilanowski, Żaba, 2016).

The Tarnów Beds dolomites occur on the surface or under a thin cover of Quaternary sediments only in the vicinity of Grodziec and Dąbrówka Wielka, where they form the slopes and tops of hills rising to an elevation of 300–316 m a.s.l. (Biernat, 1955; updated by Wilanowski, Żaba, 2010). These are light grey marly dolomites, almost lacking of fossils, followed upwards by light grey-yellow marly limestones, locally with interbeds of conglomeratic limestones, attaining a total thickness of 10 m (Wilanowski, Żaba, 2016).

The **Paleogene**–**Neogene** deposits are represented mainly by clays, silts, clays and sands that occur at the surface or under a thin cover of Quaternary sediments. Minor outcrops are found in the vicinity of Wojkowice in the central-western part of the map sheet (Biernat, 1955; updated by Wilanowski, Żaba, 2010). These deposits accumulated predominantly in karst funnels and sinkholes that developed at the top of Triassic carbonates, especially in the outcrop zones of the Gogolin limestones and ore-bearing dolomites. Locally, there are also silty loams ochre in colour, and white fine-grained sands, as well as celadon-grey muds with variable admixtures of quartz gravels (Wilanowski, Żaba, 2016). These deposits were previously included in the Lower Jurassic. Studies of karst regoliths in the Silesian Upland indicate their Oligocene–Miocene age. They are usually several metres thick (Lewandowski, Ciesielczuk, 1997).

Quaternary sediments cover about 35% of the map sheet area, and their thickness is commonly up to several metres, attaining about 30 m in the fossil valleys. The lithology is dependent on the relief of sub-Quaternary bedrock. Over most of the study area, the sediments overlie Middle Triassic rocks. In the southern part, they rest upon Carboniferous deposits of the Paralic Series, Upper Silesian Sandstone Series, and locally upon Oligocene–Miocene deposits (Wilanowski, Żaba, 2016).

The South Polish Glaciation sediments are represented by glacial tills that occur in valley depressions, where they partly cover clays and muds of glacial lakes, and in the lower parts of the slopes, where they lie directly on the older bedrock. These sediments are predominantly grey, locally brown, silty and slightly clayey, or they contain clay clasts. On the surface, the tills occur mainly in the south-eastern and north-western parts of the map sheet area, while in the surroundings of Dąbrówka Wielka, they are covered by a thin layer of eluvial sediments and commonly attain a thickness of 2–4 m, and only locally in excess of 8 m. Glaciofluvial sands and gravels occur in the fossil valley of the Czarna Przemsza River in the south-eastern part of the map sheet, and are covered by fluvial or glaciofluvial sediments of the Odranian Glaciation. These are medium-grained sands interbedded with fine-grained gravels, with an estimated thickness not exceeding 10 m (Biernat, 1955; updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

Fluvial sands and gravels of the Mazovian Interglacial fill the fossil valleys of the Czarna Przemsza and Brynica rivers and are not exposed on the ground surface. These are usually variably grained sands, admixed with fine-grained gravels, predominantly with gravels in the bottom part, about 20 m in thickness (Biernat, 1955; updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

Sediments of the Middle Polish Glaciations cover about 15% of the map sheet area. Glacial lake clays and muds (lower) fill a relatively large ice-dammed lake in the valley of the Czarna Przemsza River and its tributaries in the south-eastern part of the map sheet. These are light and dark grey clays and sandy clays, with numerous interbeds of muds and sandy muds at the top, mostly a few metres in thickness, but reaching a maximum of 10 m. They are covered by glaciofluvial (lower) sands and gravels, ranging in thickness from 2 to 8 m. The deposits are not exposed on the ground surface. Glaciofluvial sands and gravels (upper), deposited during the standstill and recession of the Odranian ice sheet, are relatively common in the north-western and south-eastern parts of the map sheet, where they occur in the areas located at an elevation of up to *ca.* 340 m a.s.l. These are light to dark yellow, medium-grained or variably grained sands with an admixture of fine gravels. Their thickness is mostly about 5 m and locally increases to about 10 m (Biernat, 1955; updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

Undivided Quaternary sediments occupy a small portion of the map sheet. These are mainly muds, sands and gravels of weathering mantles (eluvial sediments), most often accompanying tills (as products of their weathering) or other surface deposits, mainly Quaternary. The eluvial sediments are mostly about 2 m thick, locally up to 3 m. They are found in the vicinity of Dąbrówka Wielka, where they cover a relatively extensive area. Slope wash loams, sands and gravels occur at the foot and lower parts of hillslopes composed of Triassic and Carboniferous rocks in the central and southern parts of the map sheet. These are washed loamy-sandy sediments with sparse gravels and clasts of local rocks, mostly 2–4 m and locally 4–6 m thick. Slope wash-fluvial sands, gravels and muds fill numerous small and short valleys, mainly on the hillslopes composed of Triassic and Carboniferous rocks. They are represented by variably grained sands with varying admixtures of fine-grained gravels and numerous lenses of sandy muds, 2–4 m thick. A small field of aeolian sands occurs in the northern part of the map sheet. The sands were deposited towards the end of the Vistulian Glaciation and at the beginning of the Holocene (Biernat, 1955; updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

Holocene sediments fill the bottoms of the valleys of the Brynica, Wielonka and Jaworznik and other minor watercourses. These are mainly fluvial sands and gravels of floodplain terraces, up to 8 m thick, and fluvial sands, gravels and muds of floodplain terraces and valley bottoms. The most extensive terraces, over 500 m wide, occur in the Brynica River valley near Wojkowice and Ożarowice. The deposits attain a thickness of 5.0–10.0 m. Alluvial muds of valley bottoms – silty sands with an admixture of organic matter, 1.5–3.0 m in thickness – occupy a small area in the north-western part of the map sheet, in the Rogoźnik region (Biernat, 1955; updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

Mineral deposits. The Wojkowice map sheet area has a rich history of geological exploration owing to the numerous mineral resources: hard coal, zinc and lead ores, and rock raw materials – limestones and marls, sands, clays, and clay shales.

The mining of hard coal in the study area dates back to the 19th century, when the first small mines were established in the south-eastern part of the area (near Grodziec, Psary and Strzyżowice). Some of them originated from mines previously extracting zinc ore (calamine). In later years, the number of mines and the coal production increased rapidly, among others due to the great activity of Towarzystwo Górniczo-Przemysłowe Saturn (Saturn Mining and Industrial Society). The activity of the mines varied depending, inter alia, on the geopolitical situation (*e.g.* two world wars). They operated until the end of the 20th century, when mining was terminated due to the depletion of resources and the consequent significant increase in production costs.

The mining and smelting of silver and lead in the areas of ore-bearing dolomites, which began in the early Middle Ages, experienced periods of both prosperity and stagnation in this region. On the one hand, the shallow-seated ore deposits were being successively depleted, while on the other, the situation was heavily affected by geopolitical events. The development of mining techniques, including ventilation and mine drainage systems, made it possible to reach deeper ore deposits of zinc, lead and silver. Initially, galena, calamine and limonite (iron ore) were mined, which were associated mainly with weathering mantles filling karst funnels. As late as the late 19th century, technology was developed for the production of concentrates from zinc blende.

From the early Middle Ages until the turn of the 14th and15th centuries, zinc-lead ores were mined on outcrops, mainly by surface mining. Due to mine flooding by ground water, there were longer or shorter periods of decline in ore mining. Exploitation of deposits located below the groundwater table began in the late 15th century with the construction of the first drainage adits. However, opencast mining was also carried out in parallel. In the 16th and 17th centuries, ore mining was carried out slightly below the water table, to a depth of around 50 m. The next ore mining boom began after 1780 and was associated with the use of the steam engine for deposit dewatering and the capability of drilling deep adits. The particularly rapid development of zinc-lead ore mining took place around 1865–1870, following the mastery of zinc blende concentrate production technology. Blende production increased significantly after the Second World War, and was finally terminated in 1989 with the liquidation of the last mine ("Dąbrówka" mine as part of ZGH "Orzeł Biały") in 1990.

Currently (as at December 31, 2022), 14 mineral deposits are documented in the map sheet area: hard coal, zinc and lead ores, limestones, clay raw materials, and sands (Szuflicki *et al.*, 2023). Information on the parameters of the mineral deposits, as well as on 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 – http://geoportal.pgi.gov.pl/midas-web).

There are nine hard coal deposits in the southern part of the map sheet, although each of them is partially, but to a different extent, located within the sheet area. These are the "Andaluzja", "Wojkowice", "Jowisz", "Saturn", "Grodziec", "Siemianowice", "Rozalia", "Paryż" and "Brzeziny" mines. 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. Hard coal reserves have been documented to a depth of between 700 m ("Siemianowice" deposit) and 1,000 m ("Wojkowice", "Jowisz", "Grodziec", "Rozalia", "Paryż" deposits) in categories $A–C_2$. The mineral deposit bed is represented by the Saddle Beds (group 500) and by the Paralic Series (seams of groups 800, 700 and 600 – Namurian A), and its total thickness varies from 200 to 950 m. The number of documented seams is highly variable, ranging from three in the "Rozalia" deposit, five in the "Andalusia" deposit, to 29 in the "Paryż" deposit. The study area hosts type 31+32 power coals. The thicknesses of the individual economic coal seams vary from 0.7 to 13.4 m. The quality parameters of the power coals are characterized by high variability. Their calorific value varies from 18,087 kJ/kg to 32,328 kJ/kg, the ash content ranges widely from 4 to 26%, and the sulphur content is 0.2–2.3%.

All hard coal deposits in the Wojkowice sheet were exploited in the past. Hard coal mining ended in the latest 20th century and the mining plants and industrial infrastructure were mostly decommissioned. Due to more than 100 years of hard coal mining in the area, the anticipated economic resources of hard coal are small, ranging from 4.7 to 61 million tonnes, with no economic resources.

The "Dąbrówka Wielka" zinc-lead deposit has been documented within the outcrops of Middle Triassic ore-bearing dolomites over an area of 2,498 ha and is partly located on the neighbouring Piekary Śląskie sheet. The deposit bed ranges from 2.9 to 3.9 m, and the overburden varies considerably from 5 to 72 m in thickness. The Zn content in the ore is up to 4.2% and the lead content up to 1.2%. The deposit was mined between 1970 and 1989 and currently has only anticipated subeconomic resources of zinc-lead ore of 363,0 tonnes.

The map sheet area provides mineral deposits of rock raw materials: carbonates (limestones), clay raw materials for the ceramics industry (loams, clays, clay shales) and sands. In the western part of the study area, within the limestone outcrops of the Middle Triassic Gogolin Beds, the "Kamyce" deposit has been documented, 49.9 ha in area. On the ground surface or under a thin overburden (up to 12.0 m), there are limestones and marls for the cement industry, ranging in thicknesses from 11 to 36.8 m. The average content of CaO in the mineral product is 48.4%, MgO 1.1%, and SiO_2 6.8%. The mineral resources of the deposit amount to 27.0 million tonnes. The "Kamyce" deposit remains undeveloped.

Two mineral deposits of Carboniferous clays and clay shales "Gródków-Łagisza" and "Grodziec" have been documented within the outcrops of the Paralic Series. These are bedded deposits of simple geological structure and small areas. The "Gródków-Łagisza" deposit of clay raw materials for the ceramics industry, ranging in thickness from 18.6 to 29.9 m, covers an area of 10.66 ha. The mineral deposit occurs directly on the ground surface or is covered by an overburden with an average thickness of approximately 1.9 m. The parameters of the mineral product are as follows: the Al_2O_3 content varies from 13.5 to 18.9%, the CaO content from 0.74 to 3.7%, and the SiO_2 content from 55.3 to 69%. The raw material can be used for the production of solid bricks. The deposit remains undeveloped. The "Grodziec" deposit of clay raw materials for cement production, with a variable thickness ranging from 8.8 to 27.8 m, has been documented over an area of 5.42 ha. The parameters of the mineral product are as follows: Al_2O_3 content – from 15.98 to 25.3%, Fe_2O_3 – from 5.4 to 11.6%, and SiO_2 – from 52.2 to 68.1%. Exploitation of the deposit was carried out in the 1960s and 1970s.

The "Rozkówka" filling sands deposit has been documented within Quaternary glaciofluvial sands. This is a lenticular deposit of fine-grained sands, which occupies an area of 31 ha. The sands, 2.0–11.6 m thick, occur under an overburden ranging in thickness from 0.1 to 4 m. The sand point of the aggregate is 94.51%, and the compressibility is 10.0%. The sands were used for the preparation of hydraulic backfill, *i.e.* a mixture of sand and water, used to fill depleted mine workings in nearby coal mines. Along with the cessation of hard coal mining and the decommissioning of the mines, the demand for backfill sand ceased and the exploitation of the "Rozkówka" deposit was also terminated.

HUMAN IMPACT (ANTHROPOPRESSION)

Anthropogenic transformations in the southern, western and north-western parts of the map sheet are related chiefly to the historical activities of the mining and cement industries. They are evident as continuous and discontinuous deformations, rehabilitated dumps and mine water settling ponds, as well as areas of decommissioned mining plants. Areas threatened by discontinuous deformation as a result of mining of shallow-seated coal seams are found in the Strzyżowice region (shallow goafs of the historical Tadeusz and Strzyżowice mines, currently flooded). Such areas are also observed in Będzin (Barlickiego, Wolności and Mickiewicza streets and Góra Parcina Mt. – historical mining in the former Maria Mine, and Las Grodziecki – historical mining in the former Bory Mine) and in the Wojkowice region (Głowackiego Street – former Aleksandra Mine). Mining has also resulted in the formation of sinkholes and fractures in Triassic limestones and dolomites, which developed in the area of the former farming production cooperative Rolnicza Spółdzielnia Produkcyjna Przyjaźń (south of Sucharskiego Street) in the municipality of Wojkowice (Goszcz *et al.*, 2004a, 2008). Dumps and settling ponds were located on the border between Będzin (Grodziec quarter) and Wojkowice (Goszcz *et al.*, 2004b, 2008).

In the southern and north-western part of the sheet, there are also depressions and hollows left after limestone and sand mining. The largest ones are associated with limestone extraction for the former cement industry, *i.e.* the Rogoźnik post-mining pits (42.53 ha) in the municipalities of Bobrowniki and Żychcice (50 ha) on the border of the Wojkowice and Bobrowniki municipalities. Post-excavation pits of filling sands occur in the Bobrowniki municipality (Rogoźnik field) and in the Wojkowice municipality between Długosza and Brzeziny streets (Goszcz *et al.*, 2004a, 2008; Góra, 2012; Woźnica *et al.*, 2018). The Rogoźnik post-mining pit of limestone extraction (its western and northern faces) hosts abundant fossils of Triassic bivalves, gastropods, brachiopods, and crinoid and vertebrate remains. The site is characterized by high scenic and educational values, hence it has been proposed for protection as a documentation site (Uchwała, 2019).

Post-industrial areas are concentrated mainly in the southern part of the map sheet, where currently inactive mining plants (former KWK Jowisz and KWK Grodziec mines), former mine shafts (*e.g.* sand-filling shaft Alfred of the former KWK Jowisz Mine) and cement works were located. Furthermore, the terrain transformation is also influenced by factors such as urbanization (residential, service and commercial development) and by the current and former linear infrastructure that includes, for example, road embankments, levees, railway embankments (including after former railway tracks to the mines or cement works) or the remains of the tramway tracks of line 15 (Zuzańska-Zyśko *et al.*, 2017).

Atmospheric air. The map sheet area is located within the range of two zones, for which assessments of the levels of substances in the air are carried out annually under the system of state environmental monitoring. The Upper Silesian agglomeration zone (*Upper Silesian metropolitan area)* includes the cities of Piekary Śląskie and Siemianowice Śląskie, located in the south-western part of the sheet, while the będziński district is part of the Silesian zone (Ustawa, 2001). Air quality data provided by measurement stations located outside the map sheet area indicate that both zones record excessive concentrations of particulate matter (both PM10 and PM2.5) and benzo(a)pyrene contained in PM10. These contaminants are associated mainly with emissions from the municipal and domestic sector, including the operation of individual, low-efficiency and non-environmental heat sources. Of lesser significance for their distribution are industrial emissions (fuel combustion and technological sources, mining processes, mineral processing) and linear emissions, the share of which intensifies near roads with heavy traffic and is the result of abrasion of roadways and car tyres and linings (Roczna ocena, 2023; Uchwała, 2023). Some particulate contaminants also come from fugitive emission sources (Uchwała, 2023).

The Upper Silesian agglomeration zone also records exceedances of the permissible level of annual average nitrogen dioxide (Roczna ocena, 2023). The main anthropogenic source of nitrogen oxides is combustion vehicles, but they can also be emitted into the environment as a result of secondary emissions of dust contaminants from outdoor surfaces (roads, pavements, playing fields).

When characterizing the anthropogenic factors affecting aerosanitary conditions in the map sheet area, it should be borne in mind that they are also determined by allochthonous contaminants. Not only are the geographical location and dominant wind directions (which affect the movement of air masses) important here, but also the functional and spatial aspect resulting from belonging to the Metropolis GZM, including the location of other sources of contaminants.

Surface water and groundwater. The hydrographic network in the southern part of the map sheet area is highly transformed anthropogenically due to former mining activities in the area and the resulting land subsidence. The Brynica River flows in a regulated, concreted and embanked channel. Near the former KWK Jowisz Mine, in the municipality of Wojkowice, the river channel was relocated due to underground mining activities, and embanked using mining waste from the mine (Goszcz *et al.*, 2004a). The Jaworznik and Wielonka streams are also engineered along their sections from the built-up areas to the mouth of the Brynica River (Jechna, Gallus, 2017).

The quality status of surface waters flowing across the map sheet has been assessed as poor (Rozporządzenie..., 2022). This is confirmed by the result of the environmental assessment carried out for the three Surface Water Bodies (fluvial) in the study area, where all of them are considered to be at risk of failing to meet the environmental objectives set out in the Vistula River Basin Management Plan (Rozporządzenie..., 2022). The water is of poor quality because of (1) municipal and industrial wastewater discharges (as the watercourses flow through highly urbanized and industrialized areas), (2) surface runoff of rainwater from industrial areas, roads, squares, and roof surfaces, (3) mine water discharges, (4) leachate from landfills, (5) riverbeds, and (6) atmospheric deposition (Rozporządzenie..., 2022; http://karty.apgw.gov.pl:4200/jcw-powierzchniowe [access: 19.02.2024]).

The map sheet area is situated in the central macro-region and the Silesian-Cracow (XII) hydrogeological region (Paczyński, 1995), within the boundaries of GWB 111 (western and central part of the sheet) and GWB 112 (eastern area of the sheet) according to the characterization of Groundwater Bodies (CBDG Database). Usable groundwater occurs in sandstones of the Upper Silesian Sandstone Series and the Carboniferous Paralic Series (Nowicki, 2007). The water quality is assessed as poor due to pressure from urbanized and industrialized areas (including changes and deficiencies in hydraulic connection, drainage of mine workings). In the eastern region of the map sheet, the overall groundwater status is assessed as good (Nowicki, 2007; http://karty.apgw.gov.pl:4200/jcw-podziemne [access: 07.12.2023 r.]).

The map sheet area is located within the range of two Major Groundwater Reservoirs: MGR No. 329 and MGR No. 454. The former occurs in a belt stretching from the western through central to the southern part of the sheet, except for its south-western and south-eastern extremes. It is composed of Lower and Middle Triassic (Muschelkalk and Röt) dolomitic and calcareous rocks, and the aquifers occur in fracture-karst rocks. The reservoir has no established protection zones. The waters are mostly assigned to quality classes II and III (locally to class IV) and their chemical status is assessed as good. The potential threat to water quality is posed mainly by long-term mining of Zn and Pb ores and by contamination outbreaks on the ground surface, such as coal mining spoil heaps and settling ponds (Mikołajków, Sadurski, 2017).

Major Groundwater Reservoir No. 454 covers a small part at the north-eastern edge of the map sheet. It is composed of calcareous, dolomitic and marly rocks of the Lower and Middle Triassic (Muschelkalk), Röt and Middle–Lower Buntsandstein (these deposits occur locally and are of little economic significance). The reservoir has no established protection zones. Due to the major impact of Zn and Pb ore mining (including the formation of an extensive cone of depression), disappearance of springs, and the change in the nature of surface watercourses from drainage to infiltration, a protection area of 426.3 km^2 has been proposed for establishment. It will also include degraded water areas covering approximately 167 km^2. The waters represent mostly quality classes I–III and their chemical status is good. Locally in urban-industrial and agricultural areas, the reservoir's waters are categorized into classes IV–V (Mikołajków, Sadurski, 2017).

Treatment plants. Located in the southern part of the map sheet, within the administrative boundaries of Piekary Śląskie, the "Południe" Municipal Sewage Treatment Plant is a mechanical-biological installation with enhanced nutrient removal. The facility receives wastewater from the Dąbrówka Wielka quarter and from other sectors of the city, located outside the sheet boundaries: Brzeziny Śląskie and Dołków.

One of the largest plants connected to the collective sewage system supplying wastewater to the "Południe" treatment plant is Orzeł Biały SA. Its average capacity is 1,200 m^3/day. Treated wastewater is discharged into the Rów Gminny ditch (km 0+185) (Uchwała, 2020a), which connects to the Rów z Dąbrówki Wielkiej ditch.

The Wojkowice Wastewater Treatment Plant receives wastewater from the central parts of the town of Wojkowice, from the residential neighbourhoods of Maszyńsko, T. Kościuszko, and J. Plak, as well as from Żychcice (part), Kamycice, Piaski and Krzyżówka. It also receives wastewater from some areas of Psary and Strzyżowice, as well as from parts of Grodziec (Będzin). It is a mechanical-biological treatment plant with enhanced nutrient removal, with an average throughput of 741 m^3/day. After treatment, the wastewater is discharged into the Brynica River (km 14+069) (Uchwała, 2020c).

Wastewater from parts of the localities of Dobieszowice and Rogoźnik, from Sączów located outside the sheet boundaries (Bobrowniki municipality), and from the area of Stara Street in Wojkowice is transferred to the mechanical-biological wastewater treatment plant located in Rogoźnik. The average throughput of the installation is 1,600 m^3/day. The Jaworznik Stream is the recipient of the treated wastewater (km 3+100) (Uchwała, 2020b).

Soils. The soils of the study area developed mainly on Triassic and Carboniferous deposits, while younger geological formations were less important in their origin (Jochemczyk *et al.*, 2004). Consequently, the spatial structure of the map sheet area is dominated by rendzina and brown soils. In some areas there are also podzolic soils (*e.g.* in the Dobieszowice sołectwo (an administrative unit in Poland, an optional subdivision of a municipality, in the Bobrowniki municipality and near Dąbrówka Wielka in Piekary Śląskie). In terrain depressions, in the Jaworznik, Wielonka and Brynica valleys, alluvial muds and mud-peaty soils have developed (Studium, 2019; Program, 2021; Uchwała, 2021; Studium, 2022). Most of the soils are categorized into quality classes III and IV (Uchwała, 2021).

Many centuries of mining and industrial activities have caused mechanical and qualitative degradation of the soil cover over a large part of the study area, *e.g.* through surface deformation, disturbance of water relations, or atmospheric contamination. The negative effects of industrialization also include an increase in the content of heavy metals in soils above permissible levels, especially of zinc, cadmium and lead (Jochemczyk *et al.*, 2004).

Waste dumps and landfills. The rehabilitated (partly demolished) area mine dumps and depression mine dumps located in the southern part of the map sheet on the border of Będzin and Wojkowice were created as a result of had coal mining. These were Zwałowisko Nr 1 and Nr 2 dumps of the former Jowisz coal mine, Zwałowisko Nr 2 dump of the former Jowisz mine, and Zwałowisko dump of the former KWK Grodziec mine, within which settling ponds of mine water were also located. They covered a total area of approximately 38 ha; the largest one was the depression mine dump of the former KWK Grodziec mine (25 ha). Waste was deposited on these dumps in the 1960s, 1970s and 1980s, while their reclamation was carried out intermittently from the late 1980s to the beginning of the 21st century. (Goszcz *et al.*, 2004a, 2008; Jechna, Gallus, 2017).

The waste stored in the dumps (mainly of the former KWK Jowisz mine) was used, among other things, as aggregate for the construction and road building industries. Gangue waste was also used in the process of filling in post-mining areas of raw materials extraction located in the study area, *e.g.* the post-mining pit of the Żychcice Triassic limestones. In its southern and south-western part (17 ha), within the boundaries of the town of Wojkowice, mining waste from the former KWK Jowisz was deposited to form a heap. The heap is thermally active over an area of 5.2 ha (Stangiel, 2020). The south-eastern part of the pit has also been filled with waste, including post-extraction one. These are loam and limestone wastes, mixed with slag, ashe, construction rubble and post-mining waste. The waste forms a mound 10 m thick (Durjasz-Majewska *et al.*, 2017). The remaining area of the pit is currently undeveloped and overgrown by a natural plant succession. On the slopes of the excavation, floristically rich xerothermic grasslands of the Festuco-Brometea class have been found there, with sites of protected species (Inwentaryzacja, 2014). The area of the former pit, due to its natural values and recreational potential, can perform new functions in the spatial development of the town.

Mining and energy industry waste was also disposed of in a limestone and dolomite excavation pit of the so-called Góra Kijowa Mt. located in Grodziec (a quarter of Będzin). Its area was approximately 6 ha. Waste was deposited there in 1997–1999, while reclamation was carried out at the beginning of the 21st century according to a technical project approved by a decision of the Będzin Starost. In 2013, the Góra Kijowa Mt. nature-park complex was proposed to be established on the reclaimed area due to the natural values that had developed in the area (Goszcz *et al.*, 2004b; Luszka *et al.*, 2013).

The area settling ponds of the former KWK Jowisz mine, located to the north of the former mine property on the Brynica River bank, were also subjected to reclamation using mining waste. The settling ponds, covering an area of 9.51 ha, were surrounded by mining waste slopes ranging from about 1 m to about 6 m in height (Goszcz *et al.*, 2008).

Within the map sheet area there are also reclaimed landfills for non-hazardous and inert waste, where municipal waste has been deposited. In the municipality of Wojkowice (in the Gawczyce pit of limestone extraction for the former Saturn Cement Works) there is a reclaimed municipal waste landfill active from 1982 to the 1990s. The facility covered an area of 5.8 ha (Goszcz *et al.*, 2004a). Another reclaimed municipal waste landfill was located in the same region of the Wojkowice municipality. It was a joint enterprise of four municipalities: Wojkowice, Ożarów, Bobrowniki and Psary. It operated from 1998 to 2015 (Plan, 2004; Analiza, 2016). The total capacity was 262,700 m^3 (Kobiela *et al.*, 2012), and the total area was 3.3 ha, including the area of 1.4 ha occupied by waste (Plan, 2004).

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).

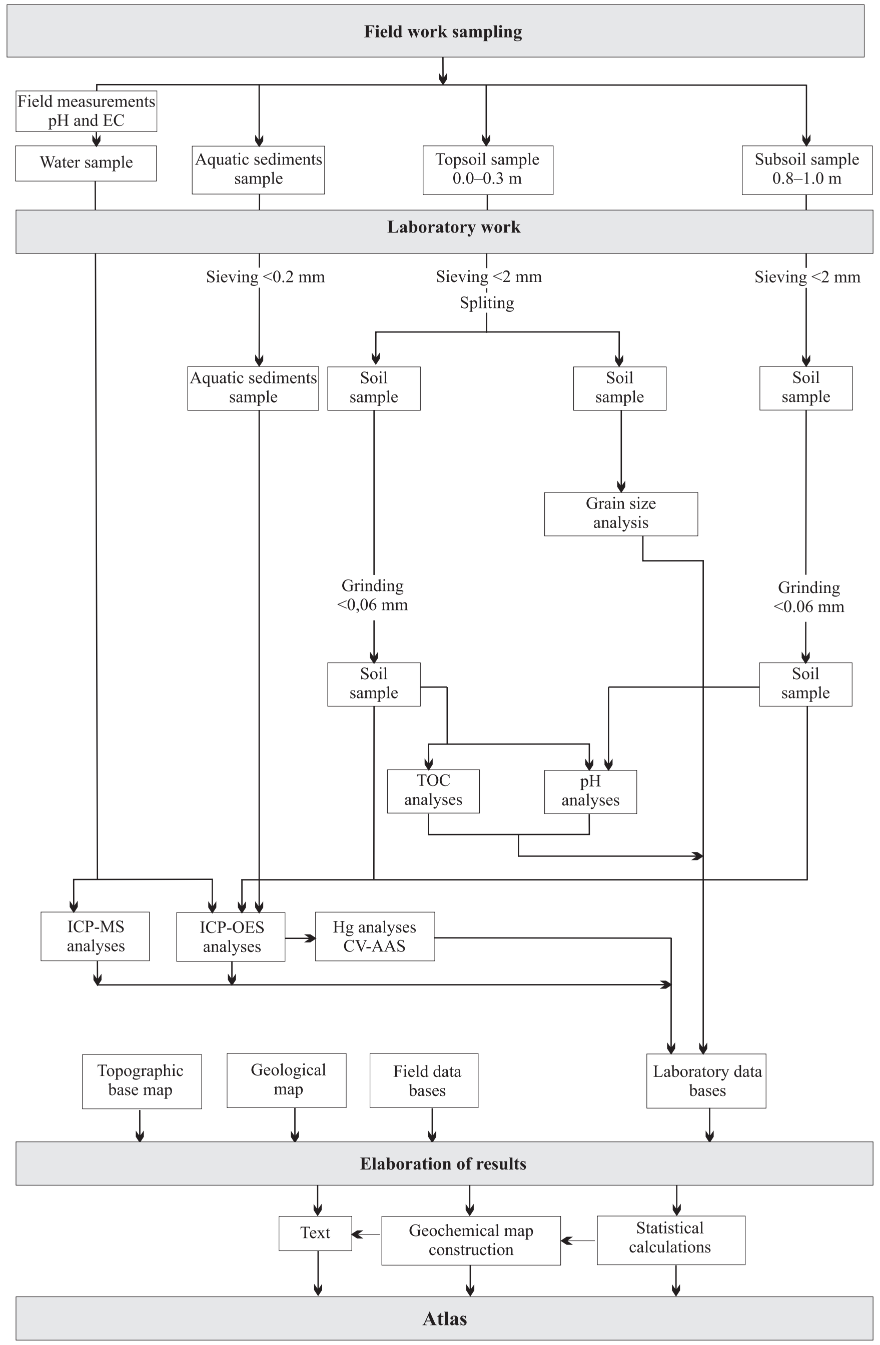


Fig. 1. Scheme of the work performed

FIELDWORK

Soils were sampled using a 60 mm diameter hand auger in a regular 250 × 250 m grid (16 samples/km²). The location of sampling sites is documented by maps showing both the housing type and land use (Plates 2–3). A total of 1,295 samples were collected from a depth of 0.0–0.3 m, and 1,279 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 (276 and 281 samples, respectively) were collected 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 are 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 cm³ bottles, and acidified with nitric acid (V) to the pH < 2. The bottles were labelled with the appropriate numbers.

Aquatic 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 cm³ 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).

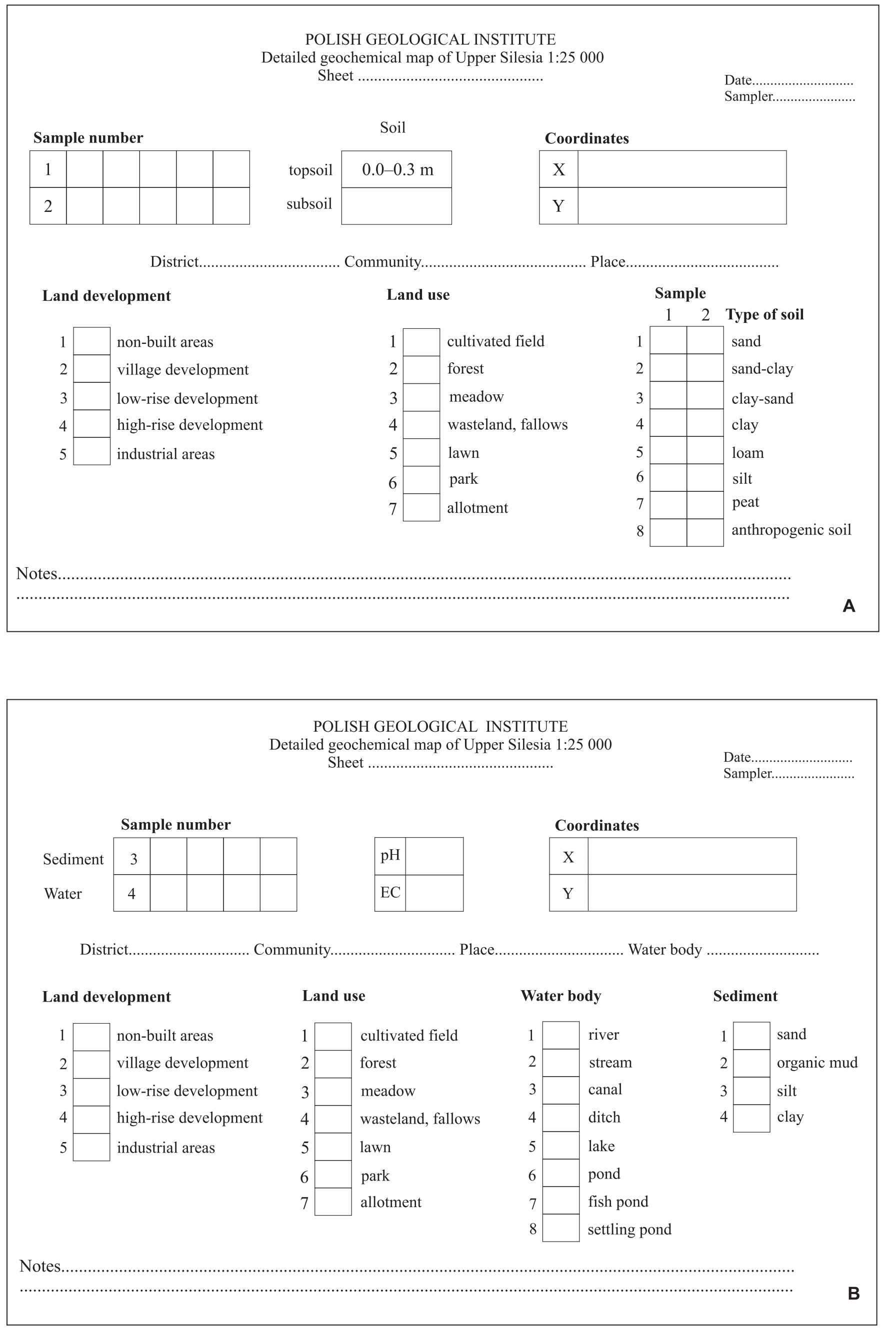
LABORATORY WORK

Sample preparation for testing, determinations of physico-chemical parameters, and chemical analyses were carried out at the chemical laboratory of the Polish Geological Institute – National Research Institute (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. The 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. Soil and aquatic sediment samples 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


POLISH GEOLOGICAL INSTITUTE
Detailed geochemical map of Upper Silesia 1:25 000
Sheet ....
Date............................
Sampler.......................

Sample number		Soil		Coordinates	
1		topsoil	0.0–0.3 m	X	
2		subsoil		Y	

District.................................. Community.. Place.....................................

Land development		Land use		Type of soil (Sample 1, 2)	
1	non-built areas	1	cultivated field	1	sand
2	village development	2	forest	2	sand-clay
3	low-rise development	3	meadow	3	clay-sand
4	high-rise development	4	wasteland, fallows	4	clay
5	industrial areas	5	lawn	5	loam
		6	park	6	silt
		7	allotment	7	peat
				8	anthropogenic soil

Notes...
A

POLISH GEOLOGICAL INSTITUTE
Detailed geochemical map of Upper Silesia 1:25 000
Sheet ....
Date............................
Sampler.......................

	Sample number			Coordinates	
Sediment	3	pH		X	
Water	4	EC		Y	

District............................ Community.............................. Place.............................. Water body ....

Land development		Land use		Water body		Sediment	
1	non-built areas	1	cultivated field	1	river	1	sand
2	village development	2	forest	2	stream	2	organic mud
3	low-rise development	3	meadow	3	canal	3	silt
4	high-rise development	4	wasteland, fallows	4	ditch	4	clay
5	industrial areas	5	lawn	5	lake		
		6	park	6	pond		
		7	allotment	7	fish pond		
				8	settling pond		

Notes...
B

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

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.

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/dm³, mercury content in soil and sediment samples, and total 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 p. 4.1. 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, 0.1 mm 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, 0.1–0.02 mm – silt fraction, and <0.02 mm – clay fraction (Plates 4–6).

DATABASES AND GEOCHEMICAL MAPS 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, 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 sub-

Tabela 1
Table

Metody analityczne i granice oznaczalności

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

sets 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 (Plates 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 supporting 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 Wojkowice M-34-51-C (Biernat, 1955; updated by Wilanowski, Żaba, 2010) 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 (Plate 1).

Map construction. The following maps were produced for the Wojkowice sheet (Plates 2–63):
- land development;
- land use;
- content of 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 Wojkowice 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 (Plate 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.

RESEARCH RESULTS

SOILS

Important factors in determining the extent and intensity of contamination are the geological structure of the area and the associated occurrence of mineral deposits. The quality status of soils in the map sheet area, including the content of heavy metals, is influenced by the presence of Triassic zinc and lead ore deposits. The Carboniferous coal deposits, which have been extensively mined in the region, and the resultant heaps and dumps, which were the storage sites for mining and processing wastes, do not directly contribute to substantial environmental contamination by heavy metals. In the area of coal mining and processing, a range of processes may occur, e.g. increased soil salinization and sulphidation. In addition, the oxidation process of pyrite contained within the waste may contribute to the acidification of the environment and, consequently, to the mobilization of metals and their migration to the soil environment (Lis, Pasieczna 1997; Pasieczna 2008; Fajfer *et al.*, 2010).

Grain size composition is defined as the fineness of the mineral part of the soil's solid phase. This is expressed in terms of the particle size and the percentage of

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	0,06	<3	13	0,10	0,01	<0,5	<1	1	2	0,10	<0,02	<0,01	8	<1	0,004	14	0,004	1	15	<1	35	3,50
Total soils	b	16	2,39	355	978	31,99	19,11	135,0	67	129	415	20,97	2,15	10,78	16 228	73	2,360	6300	0,752	335	567	147	24 820	9,51
n = 1295	c	–	0,59	17	120	3,16	1,11	10,1	5	13	21	1,31	0,08	0,34	582	12	0,044	235	0,037	21	77	17	979	7,28
	d	–	0,51	12	102	2,48	0,45	6,9	4	10	16	1,07	0,06	0,15	420	10	0,036	173	0,028	14	66	15	599	7,23
	e	–	0,53	11	99	2,36	0,41	6,6	4	11	16	1,14	0,06	0,14	487	10	0,038	167	0,027	13	62	16	583	7,50
Tereny bez zabudowy	a	<1	0,06	<3	15	0,32	0,01	<0,5	<1	1	2	0,10	<0,02	<0,01	8	<1	0,004	21	0,004	1	15	2	35	3,50
Non-built-up areas	b	8	2,39	355	978	31,99	19,11	135,0	21	90	415	7,28	2,15	10,78	4963	73	2,360	4002	0,752	304	411	80	24 820	9,51
n = 962	c	–	0,59	17	115	3,09	1,01	10,4	5	12	19	1,27	0,08	0,32	584	12	0,043	229	0,036	18	69	17	993	7,14
	d	–	0,50	12	98	2,39	0,37	7,0	4	10	15	1,02	0,06	0,13	410	9	0,034	173	0,027	12	61	15	578	7,08
	e	–	0,53	11	95	2,21	0,32	6,8	4	10	14	1,10	0,06	0,13	503	10	0,036	169	0,025	12	59	16	560	7,32
Tereny z zabudową wiejską	a	<1	0,17	<3	37	0,83	0,06	1,1	<1	3	4	0,32	<0,02	0,02	87	2	0,013	42	0,010	4	25	5	141	5,77
Village areas	b	<1	1,27	244	430	10,05	5,09	35,1	46	30	183	20,97	0,23	1,36	16 228	62	0,181	6300	0,089	64	195	40	6638	8,47
n = 44	c	–	0,56	18	127	2,94	0,90	9,3	6	12	23	1,67	0,07	0,23	872	13	0,050	355	0,034	18	71	17	921	7,39
	d	–	0,50	12	106	2,59	0,49	7,1	4	11	18	1,14	0,06	0,14	465	10	0,044	189	0,030	15	65	15	622	7,37
	e	–	0,49	11	93	2,67	0,42	7,2	5	10	16	1,16	0,06	0,13	495	12	0,045	198	0,030	15	62	16	582	7,56
Tereny z zabudową miejską	a	<1	0,09	<3	13	0,59	0,05	0,6	<1	1	4	0,10	<0,02	0,01	10	<1	0,007	18	0,007	3	15	<1	61	5,52
Urban areas	b	16	1,45	146	636	15,86	9,37	53,9	67	129	298	8,82	0,92	5,47	2279	73	0,257	1503	0,197	240	567	57	8772	8,82
n = 257	c	–	0,58	16	132	3,19	1,38	9,0	5	15	27	1,37	0,08	0,42	526	13	0,046	220	0,039	29	98	17	924	7,73
	d	–	0,53	12	113	2,75	0,86	6,5	4	12	21	1,18	0,06	0,25	446	11	0,042	169	0,033	21	83	15	667	7,72
	e	–	0,53	11	113	2,87	0,98	6,1	4	13	21	1,27	0,06	0,25	456	12	0,043	155	0,034	23	81	16	631	7,83
Tereny przemysłowe	a	<1	0,20	<3	23	0,10	0,09	<0,5	<1	3	6	0,23	<0,02	0,03	76	2	0,006	14	0,008	6	29	3	61	6,47
Industrial areas	b	5	1,55	52	521	21,35	14,15	44,3	16	47	261	4,92	0,24	1,47	2157	46	0,153	5018	0,195	335	420	147	4007	9,07
n = 32	c	–	0,63	15	185	5,33	2,35	11,0	6	16	41	1,64	0,10	0,38	561	15	0,044	387	0,059	52	148	24	1095	7,82
	d	–	0,55	11	144	3,24	1,13	6,6	5	13	27	1,33	0,08	0,25	449	12	0,036	184	0,041	31	105	17	681	7,80
	e	–	0,65	11	166	2,93	1,20	5,4	6	15	31	1,48	0,07	0,30	502	14	0,039	171	0,037	30	87	20	570	7,78
Pola uprawne	a	<1	0,17	<3	28	0,46	0,02	0,8	<1	3	4	0,28	<0,02	0,02	59	2	0,011	31	0,005	2	17	4	82	5,94
Cultivated fields	b	4	1,96	160	720	10,05	13,11	91,2	13	54	115	3,82	0,36	4,47	3145	35	0,276	2077	0,105	68	281	51	5570	8,29
n = 276	c	–	0,65	16	111	2,14	0,68	9,4	5	12	18	1,30	0,09	0,29	662	12	0,051	235	0,025	15	74	18	887	7,32
	d	–	0,59	12	100	1,92	0,35	7,3	4	11	16	1,16	0,07	0,15	563	10	0,047	179	0,022	12	69	16	660	7,30
	e	–	0,62	12	101	1,92	0,30	7,0	5	11	16	1,21	0,07	0,13	600	11	0,047	170	0,022	12	66	17	652	7,41
Lasy	a	<1	0,06	<3	15	0,32	0,01	<0,5	<1	1	2	0,10	<0,02	<0,01	8	<1	0,004	26	0,004	1	17	2	35	3,50
Forests	b	2	1,61	94	407	31,99	12,57	85,1	20	40	193	7,28	0,44	5,27	3100	53	0,149	1455	0,311	177	439	80	8772	8,36
n = 251	c	–	0,47	13	113	4,26	0,77	8,7	3	9	16	1,00	0,08	0,20	382	9	0,027	216	0,038	16	64	14	711	6,58
	d	–	0,37	9	92	2,99	0,22	5,5	2	7	13	0,71	0,05	0,06	204	6	0,022	164	0,027	10	56	11	377	6,49
	e	–	0,36	9	89	2,89	0,21	5,9	2	7	13	0,66	0,06	0,05	211	5	0,022	163	0,026	10	53	10	374	6,68
Łąki	a	<1	0,10	<3	33	0,49	0,03	1,7	<1	2	4	0,21	<0,02	0,01	46	1	0,013	39	0,006	2	20	3	107	5,86
Meadows	b	1	1,45	115	612	12,85	6,02	126,6	21	57	245	8,82	0,28	3,57	2163	73	0,098	1379	0,142	64	294	41	10 160	8,22
n = 119	c	–	0,61	17	108	2,57	0,76	11,5	5	13	17	1,37	0,07	0,24	625	13	0,040	211	0,029	15	60	18	976	7,22
	d	–	0,52	12	92	2,23	0,36	7,1	4	11	14	1,10	0,05	0,12	486	10	0,037	162	0,025	11	55	15	578	7,20
	e	–	0,53	11	94	2,25	0,28	5,6	5	11	14	1,13	0,05	0,12	550	10	0,038	143	0,025	11	53	16	456	7,29
Nieużytki, ugory	a	<1	0,09	<3	13	0,10	0,02	<0,5	<1	1	3	0,10	<0,02	0,01	10	<1	0,006	14	0,006	3	15	<1	61	4,64
Wasteland, fallows	b	8	2,39	355	978	29,67	19,11	135,0	67	129	415	20,97	2,15	10,78	16 228	73	2,360	6300	0,752	335	420	147	24 820	9,51
n = 473	c	–	0,62	20	127	3,31	1,48	11,6	6	14	24	1,45	0,09	0,43	652	14	0,049	262	0,044	25	79	19	1195	7,43
	d	–	0,55	13	107	2,55	0,61	7,8	4	11	18	1,19	0,06	0,20	489	11	0,039	179	0,032	16	67	16	699	7,40
	e	–	0,58	12	100	2,45	0,56	7,3	5	12	16	1,28	0,06	0,17	529	12	0,038	170	0,028	15	62	17	660	7,59
Parki	a	<1	0,23	<3	41	0,57	0,05	1,6	1	3	6	0,27	<0,02	0,03	111	2	0,007	46	0,007	4	30	4	108	5,81
Parks	b	4	0,96	173	161	5,30	2,29	41,2	7	17	133	2,12	0,13	0,75	888	20	0,108	520	0,079	31	120	26	3200	8,45
n = 16	c	–	0,46	20	100	3,07	0,71	8,9	4	10	21	1,00	0,07	0,20	450	9	0,032	212	0,031	15	64	13	699	7,28
	d	–	0,42	10	93	2,73	0,46	5,9	3	8	14	0,84	0,06	0,12	358	8	0,025	169	0,027	13	59	11	443	7,24
	e	–	0,45	9	101	3,03	0,52	5,0	4	10	14	1,01	0,07	0,12	431	9	0,024	160	0,027	14	53	15	433	7,47

Tabela 2 cd.
Table 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
Trawniki *Lawns* n = 156	a	<1	0,22	<3	23	0,59	0,09	1,1	1	4	4	0,39	<0,02	0,03	147	3	0,010	42	0,007	3	32	5	152	6,43
	b	16	1,43	210	483	12,29	7,69	35,6	13	98	298	4,60	0,92	4,14	2279	33	0,257	1402	0,197	240	567	43	6200	8,84
	c	–	0,57	17	138	3,21	1,57	8,3	5	16	30	1,38	0,08	0,46	528	13	0,047	209	0,042	32	108	17	955	7,91
	d	–	0,53	13	118	2,81	1,08	6,3	4	13	24	1,24	0,06	0,30	459	12	0,041	166	0,036	25	94	16	698	7,90
	e	–	0,52	12	115	2,82	1,14	6,1	5	13	23	1,29	0,06	0,30	454	13	0,043	159	0,036	27	90	16	651	7,95
Gleby piaszczyste *Sandy soils* n = 971	a	<1	0,06	<3	13	0,40	0,01	<0,5	<1	1	2	0,10	<0,2	<0,01	8	<1	0,004	18	0,004	1	15	<1	35	4,28
	b	6	1,76	244	978	16,13	15,79	135,0	46	64	261	20,97	1,11	5,27	16 228	73	0,590	6300	0,277	149	380	80	24 820	8,55
	c	–	0,55	15	111	2,63	0,82	9,7	4	11	17	1,17	0,07	0,27	560	11	0,041	220	0,029	15	65	16	881	7,15
	d	–	0,47	11	95	2,22	0,33	6,7	3	9	14	0,95	0,06	0,12	396	8	0,035	165	0,024	11	59	14	544	7,10
	e	–	0,49	10	93	2,18	0,30	6,7	4	9	14	1,00	0,06	0,11	455	9	0,037	159	0,024	11	58	14	515	7,33
Gleby gliniaste *Clay soils* n = 57	a	<1	0,16	5	37	0,93	0,12	3,4	<1	3	5	0,20	<0,02	0,02	42	2	0,013	71	0,010	5	15	5	269	6,11
	b	3	1,96	118	527	11,79	8,55	126,6	14	30	66	3,63	0,33	3,96	3145	35	0,128	2077	0,161	78	180	51	10 160	8,24
	c	–	0,90	24	153	3,00	1,56	13,6	7	17	22	1,87	0,09	0,65	962	18	0,051	312	0,037	21	67	26	1280	7,49
	d	–	0,84	19	134	2,56	0,77	10,1	6	15	20	1,71	0,08	0,29	789	16	0,045	241	0,032	17	61	24	954	7,47
	e	–	0,91	18	121	2,48	0,54	8,2	7	17	20	1,87	0,08	0,22	872	18	0,049	210	0,029	17	61	27	847	7,55
Gleby antropogeniczne *Anthropogenic soils* n = 259	a	<1	0,14	<3	15	0,10	0,04	<0,5	<1	3	3	0,23	<0,2	0,01	13	2	0,006	14	0,007	2	21	3	61	3,50
	b	16	2,39	355	612	31,99	19,11	89,7	67	129	415	8,82	2,15	10,78	3857	73	2,360	5018	0,519	335	567	147	10 241	9,51
	c	–	0,67	21	147	4,96	2,12	10,6	6	18	38	1,72	0,10	0,56	590	17	0,054	271	0,062	42	124	21	1219	7,77
	d	–	0,60	15	124	3,56	1,31	6,9	5	15	28	1,47	0,07	0,35	473	14	0,039	187	0,047	31	103	18	778	7,72
	e	–	0,61	14	127	3,57	1,35	6,1	6	16	27	1,51	0,07	0,35	520	15	0,041	177	0,042	31	100	19	691	7,94
Tło geochemiczne/*Geochemical background*																								
Gleby Europy[1] *Soils of Europe*[1]	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*[2] 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*[3] 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 substancji 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 Ministra Środowiska..., 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 topsoils (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	0,03	<3	4	<0,01	<0,5	<1	<1	<1	<0,01	<0,02	<0,01	<2	<1	<0,002	<2	<0,003	<1	8	<1	3	4,62
Gleby ogółem	b	9	3,73	531	4774	21,41	266,2	62	227	18 426	12,30	3,45	11,87	21 157	123	2,022	8870	1,261	2692	1351	259	29 800	9,66
Total soils	c	–	0,68	14	85	1,64	7,7	5	14	29	1,44	0,06	0,60	612	15	0,025	145	0,021	21	82	19	863	7,73
n = 1279	d	–	0,50	6	52	0,26	1,7	3	9	9	0,85	0,03	0,14	250	8	0,016	48	0,008	9	63	13	228	7,70
	e	–	0,55	6	57	0,18	1,5	4	11	9	1,14	0,04	0,14	365	11	0,018	48	0,007	8	60	16	197	7,81
	a	<1	0,03	<3	4	<0,01	<0,5	<1	<1	<1	<0,01	<0,02	<0,01	<2	<1	<0,002	<2	<0,003	<1	8	<1	3	4,72
Tereny bez zabudowy	b	9	3,73	531	4774	21,41	266,2	62	79	18 426	12,30	3,45	11,87	21 157	123	2,022	8870	1,261	305	1351	165	29 800	9,66
Non-built-up areas	c	–	0,69	15	78	1,66	7,8	5	13	33	1,44	0,06	0,63	644	15	0,024	146	0,018	17	78	19	874	7,64
n = 952	d	–	0,50	6	47	0,21	1,6	3	9	8	0,81	0,03	0,13	232	8	0,015	44	0,007	8	60	12	210	7,61
	e	–	0,56	6	50	0,15	1,1	4	10	8	1,07	0,03	0,13	342	10	0,016	38	0,006	7	58	16	156	7,75
	a	<1	0,06	<3	9	0,01	<0,5	<1	<1	2	0,03	<0,02	<0,01	9	<1	<0,002	3	<0,003	1	14	1	10	4,62
Tereny z zabudową wiejską	b	3	2,16	134	324	12,25	161,2	19	52	38	6,12	0,20	2,63	3104	77	0,165	1060	0,172	161	337	66	10345	8,72
Village areas	c	–	0,76	13	82	0,97	10,2	6	16	13	1,54	0,04	0,25	571	17	0,030	152	0,017	16	74	20	787	7,62
n = 45	d	–	0,56	7	57	0,24	2,0	4	10	10	1,00	0,03	0,12	312	10	0,021	63	0,008	9	62	14	265	7,57
	e	–	0,66	9	64	0,21	2,1	5	14	11	1,28	0,03	0,15	442	12	0,026	55	0,008	11	62	20	244	7,78
	a	<1	0,06	<3	8	0,01	<0,5	<1	<1	<1	0,02	<0,02	<0,01	7	<1	<0,002	3	<0,003	1	14	1	7	6,03
Tereny z zabudową miejską	b	4	2,24	175	637	17,24	143,1	60	227	159	5,04	1,54	8,08	3993	90	0,142	2650	0,360	281	797	91	24 080	9,08
Urban areas	c	–	0,63	12	105	1,51	7,0	6	15	18	1,41	0,06	0,55	502	14	0,027	139	0,022	25	97	18	868	8,02
n = 251	d	–	0,51	7	69	0,45	2,2	4	10	11	0,98	0,04	0,19	311	9	0,021	62	0,011	13	77	13	296	8,01
	e	–	0,54	7	75	0,44	2,5	5	11	11	1,25	0,04	0,20	392	12	0,024	66	0,012	12	74	16	288	8,05
	a	<1	0,09	<3	10	0,03	<0,5	<1	<1	2	0,06	<0,02	<0,01	12	<1	<0,002	4	<0,003	2	22	1	15	5,41
Tereny przemysłowe	b	1	0,96	45	895	17,31	31,7	18	26	89	4,91	0,41	6,21	2860	60	0,052	505	0,995	2692	403	259	3121	9,14
Industrial areas	c	–	0,55	11	139	2,83	4,6	5	12	21	1,39	0,08	0,52	549	14	0,023	120	0,084	122	108	26	593	8,03
n = 31	d	–	0,49	7	87	0,68	2,3	4	9	14	0,96	0,05	0,18	317	9	0,018	70	0,022	20	87	15	295	8,00
	e	–	0,53	7	93	0,65	2,8	4	10	15	1,11	0,04	0,23	412	12	0,019	77	0,018	14	86	17	371	8,07
	a	<1	0,06	<3	8	<0,01	<0,5	<1	<1	<1	0,02	<0,02	<0,01	5	<1	<0,002	3	<0,003	1	12	<1	7	4,62
Pola uprawne	b	6	3,73	141	1278	20,15	179,7	59	59	99	12,30	0,51	11,87	21 097	123	0,252	8870	0,179	107	1150	165	21 350	9,13
Cultivated fields	c	–	0,82	15	76	1,41	8,3	6	15	13	1,73	0,06	0,71	835	17	0,025	173	0,011	15	88	22	1051	7,67
n = 275	d	–	0,64	7	51	0,25	1,7	4	11	9	1,12	0,04	0,17	363	10	0,018	56	0,006	8	71	16	272	7,65
	e	–	0,70	8	54	0,16	1,4	5	12	10	1,30	0,04	0,15	472	12	0,018	56	0,005	8	68	19	230	7,71
	a	<1	0,03	<3	4	<0,01	<0,5	<1	<1	<1	<0,01	<0,02	<0,01	<2	<1	<0,002	<2	<0,003	<1	9	<1	3	4,99
Lasy	b	2	2,58	531	365	17,55	90,7	22	71	94	9,37	1,54	6,29	3876	85	0,105	1838	0,629	225	589	67	10416	9,07
Forests	c	–	0,48	10	51	1,05	4,0	3	9	10	0,93	0,04	0,33	346	9	0,015	82	0,018	12	66	13	479	7,40
n = 249	d	–	0,34	4	33	0,09	0,9	2	5	6	0,45	0,02	0,06	98	4	0,010	25	0,006	4	52	7	101	7,37
	e	–	0,30	2	28	0,05	0,6	2	4	5	0,45	0,01	0,04	99	4	0,010	19	0,005	3	49	7	82	7,53
	a	<1	0,04	<3	8	<0,01	<0,5	<1	<1	<1	0,03	<0,02	<0,01	3	<1	<0,002	<2	<0,003	1	10	<1	7	4,80
Łąki	b	2	2,25	220	672	15,53	200,0	30	65	57	8,83	0,20	8,50	6918	98	0,074	1657	0,103	187	1351	91	9883	8,96
Meadows	c	–	0,75	19	79	1,71	10,8	6	16	14	1,73	0,05	0,52	658	17	0,023	145	0,011	16	86	22	973	7,68
n = 119	d	–	0,54	7	48	0,24	1,7	4	10	9	0,97	0,03	0,13	265	9	0,016	45	0,006	8	57	14	249	7,65
	e	–	0,57	8	50	0,16	1,2	5	14	11	1,33	0,04	0,15	436	13	0,019	42	0,006	8	57	20	177	7,81
	a	<1	0,04	<3	6	<0,01	<0,5	<1	<1	<1	0,02	<0,02	<0,01	3	<1	<0,002	<2	<0,003	<1	8	<1	6	4,72
Nieużytki, ugory	b	9	3,52	475	4774	21,41	266,2	62	227	18 426	9,13	3,45	10,01	21157	96	2,022	6722	1,261	2692	696	259	29 800	9,66
Wasteland, fallows	c	–	0,72	17	102	2,11	8,8	6	15	56	1,51	0,07	0,72	641	16	0,029	162	0,029	29	81	20	950	7,80
n = 463	d	–	0,55	7	61	0,37	2,1	4	10	10	0,96	0,04	0,19	297	10	0,018	55	0,010	11	63	14	278	7,78
	e	–	0,62	8	69	0,25	2,0	5	11	11	1,30	0,04	0,19	437	12	0,020	56	0,009	10	60	18	282	7,88

Tabela 3 cd.
Table 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 = 16	a	<1	0,16	<3	12	0,02	<0,5	<1	2	2	0,18	<0,02	0,01	30	1	0,004	5	<0,003	2	26	2	25	6,83
	b	1	0,98	36	310	9,13	131,3	11	17	21	2,24	0,14	5,40	5262	21	0,087	2174	0,059	47	81	30	7701	8,77
	c	–	0,39	9	77	1,91	12,2	4	9	8	0,96	0,03	0,80	809	9	0,023	272	0,013	13	50	13	807	7,73
	d	–	0,34	4	49	0,26	2,4	2	7	6	0,67	0,02	0,12	292	6	0,016	70	0,007	7	47	10	214	7,71
	e	–	0,36	4	37	0,08	2,0	3	9	6	0,59	0,03	0,07	185	9	0,018	61	0,007	4	51	8	140	7,64
Trawniki *Lawns* n = 153	a	<1	0,08	<3	10	0,01	<0,5	<1	1	<1	0,06	<0,02	0,01	8	1	<0,002	3	<0,003	1	18	1	15	7,30
	b	4	2,20	110	615	13,78	143,1	17	175	159	4,68	1,01	8,08	3993	90	0,142	2160	0,360	281	797	48	24 080	8,86
	c	–	0,59	12	106	1,49	6,2	5	15	19	1,34	0,06	0,52	492	14	0,028	127	0,025	26	102	17	812	8,13
	d	–	0,49	7	74	0,55	2,6	4	10	12	0,99	0,04	0,20	323	9	0,022	67	0,013	14	81	13	323	8,12
	e	–	0,52	7	82	0,69	2,8	4	11	12	1,18	0,04	0,20	391	11	0,024	73	0,014	15	77	15	313	8,13
Gleby piaszczyste *Sandy soils* n = 581	a	<1	0,03	<3	4	<0,01	<0,5	<1	<1	<1	<0,01	<0,02	<0,01	<2	<1	<0,002	<2	<0,003	<1	9	<1	3	4,76
	b	6	2,04	475	527	20,58	131,3	62	35	229	4,65	3,45	11,87	5262	76	0,110	2659	0,685	186	797	51	13 360	9,13
	c	–	0,34	6	39	0,69	2,9	2	6	6	0,57	0,03	0,28	251	6	0,013	58	0,008	7	55	8	288	7,65
	d	–	0,27	3	27	0,07	0,7	1	4	4	0,35	0,02	0,05	93	3	0,009	20	0,004	4	47	6	83	7,63
	e	–	0,27	2	23	0,05	0,3	1	4	4	0,35	0,01	0,04	101	3	0,010	17	0,003	3	45	5	65	7,71
Gleby gliniaste *Clay soils* n = 520	a	<1	0,14	<3	11	0,01	<0,5	<1	2	1	0,19	<0,02	0,02	15	1	0,003	4	<0,003	2	8	3	24	4,62
	b	6	3,73	531	4774	21,41	266,2	59	175	99	12,30	0,51	8,60	21 157	123	0,252	8870	0,174	219	1351	165	29 800	8,89
	c	–	1,03	21	116	2,31	11,5	8	21	17	2,26	0,07	0,90	990	23	0,030	191	0,015	22	95	29	1334	7,72
	d	–	0,92	12	82	0,58	3,0	7	18	14	1,86	0,05	0,34	589	18	0,025	83	0,010	14	75	26	480	7,69
	e	–	0,92	13	81	0,35	3,4	7	17	15	1,89	0,06	0,24	664	19	0,026	87	0,010	12	69	27	544	7,84
Gleby antropogeniczne *Anthropogenic soils* n = 176	a	<1	0,12	<3	7	<0,01	<0,5	<1	2	1	0,06	<0,02	0,01	6	<1	0,003	4	<0,003	1	23	2	6	4,72
	b	9	2,58	443	895	20,09	143,1	60	227	18 426	5,04	2,38	10,01	3993	70	2,022	6722	1,261	2692	696	259	17 110	9,66
	c	–	0,73	22	143	2,81	11,8	7	19	137	1,86	0,12	0,77	686	19	0,044	281	0,077	62	133	24	1326	8,03
	d	–	0,64	13	113	1,54	5,7	6	14	24	1,55	0,07	0,40	509	16	0,029	150	0,039	34	106	20	695	8,00
	e	–	0,65	13	112	1,71	5,3	6	15	24	1,63	0,07	0,36	510	17	0,029	144	0,036	36	99	21	671	8,15

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
Osady wodne (wszystkie próbki)	a	<1	0,06	<3	8	0,02	<0,5	<1	2	<1	0,11	<0,02	0,01	13	1	0,003	9	<0,003	<1	21	2	33
Aquatic sediments (all samples)	b	4	1,83	142	3069	19,54	109,9	362	290	2078	13,85	0,97	7,75	44 978	260	3,081	3927	2,900	252	591	59	31 946
n = 281	c	–	0,53	17	143	1,57	11,5	9	16	42	1,70	0,10	0,36	1683	17	0,105	249	0,230	30	80	15	2001
	d	–	0,41	10	95	0,73	5,6	4	12	16	1,21	0,05	0,20	487	11	0,052	137	0,107	18	69	12	598
	e	–	0,46	11	117	0,71	5,9	5	13	17	1,44	0,05	0,21	505	13	0,059	133	0,108	21	63	14	530
Strumienie i rowy (bez nazwy)	a	<1	0,06	<3	8	0,03	<0,5	<1	2	1	0,16	<0,02	0,02	13	1	0,004	9	<0,003	1	21	2	35
Streams and ditches (no name)	b	4	1,55	142	3069	18,39	109,9	362	47	109	13,85	0,33	7,75	44 978	260	3,081	2321	2,900	231	591	59	9036
n = 139	c	–	0,52	18	182	1,44	9,9	13	14	22	1,92	0,08	0,35	2488	18	0,091	217	0,177	27	75	15	810
	d	–	0,41	10	111	0,66	5,3	5	11	14	1,32	0,04	0,17	569	11	0,047	132	0,087	17	66	12	467
	e	–	0,47	12	126	0,65	6,2	5	12	16	1,45	0,06	0,17	530	13	0,053	147	0,106	20	64	14	513
Zlewnia zb. Kozłowa Góra	a	<1	0,12	<3	23	0,04	1,0	<1	2	3	0,33	<0,02	0,02	13	2	0,006	31	0,028	3	21	3	61
Catchment of the Kozłowa Góra reservoir	b	2	1,55	142	879	6,68	109,9	186	28	96	5,65	0,33	2,29	25 208	165	0,134	2321	1,337	57	97	59	9036
n = 22	c	–	0,72	31	241	1,15	22,2	17	13	33	2,11	0,14	0,37	2527	24	0,064	477	0,267	25	56	21	1748
	d	–	0,60	18	143	0,52	11,4	5	11	25	1,51	0,10	0,13	259	13	0,051	310	0,196	19	51	17	753
	e	–	0,77	18	171	0,41	9,9	4	12	29	1,57	0,13	0,12	205	14	0,058	309	0,220	18	50	18	671
Zlewnia Jaworznika	a	<1	0,06	<3	8	0,02	<0,5	<1	2	<1	0,11	<0,02	0,01	13	1	0,003	9	<0,003	<1	25	2	33
Catchment of the Jaworznik Stream	b	1	1,06	82	645	19,54	58,3	33	37	86	13,85	0,53	7,75	14 932	35	3,081	1478	1,009	252	433	32	3156
n = 106	c	–	0,30	10	107	1,50	5,6	4	9	15	1,03	–	0,29	779	8	0,074	141	0,129	20	82	9	527
	d	–	0,23	5	65	0,54	2,7	2	7	8	0,67	–	0,12	242	5	0,028	76	0,062	10	67	7	284
	e	–	0,21	5	77	0,60	3,3	2	7	9	0,68	–	0,13	206	5	0,028	76	0,086	11	61	7	328
Jaworznik	a	<1	0,08	<3	8	0,04	<0,5	<1	2	<1	0,14	<0,02	0,02	58	1	0,003	17	0,004	<1	36	2	56
Jaworznik Stream	b	<1	0,94	25	181	5,26	14,4	11	33	60	2,37	0,53	0,69	1501	35	0,170	463	0,546	42	433	32	3110
n = 28	c	–	0,24	6	73	1,03	3,8	2	10	17	0,76	–	0,20	288	7	0,049	102	0,146	14	113	8	545
	d	–	0,19	4	54	0,50	2,7	2	7	9	0,61	–	0,12	197	5	0,029	73	0,067	8	84	7	362
	e	–	0,18	4	74	0,63	3,0	2	8	12	0,66	–	0,16	148	5	0,043	75	0,090	11	61	6	386
Jezioro Rogoźnickie	a	<1	0,06	<3	8	0,02	<0,5	<1	2	1	0,11	<0,02	0,01	13	1	0,004	9	0,004	<1	25	2	33
Lake Rogoźnickie	b	<1	0,21	8	123	10,38	17,9	25	5	18	1,21	0,07	0,22	538	20	0,076	95	1,009	51	82	24	376
n = 19	c	–	0,13	–	37	1,91	2,1	3	3	5	0,35	–	0,07	116	4	0,015	35	0,176	11	50	5	101
	d	–	0,12	–	27	0,43	1,0	1	3	4	0,30	–	0,05	62	3	0,011	28	0,075	5	48	4	82
	e	–	0,13	–	20	0,44	1,0	1	3	4	0,31	–	0,04	49	3	0,012	34	0,084	5	52	3	80
Zlewnia Wielonki	a	<1	0,06	<3	8	0,06	<0,5	<1	3	1	0,20	<0,02	0,02	29	2	0,007	24	0,005	1	37	3	63
Catchment of the Wielonka Stream	b	1	1,56	42	394	6,92	33,2	362	233	101	7,40	0,97	1,07	24 222	260	0,506	545	2,900	107	228	41	3477
n = 64	c	–	0,54	12	124	1,15	6,3	14	20	21	1,86	0,06	0,33	2001	21	0,079	125	0,163	24	85	16	615
	d	–	0,41	9	98	0,72	4,6	6	14	14	1,43	0,03	0,24	928	14	0,052	105	0,074	17	79	13	457
	e	–	0,46	10	106	0,72	4,7	7	16	17	1,42	0,03	0,29	933	14	0,055	107	0,071	22	74	14	494
Wielonka	a	<1	0,20	4	53	0,27	2,2	3	6	7	0,65	<0,02	0,12	350	6	0,023	50	0,028	8	37	6	246
Wielonka Stream	b	<1	1,56	25	267	3,61	18,5	24	37	69	3,74	0,14	0,89	4691	41	0,239	259	0,682	79	150	36	1708
n = 26	c	–	0,53	11	123	1,03	5,1	8	17	21	1,74	0,04	0,36	1554	18	0,072	113	0,104	23	82	15	566
	d	–	0,45	9	112	0,85	4,4	7	15	19	1,58	0,03	0,32	1319	16	0,059	106	0,080	20	77	13	502
	e	–	0,44	10	108	0,82	4,0	7	17	19	1,54	0,03	0,30	1288	14	0,057	100	0,075	22	71	13	494
Zlewnia Czarnej Przemszy od zapory zb. Przeczyce do Brynicy	a	<1	0,12	3	26	0,15	0,9	2	4	3	0,47	<0,02	0,08	166	3	0,026	23	0,026	6	23	5	81
Catchment of the Czarna Przemsza River from the Przeczyce reservoir dam to the Brynica River	b	4	1,39	129	3069	18,39	29,9	73	47	109	10,25	0,30	1,91	44 978	72	0,440	393	0,930	212	591	42	1539
n = 43	c	–	0,63	17	228	1,96	8,1	15	16	22	2,63	0,08	0,29	3976	24	0,083	148	0,179	35	73	17	614
	d	–	0,59	12	153	0,88	6,5	11	15	17	2,27	0,06	0,23	1192	21	0,070	125	0,124	25	60	16	529
	e	–	0,62	11	142	0,66	6,6	10	16	16	2,13	0,06	0,21	871	18	0,066	123	0,113	23	54	16	513
Zlewnia Brynicy od Szarlejki do Rawy	a	<1	0,26	8	46	0,17	5,2	2	7	10	0,80	<0,02	0,07	74	7	0,026	229	0,051	10	36	7	416
Catchment of the Brynica River from the Szarlejka Stream to the Rawa Stream	b	2	1,83	85	281	11,53	79,8	12	290	2078	3,08	0,78	3,53	2239	63	0,820	3927	1,680	241	233	31	31 946
n = 46	c	1	0,89	33	129	2,15	30,6	7	29	155	1,94	0,28	0,63	776	26	0,250	657	0,588	56	86	20	8741
	d	1	0,83	29	120	1,49	24,3	6	23	68	1,84	0,21	0,50	580	23	0,171	555	0,409	45	78	19	4829
	e	1	0,90	33	126	1,50	26,2	7	26	65	1,91	0,21	0,59	544	25	0,149	524	0,402	47	67	20	3592

Tabela 4 cd.
Table cont.

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
Brynica *Brynica River* n = 23	a	<1	0,33	11	46	0,35	9,1	2	7	10	0,80	0,04	0,15	134	8	0,068	229	0,142	12	40	7	3222
	b	2	1,83	46	281	3,43	79,8	12	37	615	3,08	0,78	0,85	2239	53	0,817	1341	1,679	94	159	31	31 946
	c	2	1,04	30	135	1,84	44,7	8	28	96	2,24	0,41	0,62	922	33	0,402	592	0,872	60	73	21	15 497
	d	1	0,98	27	122	1,59	39,1	7	26	69	2,14	0,34	0,58	689	30	0,341	541	0,714	54	67	20	13 309
	e	2	1,08	33	123	1,77	40,9	8	30	78	2,27	0,40	0,63	625	33	0,363	581	0,795	59	60	20	14 798
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 the 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*

Parametry statystyczne przewodności elektrolitycznej właściwej, odczynu oraz 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 (wszystkie próbki)	a	0,08	5,17	<0,05	0,9	<2	0,01	0,020	<0,05	8,2	<0,05	<0,05	<0,003	0,27	<0,01	<0,5	<0,3	1,6	<0,001	<0,05	1,0	0,5	<0,05	<0,05	5	<0,05	<2	0,7	0,037	<0,002	<0,05	<0,05	<1	<0,003
Surface water (all samples)	b	8,95	9,70	<0,05	3346,9	17	1,02	0,279	0,55	270,8	8,08	21,51	0,005	6,97	16,62	120,4	279,1	109,1	6,232	12,97	1872,2	25,9	6,69	24,39	587	3,83	4	25,7	0,775	0,008	2,34	10,25	8	2,216
n = 276	c	0,87	7,45	–	65,3	–	0,14	0,094	–	91,1	0,27	0,90	–	1,51	0,47	7,8	10,2	28,1	0,327	0,67	36,0	3,6	–	0,82	136	0,27	–	10,8	0,221	–	0,15	1,00	–	0,111
	d	0,76	7,42	–	12,2	–	0,11	0,086	–	79,6	0,08	0,17	–	1,28	0,05	5,2	4,7	22,3	0,095	0,41	18,5	2,5	–	0,22	96	0,18	–	9,9	0,178	–	0,06	0,66	–	0,018
	e	0,74	7,49	–	9,2	–	0,12	0,092	–	90,9	0,06	0,16	–	1,34	0,04	5,8	5,1	24,8	0,148	0,45	20,7	2,2	–	0,18	81	0,21	–	10,9	0,188	–	0,05	0,90	–	0,011
Strumienie i rowy bez nazwy	a	0,08	5,17	<0,05	0,9	<2	0,01	0,022	<0,05	8,2	<0,05	<0,05	<0,003	0,43	<0,001	1,0	<0,3	1,6	<0,001	<0,05	1,0	0,6	<0,05	<0,05	5	<0,05	<2	5,3	0,037	<0,002	<0,05	<0,05	<1	<0,003
Streams and ditches no name	b	2,05	8,86	<0,05	3346,9	17	0,70	0,279	0,55	270,8	8,08	21,51	0,005	5,13	16,62	25,6	61,8	105,5	6,232	3,84	148,3	25,9	6,69	24,39	587	2,19	<2	25,7	0,775	0,007	0,62	10,25	7	1,983
n = 137	c	0,83	7,31	–	115,5	–	0,15	0,099	–	88,9	0,41	1,18	–	1,42	0,77	6,2	8,9	25,3	0,402	0,62	23,8	3,5	–	1,21	118	0,27	–	12,2	0,209	–	0,07	1,12	–	0,073
	d	0,73	7,27	–	15,3	–	0,11	0,089	–	72,2	0,11	0,23	–	1,23	0,09	4,6	4,5	18,6	0,125	0,34	14,6	2,5	–	0,26	79	0,16	–	11,7	0,163	–	0,05	0,58	–	0,018
	e	0,78	7,40	–	9,2	–	0,11	0,098	–	90,1	0,08	0,20	–	1,21	0,06	4,9	5,4	22,3	0,207	0,33	16,4	2,3	–	0,20	72	0,21	–	11,4	0,178	–	0,05	0,90	–	0,012
Zlewnia zb. Kozłowa Góra	a	0,08	5,17	<0,05	12,3	<2	0,05	0,051	<0,05	8,2	0,06	0,13	<0,003	0,43	0,03	1,9	2,0	1,6	0,039	<0,05	1,0	0,7	<0,05	0,14	6	0,11	<2	5,3	0,039	<0,002	<0,05	<0,05	<1	0,009
Catchment of the Kozłowa Góra reservoir	b	1,59	7,28	<0,05	3346,9	16	0,14	0,180	0,55	115,2	8,08	7,43	0,004	5,13	4,44	9,3	17,7	26,2	0,706	0,44	148,3	10,0	0,22	24,39	278	1,16	<2	25,7	0,324	0,007	0,62	0,44	7	1,983
n = 19	c	0,70	6,27	–	680,0	–	0,09	0,108	0,19	32,1	2,00	2,50	–	1,68	1,34	3,5	7,9	7,3	0,296	0,14	17,0	5,1	–	5,34	55	0,36	–	14,8	0,101	–	0,14	0,14	–	0,386
	d	0,49	6,25	–	250,7	–	0,08	0,101	0,12	23,5	0,90	1,45	–	1,30	0,69	3,2	6,8	5,2	0,230	0,09	5,3	3,8	–	1,98	37	0,31	–	13,9	0,085	–	0,09	0,09	–	0,176
	e	0,47	6,24	–	218,7	–	0,08	0,108	0,20	17,9	1,84	2,28	–	1,27	0,98	2,7	7,2	4,6	0,267	0,13	3,5	5,5	–	3,26	40	0,27	–	14,5	0,083	–	0,12	0,08	–	0,300
Zlewnia Jaworznika	a	0,11	5,96	<0,05	1,8	<2	0,01	0,063	<0,05	9,1	<0,05	<0,05	<0,003	0,45	<0,01	1,0	<0,3	1,7	<0,001	<0,05	1,7	0,5	<0,05	<0,05	5	<0,05	<2	0,7	0,037	<0,002	<0,05	<0,05	<1	<0,003
Catchment of the Jaworznik Stream	b	8,95	9,70	<0,05	518,6	17	0,69	0,279	0,22	172,9	1,94	6,76	<0,003	6,90	16,62	120,4	279,1	40,5	6,232	12,97	1872,2	25,4	6,69	8,52	267	2,19	3	22,5	0,471	0,004	0,46	3,67	8	0,252
n = 105	c	0,78	7,46	–	23,6	–	0,08	0,111	–	78,3	–	–	–	1,10	0,52	5,7	6,4	23,3	0,241	0,76	36,2	1,9	–	0,50	82	0,24	–	8,2	0,145	–	–	0,92	–	0,018
	d	0,68	7,45	–	9,8	–	0,06	0,107	–	72,6	–	–	–	0,94	0,02	3,3	2,6	21,2	0,035	0,42	14,7	1,4	–	0,23	70	0,12	–	7,2	0,124	–	–	0,75	–	0,008
	e	0,69	7,45	–	8,3	–	0,06	0,103	–	80,6	–	–	–	0,82	0,02	2,4	2,2	24,6	0,030	0,31	11,6	1,2	–	0,19	74	0,11	–	8,6	0,109	–	–	0,94	–	0,009
Jaworznik	a	0,51	7,25	<0,05	3,3	<2	0,02	0,063	<0,05	58,2	<0,05	<0,05	<0,003	0,62	<0,01	1,3	1,1	22,4	<0,001	0,15	7,5	0,7	<0,05	0,07	57	<0,05	<2	2,8	0,076	<0,002	<0,05	0,55	<1	<0,003
Jaworznik Stream	b	1,07	8,04	<0,05	30,9	2	0,12	0,202	<0,05	108,4	0,29	0,22	<0,003	1,69	0,16	12,0	11,8	40,5	0,223	1,25	65,1	5,1	1,18	2,52	258	0,50	<2	10,1	0,357	0,004	0,46	1,20	<1	0,117
n = 28	c	0,67	7,58	–	9,5	–	0,06	0,099	–	75,2	–	–	–	0,90	0,04	4,2	2,5	25,5	0,076	0,46	19,0	1,4	–	0,33	80	0,14	–	6,3	0,115	–	–	0,91	–	0,012
	d	0,66	7,57	–	8,5	–	0,05	0,097	–	73,5	–	–	–	0,87	0,02	3,4	2,1	25,4	0,030	0,42	16,1	1,2	–	0,20	76	0,10	–	5,9	0,109	–	–	0,89	–	0,006
	e	0,68	7,57	–	9,1	–	0,06	0,097	–	65,4	–	–	–	0,83	0,02	2,6	2,2	24,8	0,032	0,45	12,7	1,2	–	0,15	80	0,17	–	6,1	0,105	–	–	0,95	–	0,005
Jezioro Rogoźnickie	a	0,38	7,28	<0,05	1,8	<2	0,04	0,076	<0,05	42,3	<0,05	<0,05	<0,003	0,46	<0,01	1,4	1,1	14,3	0,001	0,18	5,7	0,5	<0,05	<0,05	36	0,07	<2	0,7	0,064	<0,002	<0,05	0,38	<1	<0,003
Lake Rogoźnickie	b	0,68	8,14	<0,05	16,0	<2	0,10	0,111	<0,05	90,0	0,07	<0,05	<0,003	1,14	0,19	2,4	2,4	29,0	0,077	0,30	12,3	1,1	<0,05	0,41	100	0,13	<2	6,9	0,131	<0,002	<0,05	1,09	<1	0,009
n = 19	c	0,57	7,67	–	5,9	–	0,06	0,100	–	63,4	–	–	–	0,75	–	1,9	2,0	24,9	0,015	0,26	10,9	0,9	–	0,14	77	0,11	–	4,1	0,102	–	–	0,91	–	–
	d	0,57	7,67	–	4,9	–	0,05	0,100	–	62,5	–	–	–	0,72	–	1,9	2,0	24,6	0,009	0,26	10,7	0,8	–	0,11	75	0,11	–	3,5	0,101	–	–	0,88	–	–
	e	0,59	7,65	–	5,1	–	0,05	0,104	–	64,0	–	–	–	0,65	–	1,9	2,2	25,6	0,008	0,27	11,4	0,9	–	0,09	78	0,11	–	4,3	0,101	–	–	0,98	–	–
Zlewnia Wielonki	a	0,36	6,56	<0,05	1,0	<2	0,05	0,026	<0,05	44,9	<0,05	<0,05	<0,003	0,62	<0,01	1,8	<0,3	7,3	0,003	0,10	3,0	1,0	<0,05	<0,05	41	<0,05	<2	7,0	0,052	<0,002	<0,05	<0,05	<1	<0,003
Catchment of the Wielonka Stream	b	1,20	8,82	<0,05	132,7	4	0,55	0,187	0,08	162,8	2,10	21,51	0,005	4,88	2,25	18,0	22,0	38,1	3,823	3,37	60,7	19,0	0,72	8,31	196	0,77	<2	20,1	0,528	0,003	0,10	3,55	2	0,271
n = 69	c	0,74	7,66	–	13,9	–	0,19	0,085	–	88,0	0,16	0,72	–	1,40	0,22	7,0	7,3	23,5	0,307	0,61	23,4	2,7	0,07	0,41	94	0,22	–	12,0	0,208	–	0,05	1,02	–	0,020
	d	0,71	7,64	–	8,2	–	0,18	0,078	–	85,6	0,07	0,16	–	1,33	0,06	6,4	5,0	22,0	0,134	0,47	18,9	2,4	0,05	0,13	89	0,18	–	11,8	0,195	–	0,04	0,84	–	0,009
	e	0,73	7,70	–	7,1	–	0,19	0,077	–	92,9	0,06	0,15	–	1,37	0,05	7,3	5,8	26,8	0,135	0,57	26,8	2,3	0,06	0,10	94	0,21	–	12,6	0,199	–	0,05	0,95	–	0,008
Wielonka	a	0,36	7,13	<0,05	4,8	<2	0,12	0,054	<0,05	44,9	<0,05	<0,05	<0,003	1,14	0,01	2,0	<0,3	10,1	0,027	0,10	7,5	1,8	<0,05	<0,05	46	0,12	<2	9,7	0,120	<0,002	<0,05	0,14	<1	<0,003
Wielonka Stream	b	0,84	8,32	<0,05	11,7	<2	0,23	0,085	<0,05	95,4	0,82	0,81	<0,003	4,88	0,50	9,1	15,4	28,7	0,727	0,86	34,4	4,2	0,15	0,32	115	0,29	<2	14,2	0,246	<0,002	0,08	1,40	<1	0,023
n = 27	c	0,73	7,74	–	7,4	–	0,19	0,070	–	86,1	–	0,16	–	1,60	0,06	7,1	8,2	24,1	0,135	0,58	27,8	2,3	0,07	0,10	97	0,20	–	12,5	0,209	–	0,05	0,94	–	0,007
	d	0,72	7,74	–	7,2	–	0,19	0,069	–	85,2	–	0,09	–	1,53	0,03	6,9	5,7	23,6	0,094	0,52	27,1	2,3	0,06	0,09	95	0,20	–	12,4	0,207	–	0,05	0,89	–	0,006
	e	0,74	7,77	–	7,6	–	0,19	0,071	–	93,5	–	0,07	–	1,46	0,03	7,3	10,4	27,2	0,115	0,63	28,1	2,2	0,07	0,09	106	0,20	–	12,7	0,212	–	0,06	0,93	–	0,006
Zlewnia Czarnej Przemszy od zb. Przeczyce do Brynicy	a	0,29	6,45	<0,05	0,9	<2	0,04	0,020	<0,05	25,4	<0,05	<0,05	<0,003	0,59	<0,01	1,3	<0,3	4,0	0,007	0,08	4,0	0,6	<0,05	<0,05	40	<0,05	<2	3,7	0,088	<0,002	<0,05	<0,05	<1	0,004
Catchment of the Czarna Przemsza River from the Przeczyce reservoir dam to the Brynica River	b	2,05	8,86	<0,05	78,7	4	0,70	0,223	0,46	270,8	0,96	19,42	<0,003	3,50	7,04	16,6	61,8	105,5	2,839	3,77	130,0	25,9	0,22	0,82	587	0,66	<2	19,8	0,775	0,002	0,19	10,25	1	0,121
n = 40	c	1,03	7,62	–	17,1	–	0,21	0,072	–	119,0	0,21	2,23	–	1,80	0,68	6,9	16,1	38,0	0,521	0,56	28,9	6,6	–	0,20	226	0,21	–	13,5	0,312	–	–	1,65	–	0,028
	d	0,87	7,60	–	9,4	–	0,17	0,063	–	99,8	0,12	0,33	–	1,68	0,13	5,8	6,0	26,6	0,215	0,37	20,1	4,1	–	0,12	156	0,15	–	13,0	0,254	–	–	0,76	–	0,016
	e	0,92	7,64	–	10,9	–	0,14	0,070	–	105,3	0,12	0,30	–	1,74	0,11	5,8	10,7	22,4	0,212	0,45	19,2	3,0	–	0,10	189	0,21	–	14,0	0,224	–	–	1,18	–	0,014
Zlewnia Brynicy od Szarlejki do Rawy	a	0,36	6,80	<0,05	1,9	<2	0,09	0,022	<0,05	57,1	<0,05	<0,05	<0,003	0,27	0,01	<0,5	0,5	6,9	0,005	0,12	1,6	0,9	<0,05	0,08	8	0,22	<2	2,1	0,126	<0,002	<0,05	<0,05	<1	<0,003
Catchment of the Brynica River from the Szarlejka Stream to the Rawa Stream	b	1,90	8,53	<0,05	177,4	15	1,02	0,220	<0,05	198,1	1,46	2,39	<0,003	6,97	1,93	58,5	231,7	109,1	5,055	6,49	137,8	12,0	0,85	9,05	558	3,83	4	23,2	0,700	0,008	2,34	3,41	4	2,216
n = 43	c	1,27	7,42	–	23,2	–	0,18	0,082	–	127,4	–	0,57	–	2,36	0,15	17,0	19,7	47,5	0,400	0,90	70,8	5,8	0,29	0,85	287	0,47	–	11,0	0,396	–	–	0,96	–	0,439
	d	1,21	7,42	–	13,0	–	0,16	0,073	–	123,2	–	0,32	–	1,94	0,04	12,4	12,8	41,5	0,199	0,66	50,5	5,0	0,20	0,34	221	0,39	–	10,4	0,371	–	–	0,71	–	0,129
	e	1,25	7,45	–	11,1	–	0,14	0,068	–	119,9	–	0,33	–	1,98	0,02	12,2	13,6	44,4	0,245	0,65	66,1	5,6	0,22	0,23	276	0,36	–	11,3	0,375	–	–	0,86	–	0,120

Tabela 5 cd.
Table cont.

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
Brynica *Brynica River* n = 26	a	1,09	7,19	<0,05	7,6	<2	0,11	0,047	<0,05	110,8	<0,05	0,06	<0,003	1,38	0,01	10,0	12,3	40,4	0,096	0,45	57,0	5,2	0,12	0,08	270	0,24	<2	8,8	0,340	<0,002	0,51	0,50	<1	0,087
	b	1,90	7,65	<0,05	141,3	5	0,18	0,073	<0,05	198,1	1,00	0,54	<0,003	3,69	0,42	18,5	22,6	80,8	0,333	0,85	117,8	12,0	0,56	5,55	558	0,56	4	13,2	0,700	0,002	2,34	1,01	<1	2,216
	c	1,40	7,42	–	17,8	–	0,14	0,061	–	140,4	–	0,30	–	2,13	0,03	12,7	15,9	54,2	0,208	0,65	76,6	7,2	0,30	0,40	355	0,35	–	11,0	0,453	–	0,91	0,79	–	0,703
	d	1,37	7,42	–	13,5	–	0,14	0,061	–	137,9	–	0,27	–	2,07	0,02	12,4	15,6	52,9	0,197	0,63	74,4	7,0	0,26	0,21	344	0,35	–	11,0	0,440	–	0,80	0,77	–	0,480
	e	1,37	7,45	–	11,4	–	0,14	0,068	–	121,6	–	0,33	–	1,97	0,01	12,1	13,8	46,7	0,242	0,65	65,7	6,1	0,22	0,20	294	0,35	–	10,5	0,402	–	0,75	0,78	–	0,695
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
Środowiskowe normy jakości dla wskaźników stanu chemicznego jednolitych części wód powierzchniowych[2)] *Environmental quality standards for chemical status indicators of uniform part of 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) *(classes 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 (Rozporządzenie..., 2021)

[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 (Rozporządzenie..., 2021)

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, 0.1–0.02 mm – silt fraction, and <0.02 mm – clay fraction (Plates 4–6). Changing the ranges of grain size groups in accordance with the guidelines of the Polish Soil Association (Klasyfikacja..., 2008) would make it difficult to compare the grain size composition with data from map sheets developed earlier.

The grain size composition of the investigated soils is dominated by the sand fraction (1.0–0.1 mm). Its highest content (>90%) was found mainly in areas of Quaternary glaciofluvial sands and gravels, slope wash loams, sands and gravels, as well as slope wash-fluvial sands, gravels and muds (Plate 4). The soils that are most sandy and contain the least amount of the silt and clay fractions (often <10%) are found in the north-western part of the study area, which is covered by forests. In contrast, those developed mainly on the outcrops of Triassic carbonates and on Carboniferous deposits show a higher proportion of the silt (0.1–0.02 mm) and clay fraction (<0.02 mm). The silt fraction content varies mostly between 10% and 25%, and the clay fraction is 10%–50%. 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 neutral (pH 6.8–7.4) and alkaline (pH > 7.4) pH. In the topsoil layer, the proportion of pH >7.4 soils is 54%, while in the subsoil layer it is 78%. The greater proportion of alkaline soils in the 0.8–1.0 m depth layer suggests that the alkalinization may be attributable to their development on Triassic carbonates. Very acidic (pH < 5.0) to acidic (pH 5.0–6.0) soils (Plates 7 and 8) are found in small areas where sandy formations are present in the bedrock and the terrain is covered predominantly by forests, particularly in the north-western part of the study area.

Geochemistry. The spatial distributions of the chemical elements analysed in the soils are indicative of both the lithology of the parent rocks (*i.e.* the source of the elements) and the influence of factors related to the diverse industrial activities.

In the topsoil layer, the distribution of elements whose primary sources are the parent rocks has been distorted as a result of anthropogenic processes. The median concentrations of the elements studied in the topsoil layer exceed the values defined as the geochemical background of the Silesian-Cracow region to varying degrees (with the exception of mercury) (Tab. 2). The median contents of cobalt, phosphorus and strontium are only slightly higher than the geochemical background level. The median concentrations of arsenic, barium, calcium, chromium, copper, iron, magnesium, manganese, nickel, sulphur, titanium and vanadium are markedly (about twice) higher. The content of lead is almost four times higher, and of cadmium and zinc – about five times higher.

The content of aluminum in the soils is mostly in the range of 0.40–0.80% (maximum 2.39%) in topsoil and 0.40–1.60% (maximum 3.73%) in subsoil (Plates 11 and 12). In regions characterized predominantly by glaciofluvial sands and gravels, the soils exhibit reduced concentrations of this element (<0.40%). The mobility of aluminium in soils is contingent on its combinations with organic matter and the extent of soil acidity (*e.g.* Kabata-Pendias, Mukherjee, 2007). The prevailing acidic pH is hypothesized to be the predominant factor promoting aluminium leaching from soils and facilitating its transfer into the aquatic environment.

The organic carbon content in the 0.0–0.3 m soil layer varies within a wide range of 0.10–31.99% (median 2.36%). The soil types, which are most abundant in this component (>6%), are natural peat soils and anthropogenic soils, including those occurring around post-mining heaps and dumps created as a result of coal mining (Plate 19). Its maximum content (31.99%) is recorded in a forest soil in the north-western part of the study area. The concentration of organic carbon in soils is dependent on the nature of land use. The median content of Corg in arable field soils is 1.92%, whilst in forest soils the median content is 2.89%. (Tab. 2).

The median sulphur contents calculated for topsoil of Poland and the Silesian-Cracow region are 0.012 and 0.015%, respectively (Lis, Pasieczna, 1995a, b). In the map sheet area, the sulphur content in the majority of soils from both analysed depths does not exceed 0.080%. Concentrations of this element in excess of 0.160% (Plates 48 and 49) were found in anthropogenic soils and in wetland areas (mainly in the Brynica River valley). The subsoil layer shows a higher proportion of soils containing up to 0.010% of sulphur.

The median content of phosphorus in the topsoil layer (0.038%) is twice that in subsoil (0.018%). The smallest amounts of this element (at both depths) are found in forest soils (the medians are 0.022 and 0.010%). Elevated phosphorus levels compared to the geochemical background of the Silesian-Cracow region are measured in the topsoil layer of cultivated fields (median 0.047%) and in rural areas (median 0.045%), which may be a consequence of application of phosphorus fertilizers and discharge of domestic sewage effluents. The highest phosphorus concentration in both sampling levels is found in anthropogenic soils in the central part of the map sheet area. There was a pit in that area in the past, which was reclaimed using most probably waste material. At the location, 2.360% of phosphorus was recorded in a sample from a depth of 0.0–0.3 m, and 2.022% in the subsoil layer. High contents of silver, copper, mercury, strontium and zinc are also observed there. Significant contents of phosphorus (0.590%), copper (158 mg/kg) and mercury (1.11 mg/kg) are recorded in wasteland soils near Żychcice at an abandoned limestone quarry (Plates 44 and 45). This geochemical anomaly is likely to be anthropogenic in nature, as evidenced by the fact that it does not occur in the underlying soil layer at the site.

The soils of the two depth intervals, which were developed on carbonate deposits, show a high concentration of calcium (>1.00%; Plates 20 and 21), magnesium (>0.50%; Plates 36 and 37), manganese (>400 mg/kg; Plates 38 and 39) and strontium (>40 mg/kg; Plates 53 and 54). These soils are also locally rich in cadmium, iron, cobalt, nickel, lead, vanadium and zinc. The distribution of the contents of these elements is more clearly marked in the deeper soil layers. This is also consistent with the occurrence of outcrops of Triassic limestones and dolomites, which may indicate that the bedrock was the primary source.

The average barium concentrations in soils of the Polish Lowlands do not exceed 55 mg/kg. In Upper Silesia, particularly in the area of outcrops of Carboniferous clay-sandy coal-bearing formations, the soils contain more than 100 mg/kg of this element (Lis, Pasieczna 1995a). The barium content of the soils in the study area (120–480 mg/kg) exceeds the geochemical background level of the region. Coal burning may increase the barium concentration in the soils due to dust fallout. 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 concentrations of barium (978 mg/kg in topsoil and 4,774 mg/kg in subsoil) are found in a sample taken from wasteland near the village of Rogoźnik (Plates 16 and 17). The site also demonstrates elevated manganese concentrations in both depth levels (4,963 and 21,157 mg/kg, respectively).

In the topsoil layer of European soils, the median concentrations of cadmium, lead and zinc do not exceed 0.145 mg/kg, 15 mg/kg and 48 mg/kg, respectively (Salminen, 2005). The median concentrations of these metals in soils of Poland and the Silesian-Cracow region are <0.5 and 1.3 mg/kg of cadmium, 13 and 44 mg/kg of lead, and 35 and 104 mg/kg of zinc, respectively (Lis, Pasieczna 1995a). In comparison with the above-presented data, the soils sampled from the map sheet area can be characterized as highly contaminated with the aforementioned metals (Tab. 2).

The map sheet area has a long tradition of mining. In the areas of historical mining of Zn-Pb and Fe ores, high levels of cadmium, lead and zinc were found in soils. These elements are associated mainly with the presence of zinc and lead ores of the carbonate formation and with mining and metallurgical activities. Their geochemical anomalies are found to extend over more extensive areas in topsoil (Plates 22, 46 and 61) than in subsoil (Plates 23, 47 and 62), indicating the anthropogenic factor as a significant contributing element to the contamination. However, these anomalies appear stronger in subsoil.

The spatial distributions of cadmium, lead and zinc exhibit a similarity that is more clearly marked in the subsoil layer. This may be due to the land surface transformation. In both soil layers, high concentrations of cadmium (>8.0 mg/kg; Plates 22 and 23), lead (>250 mg/kg; Plates 46 and 47) and zinc (>1,000 mg/kg; Plates 61 and 62) occur in the Gołąsza Górna – Góra Siewierska region (north-eastern part of the sheet) and in the Krzyżówka – Wojkowice – Dąbrówka Wielka region (south-western part of the sheet). In the topsoil layer, the highest concentrations of cadmium (135 mg/kg) and zinc (24,820 mg/kg) were recorded in a sample taken from wasteland on the southern outskirts of Wojkowice. In turn, the maximum concentration of these metals (cadmium 266.2 mg/kg, and zinc 29,800 mg/kg) in the subsoil layer (in wasteland and fallow land) is found in the area of Góra Siewierska, where ore mining was active in the past. Iron ores were mined there, as evidenced, among others, by the presence of funnels ranging to various depths (sources: https://www.kg.net.pl/tekst/7496/historia-powstania-gory-siewierskiej [access: 4.11.2024]). Refractory clay deposits and limonite iron ores occurred in the cavities of Triassic limestones (Piwowar, Ciuk, 1936). These ores also contained small amounts of zinc, lead and manganese (Wójcik, Siembab, 2020). The occurrence of the mineral deposit was also documented, i.a., in the vicinity of Siemonia, Rogoźnik and Sączów. In Żychcice, calamine was mined in the “Barbara” mine from 1818 onwards. Later on, the “Kasper” mine and the “Herkules” calamine washing plant were established (Piwowar, Ciuk, 1936; Wójcik, 2008 and references therein).

The highest concentration of lead (8,870 mg/kg) is observed in the subsoil layer from agricultural fields at Dąbrówka Wielka (Piekary Śląskie). The soil is also enriched in cadmium (52.8 mg/kg), zinc (21,350) mg/kg, arsenic (109 mg/kg), iron (6.19%) and manganese (2,554 mg/kg), which may be due to geological conditions. A well-marked lead anomaly (with a maximum of 6,300 mg/kg) is also observed in a topsoil sample taken from wasteland at the village of Brzękowice Górne. High concentrations of arsenic (244 mg/kg), cobalt (46 mg/kg), iron (20.97%), manganese (16,228 mg/kg) and zinc (6,638 mg/kg) are also recorded here.

In the area of anomalous contents of cadmium, zinc and lead, the soils also locally show pronounced concentrations of arsenic. High amount of this element (>10 mg/kg) in the topsoil layer may be related to a high proportion of the silt and clay fractions in the soils. It is supposed that the greatest concentrations of, i.a., arsenic and metals are found in soils containing higher amounts of the clay fraction, as well as in organic soils (Kabata-Pendias, Pendias, 1999; Lombi *et al.*, 2000; Karczewska *et al.*, 2010). The maximum arsenic concentration (355 mg/kg) in the topsoil layer was measured in anthropogenic soil south of the Osiedle Robotnicze residential area (Rogoźnik). The highest concentration of arsenic (531 mg/kg) in subsoil was found in the village of Siewierska Góra (Plates 13 and 14). At that location, the following concentrations were measured: cadmium 74.1 mg/kg, zinc

6,686 mg/kg, iron 9.37%, manganese 3,512 mg/kg, nickel 85 mg/kg, and lead 533 mg/kg, which may indicate a relationship between these elements and the bedrock geology. Moreover, elevated concentrations of arsenic were identified in this depth level at Dąbrówka Wielka (Piekary Śląskie) in soil of a railway embankment (443 mg/kg) and at Wojkowice in the Brynica River valley (475 mg/kg).

Silver concentrations of >4 mg/kg were found locally within both depth intervals (Plates 9 and 10). The maximum concentration of this metal (16 mg/kg) was recorded in the topsoil layer of anthropogenic soil in the urban area of Dąbrówka Wielka. In most of the investigated soils from both layers analysed, the concentration of copper does not exceed 20 mg/kg. High concentrations of this element (>160 mg/kg) were recorded mainly in anthropogenic soils. The highest concentration (18,426 mg/kg) is found in a topsoil sample from a reclaimed area of a spoil heap of the former KWK "Jowisz" mine at Wojkowice (Plates 28 and 29).

In the topsoil layer of Europe, the median concentration of mercury is 0.037 mg/kg (Salminen, 2005). In Poland, the concentration of the element in soils varies from <0.05 to 7.55 mg/kg, and the median is <0.05 mg/kg (Lis, Pasieczna, 1995a). In the map sheet area, the mercury concentration in most of the studied soils is below 0.20 mg/kg (Plates 32 and 33). An anomalous occurrence of this element, manifested in both sampling levels (2.15 mg/kg in topsoil and 2.38 mg/kg in subsoil), was identified in anthropogenic soil from the central part of the map sheet area. High contents of silver, copper, phosphorus, strontium and zinc also are recorded at the site. Examining the mercury concentration in the subsoil layer exclusively, the maximum level (3.45 mg/kg) was recorded at Wojkowice in the Brynica River valley in a sample taken from a levee. This soil is also enriched in silver (5 mg/kg), arsenic (475 mg/kg), cadmium (92.2 mg/kg), lead (2,659 mg/kg), sulphur (0.685%) and zinc (13,360 mg/kg).

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 identified in 1.16% of the topsoil layer and 1.41% of the subsoil layer. The proportion of area occupied by soils contaminated by cadmium in the topsoil layer (>15 mg/kg) is 16.99%, by lead (>600 mg/kg) 4.71%, and by zinc (>2,000 mg/kg) 10.35%. At a depth of 0.8–1.0 m, the proportion of soils contaminated with these metals is 12.59% for cadmium, 3.67% for lead, and 10.56% for zinc. In the study area, the percentage of soils contaminated with the examined elements is significantly higher than in the Pyrzowice sheet adjoining to the north.

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 arsenic, 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 98.84–100% of the analysed soil samples.

Cadmium is notable by the fact that only 6.18% of soil samples met its requirements for group I. 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) were met by 88.65–100% of 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 (6.18–45.95%). Between 68.42 and 100% 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 and zinc (Tab. 7). This is significant because the land use in the map sheet area is largely agriculture (cultivated fields and grasslands) and wasteland. 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 (Tab. 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).

Tabela 6
Table

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

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

Pierwiastek *Element*	Zawartość *Content* [mg/kg]	Gleba *Soil*			
		0,0–0,3 m		0,8–1,0 m	
		[km²]	[%]*	[km²]	[%]*
As	<10	37,91	45,95	52,38	63,49
	10–25	32,94	39,92	18,96	22,98
	25–50	8,15	9,88	7,87	9,54
	50–100	2,54	3,09	2,13	2,58
	>100	0,96	1,16	1,16	1,41
Cd	<2	5,10	6,18	45,35	54,97
	2–5	25,36	30,74	12,71	15,40
	5–10	25,99	31,50	9,55	11,57
	10–15	12,04	14,59	4,52	5,48
	>15	14,01	16,99	10,39	12,59
Pb	<100	18,86	22,86	54,95	66,61
	100–200	31,28	37,91	12,13	14,70
	200–500	26,81	32,51	10,84	13,14
	500–600	1,66	2,01	1,55	1,88
	>600	3,89	4,71	3,03	3,67
Zn	<300	18,73	22,70	46,70	56,61
	300–500	17,38	21,08	6,51	7,89
	500–1000	23,64	28,65	11,42	13,84
	1000–2000	14,21	17,22	9,16	11,10
	>2000	8,54	10,35	8,71	10,56

* 82,5 km² = 100%

AQUATIC SEDIMENTS

Within the map sheet boundaries, sediments of watercourses and standing water bodies (named as sediments on the maps) were studied within the following catchments: Kozłowa Góra reservoir, Jaworznik Stream, Wielonka Stream, Czarna Przemsza River from the Przeczyce reservoir dam to the Brynica River, and Brynica River from the Szarlejka Stream to the Rawa 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 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.

Tabela 7
Table

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

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	1112	595	1240	1280	15
	3	85,87%	45,95%	95,75%	98,84%	1,16%
Ba	1	<400	<200	<1000	<1500	>1500
	2	1280	1148	1295	1295	0
	3	98,84%	88,65%	100,00%	100,00%	0,00%
Cr	1	<200	<150	<500	<1000	>1000
	2	1295	1295	1295	1295	0
	3	100,00%	100,00%	100,00%	100,00%	0,00%
Zn	1	<500	<300	<1000	<2000	>2000
	2	567	294	938	1161	134
	3	43,78%	22,70%	72,43%	89,65%	10,35%
Cd	1	<2	<2	<10	<15	>15
	2	80	80	886	1075	220
	3	6,18%	6,18%	68,42%	83,01%	16,99%
Co	1	<50	<20	<100	<200	>200
	2	1294	1291	1295	1295	0
	3	99,92%	99,69%	100,00%	100,00%	0,00%
Cu	1	<200	<100	<300	<600	>600
	2	1288	1275	1294	1295	0
	3	99,46%	98,46%	99,92%	100,00%	0,00%
Ni	1	<150	<100	<300	<500	>500
	2	1295	1295	1295	1295	0
	3	100,00%	100,00%	100,00%	100,00%	0,00%
Pb	1	<200	<100	<500	<600	>600
	2	787	296	1208	1234	61
	3	60,77%	22,86%	93,28%	95,29%	4,71%
Hg	1	<5	<2	<10	<30	>30
	2	1295	1294	1295	1295	0
	3	100,00%	99,92%	100,00%	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)

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

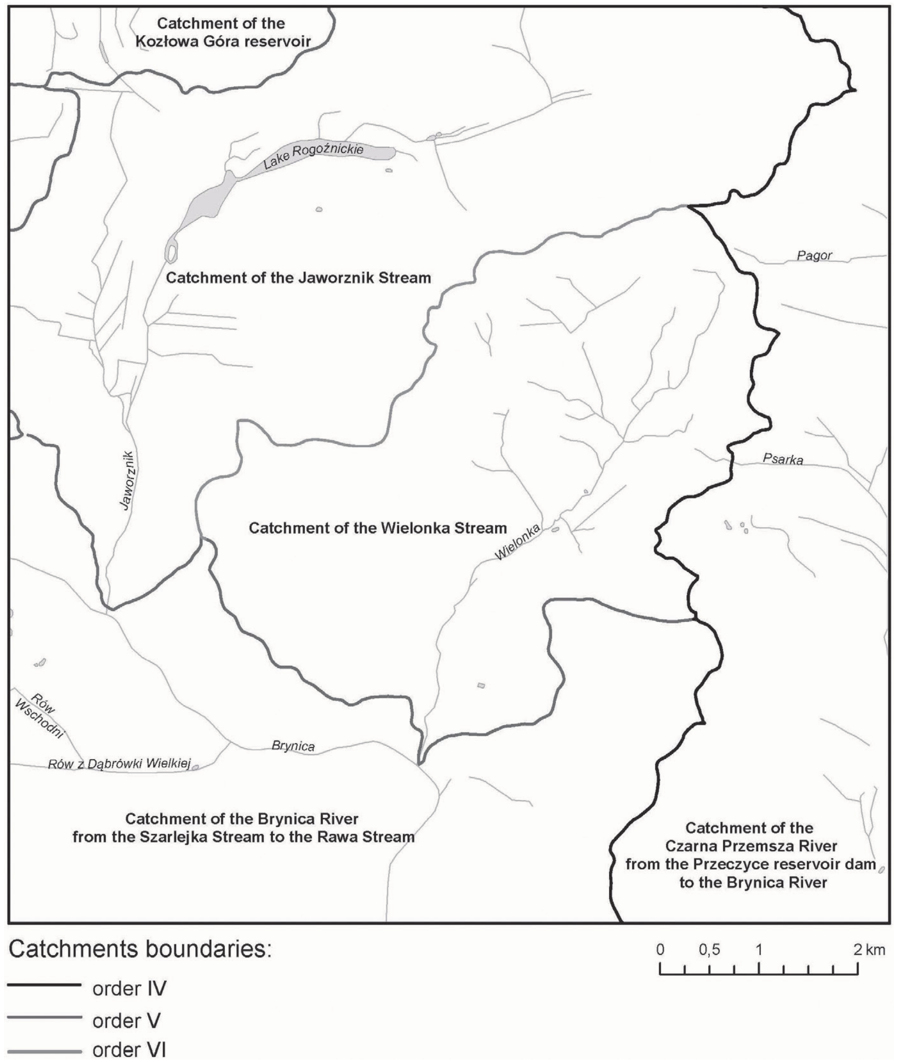


Fig. 3. Location of watercourses, standing water bodies and the catchments (https://wody.isok.gov.pl/imap_kzgw/ [access 12.09.2024])

Catchment of the Kozłowa Góra reservoir. This is a small area located in the north-western part of the map sheet, which is covered by forests. All sediment samples were taken from unnamed ditches and streams. The median concentrations of calcium, cobalt, magnesium, manganese, phosphorus and strontium in the sampled sediments are lower or close to the regional geochemical background level. Slightly higher median values are observed for chromium, nickel, titanium and vanadium. There are clear exceedances above the regional background level in the case of arsenic, barium, cadmium, copper, mercury, lead, sulphur and zinc (Tab. 4).

In the streams near the northern boundary of the catchment area, the sediments, which are locally rich in organic matter, are characterized by significant concentrations of most of the elements studied. The reported levels were as follows: 57–142 mg/kg arsenic, 18.3–109.9 mg/kg cadmium, 12–23 mg/kg chromium, 13–96 mg/kg copper, 3.13–5.65% iron, 32–165 mg/kg nickel, 229–2,321 mg/kg lead, and 1,344–9,036 mg/kg zinc. The sediments are also rich in aluminium (0.31–1.32%), barium (45–879 mg/kg) and manganese (301–25,208 mg/kg).

The PEC threshold was exceeded in some samples for arsenic, cadmium, nickel, lead and zinc. The greatest number of samples in which this indicator was exceeded were reported for cadmium and lead (80%) and zinc (59%), which points to a high risk of harmful effects on aquatic organisms.

The Jaworznik Stream catchment is located in the north-western and northern part of the map sheet. Land use in the catchment area is diverse, including cultivated fields, wasteland and forestry. The catchment extends over part of the massive area of Triassic deposits that form extensive outcrops. The Jaworznik Stream valley is lined by Quaternary sediments of floodplain terraces and slope wash and fluvial sands, gravels and silts (Plate 1).

The median contents of most of the chemical elements analysed in aquatic sediments of the catchment area are lower or close to the geochemical background level of the Silesian-Cracow region. Only cadmium, magnesium, lead, sulphur, titanium and zinc are slightly above their background levels (Tab. 4).

Relatively high concentrations of metals and arsenic were measured mainly in the western part of the catchment, in some sediment samples taken from unnamed watercourses draining mainly wasteland. A maximum of 82 mg/kg arsenic, 58.3 mg/kg cadmium, 86 mg/kg copper, 37 mg/kg chromium, 772 mg/kg lead, and 3,156 mg/kg zinc were found there. The sediments also show high levels of barium (up to 645 mg/kg), manganese (14,932 mg/kg) and cobalt (33 mg/kg). One of the likely sources of the elements is surface runoff. Sediments from an unnamed ditch draining gardens in the Osiedle Robotnicze (Rogoźnik) residential area are characterized by high concentrations of iron (13.85%), manganese (12,210 mg/kg), phosphorus (3.081%) and strontium (231 mg/kg). This is presumably due to municipal contamination or surface runoff of rainwater from agricultural land.

In the middle reach of the Jaworznik Stream is **Lake Rogoźnickie**. During the growing season, the bottom of the eastern, shallower part of the lake (Rogoźnik II reservoir) is covered by underwater vegetation, while its western part is devoid of it. Following the growing season, the vegetation dies and its remains settle to the bottom of the lake to undergo decomposition processes. This also leads to a gradual accumulation of bottom sediments (Machowski, Rzętała, 2023). Fine-grained organic sediments in the eastern part of the reservoir contain higher levels of some elements. Maximum levels have been reported there as follows [mg/kg]: 17.9 cadmium, 18 copper, 12 nickel, 95 lead, 52 titanium, 24 vanadium, and 376 zinc. The sediments also contain relatively high concentrations of strontium (51 mg/kg), calcium (up to 10.38%) and manganese (up to 538 mg/kg).

Analysis of the results shows that approximately 36–40% of aquatic sediments sampled within the catchment area, mostly from unnamed streams and ditches, contained higher levels of cadmium, lead and zinc relative to the PEC values. For arsenic, exceedances were recorded in eight samples.

The Wielonka Stream catchment extends over the central part of the map sheet. The land use in this catchment area is diverse, being mainly wasteland and to a lesser extent agricultural land (arable fields and grassland) and woodland. The Wielonka Stream valley is lined by Quaternary deposits of floodplain terraces and valley bottoms, as well as by slope wash and fluvial sands, gravels and muds (Plate 1).

Sediments from the Wielonka Stream, as well as from the entire catchment area, are characterized by similar or higher median contents of most elements compared to the regional geochemical background level. They show a very clear enrichment in manganese. In contrast, the median values of mercury, phosphorus and strontium are lower than the geochemical background level (Tab. 4).

The aluminium content in sediments of the Wielonka Stream is generally in the range of 0.20–0.79%, with only two samples exceeding 1%. Arsenic (4–11 mg/kg) and mercury (<0.02–0.05 mg/kg) remain mostly within the geochemical background range of the Silesian-Cracow region. The concentrations of calcium and magnesium are characterized by slight variability, fluctuating mostly within the limits of 0.27–1.64% and 0.12–0.50%, respectively. In the lower reach of the Wielonka Stream, upstream of the confluence with the Brynica River, the sediment is characterized by high concentrations of arsenic (25 mg/kg), mercury (0.14 mg/kg), manganese (2,397 mg/kg), sulphur (0.682%), strontium (79 mg/kg) and zinc (1,708 mg/kg). The sample was collected from an urban area, close to buildings, so the likely source of the elements is urban contamination.

High levels of metals, arsenic, phosphorus and sulphur are recorded in the sediments of an unnamed stream draining meadows are recorded near Cieluchowce. The concentrations are as follows: 394 mg/kg barium, 19.6 mg/kg cadmium, 362 mg/kg cobalt, 6.79% iron, 24,222 mg/kg manganese, and 260 mg/kg nickel. The sediments are also rich in arsenic (29 mg/kg), lead (148 mg/kg) and zinc (1,789 mg/kg). In the same area, the sediments of an unnamed ditch being a left-hand tributary of the Wielonka Stream contain copper (101 mg/kg), phosphorus (0.506%) and sulphur (2,900%). In turn, in the Krzyżówka region, near the western boundary of the catchment, aquatic sediments from a pond (probably of post-mining origin) show the catchment's highest concentrations of calcium (6.92%), cadmium (33.2 mg/kg), chromium (233 mg/kg), mercury (0.97 mg/kg), lead (545 mg/kg), strontium (107 mg/kg) and zinc (3,477 mg/kg).

The levels of arsenic, chromium and nickel exceed their PEC thresholds only in a few aquatic sediment samples collected in the catchment. In contrast, the percentages of samples in which the measured contents of cadmium, lead and zinc exceeded the levels are considerably higher: 42%, 21% and 56%, respectively.

Catchment of the Czarna Przemsza River from the Przeczyce reservoir dam to the Brynica River. The part of the catchment area that is located within the study area occupies the territory extending along the eastern edge of the map sheet. Its area includes short sections of the Pagor and Psarka streams, which are direct tributaries of the Przemsza River (outside the map sheet boundaries). Both these watercourses have their headwaters in the study area; the Pagor Stream takes its origin in the Golęsza Dolna region, while the Psarka Stream at the village of Psary at the junction of Łączna Street and Boczna Street (Prognoza..., 2020).

Sediments sampled within the catchment contain the analysed elements, expressed as their median values, in the ranges close to or above the regional geochemical background level. The median concentrations of arsenic, cadmium, cobalt, iron, lead, sulphur and zinc are approximately twice the background values, while the median concentration of manganese is three times higher. The median values of calcium and strontium in the samples are lower than the background level (Tab. 4).

Sediments from an unnamed stream flowing through a wooded area near the south-eastern boundary of the map sheet show significant concentrations of some elements, including 1.80–18.39% calcium, 3.6–13.9 mg/kg cadmium, 6–25 mg/kg cobalt, 871–24,563 mg/kg manganese, and 30–212 mg/kg strontium. The sediments are also rich in phosphorus (up to 0.440%) and sulphur (up to 0.932%). In the Nowy Grodków region, on the other hand, a sample of aquatic sediment collected from a ditch that drains farmland (near the provincial road 913) shows the catchment's highest concentrations of barium (3,069 mg/kg), cobalt (73 mg/kg), iron (10.25%) and manganese (44,978 mg/kg). Moreover, the sediment also exhibits high concentrations of lead (332 mg/kg) and zinc (1,254 mg/kg). A nearby transport route and the leaching of elements from the catchment area may also be additional sources of the contamination. This is facilitated by the slight slopie of the land.

Concentrations of arsenic, chromium and nickel are above their PEC thresholds in only a few aquatic sediment samples collected within the catchment area. As for cadmium, lead and zinc, the percentage of samples for which this threshold is exceeded is significantly higher: 70%, 46% and 60%, respectively.

The south-western and southern parts of the map sheet area lie within the **catchment of the Brynica River from the Szarlejka Stream to the Rawa Stream**. Within the sheet boundaries, the Brynica River flows in a regulated, concreted and embanked channel. The median contents of the analysed chemical elements in aquatic sediments of the catchment area above the geochemical background level of the Silesian-Cracow region. Relatively high levels of arsenic, cadmium, copper, lead and zinc are clearly evident in the sediments (Tab. 4).

Downstream of the mouth of the Rów z Orła Białego ditch (beyond the western boundary of the map sheet), high concentrations of cadmium, copper, lead and zinc are particularly evident in sediments of the Brynica River. The levels are as follows in that area [mg/kg]: 2–8 silver, 60–130 cadmium, 570–750 lead, and 17,720–33,190 zinc. According to Pasieczna and Konon (2021), the sediment contamination originates from dewatering of post-mining spoil heaps, from zinc and lead ore processing and long-term zinc metallurgy, as well as from surface runoff in the area of soils contaminated with these elements. The present study of the Brynica River sediments shows varying concentrations of metals, ranging as follows [mg/kg]: <1–2 silver, 9.1–79.8 cadmium, 229–1,341 lead, and 3,222–31,946 zinc. In addition, the alluvial deposits of the Brynica River are also distinguished from the aquatic sediments of the map sheet area by their high concentrations of mercury (often >0.20 mg/kg), phosphorus (>0.320%) and sulphur (>0.600%).

Analysis of the results shows that approximately 98-100% of aquatic sediments sampled in the catchment area are characterized by higher concentrations of cadmium, lead and zinc relative to the PEC values. For arsenic, exceedances were found in about 46% of the samples. In contrast, concentrations of chromium, copper and nickel exceeded their PEC thresholds in only a few sediment samples.

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 environmental quality standards for chemical condition indicators of surface water bodies (Rozporządzenie..., 2021).

Catchment of the Kozłowa Góra reservoir. The pH of the water in the catchment area is 5.17–7.28 and their specific electrolytic conductivity is 0.08–1.59 mS/cm. A high EC value (1.59 mS/cm) was recorded in an unnamed stream flowing through a forest area near the motorway. The catchment's highest concentrations [mg/dm^3] of calcium – 115.2, magnesium – 26.2, sodium – 148.3, sulphate – 278, and strontium – 0.324 are also observed at this location.

Water samples from the catchment area are characterized by lower levels of silver, arsenic, boron, barium, beryllium, cobalt, chromium, copper, molybdenum, antimony, selenium, titanium, thallium and vanadium than the limits set for surface water quality classes I and II. Zinc also remains within these limits in most of the waters investigated. Its higher concentration (1.128 mg/dm^3 and 1.983 mg/dm^3) was found only in two samples. Taking into account the environmental quality standards for chemical status indicators in the samples studied, the concentrations of nickel in the samples did not exceed the permitted levels. The lead content of most of the waters analysed is also below the values specified in Rozporządzenie... (2021; Tab. 5).

The water collected from the catchment area is distinguished in a few samples by relatively high concentrations of aluminium and iron, ranging from 1,016.1 to 3,346.9 µg/dm^3 and from 2.05 to 4.44 mg/dm^3, respectively. In addition, a significant proportion of the waters sampled are classified as substandard due to high concentration of cadmium (1.84–8.08 µg/dm^3). Some of the samples with elevated concentrations of cadmium are also characterized by high levels of lead (10.75–24.49 µg/dm^3) and zinc (0.910–1.983 mg/dm^3). This is probably related to the low pH of the waters and soils in this area, which may have caused remobilization of the elements from the solid phase into solution.

Catchment of the Jaworznik Stream. The pH value of the waters in the catchment area varies between 5.96 and 9.70, and the specific electrolytic conductivity is between 0.11 and 8.95 mS/cm. Of note is the maximum EC value (8.59 mS/cm) measured for a water sample taken from a pond in the area of a disused limestone quarry, where construction and municipal waste (e.g. tyres, plastics, oils, *etc.*) was found. Relatively high levels of molybdenum (12.97 µg/dm^3), sodium (1,872.2 mg/dm^3), nickel (25.4 µg/dm^3) and sulphate (265 mg/dm^3) were also determined at this site.

The levels of silver, arsenic, boron, barium, beryllium, cobalt, chromium, copper, molybdenum, selenium, titanium, thallium, vanadium and zinc in the water of the catchment area and the Jaworznik Stream are below the limits defined for surface water quality classes I and II. For antimony and aluminium, only a few water samples from unnamed ditches show higher concentrations (2.19 µg/dm^3 and 518.6 µg/dm^3, respectively). Concentrations of nickel and lead also do not exceed the permitted levels set out in Rozporządzenie... (2021). Cadmium concentrations exceed the normative values in only a few samples, reaching a maximum value of 1.94 µg/dm^3 in an unnamed stream draining wasteland in the northern part of the catchment. At the same site, the water is also characterized by higher concentrations of iron (16.62 mg/dm3), aluminium (226.8 µg/dm^3), cobalt (6.76 µg/dm^3) and zinc (0.252 mg/dm^3) than elsewhere in the catchment area.

The concentrations of phosphorus in the waters of the catchment area are often below the limit of quantification (0.05 mg/dm^3). The highest concentration (6.69 mg/dm^3 at EC=1.47 mS/cm) was found in a ditch draining the treatment plant area. The recipient of the treated effluent is the Jaworznik Stream, whose waters downstream of the treatment plant show a significant increase in phosphorus concentrations (0.73–1.18 mg/dm^3).

The pH value of the water in **Lake Rogoźnickie** ranges from 7.28 to 8.14, and the specific electrolytic conductivity is from 0.38 to 0.68 mS/cm. The water contains relatively low concentrations of the elements analysed, including metals that are potentially toxic to living organisms. The concentrations of the elements do not exceed the normative values (Rozporządzenie..., 2021; Tab. 5)

Catchment of the Wielonka Stream. The catchment waters are characterized by EC values in the range of 0.36–1.20 mS/cm and pH values in the range of 6.56–8.82. They contain low levels of the analysed constituents compared to the limit values defined for surface water quality classes I and II (Rozporządzenie..., 2021; Tab. 5). They also typically show low concentrations of metals. In the waters, the concentrations of nickel and lead do not exceed 19.0 µg/dm^3 (median 2.3 µg/dm^3) and 8.31µg/dm^3 (median 0.10 µg/dm^3), respectively. Cadmium concentrations (median 0.06 µg/dm^3) in the majority of samples are also within the limit of the permissible values set out in Rozporządzenie...(2021). Only in four cases were higher concentrations of this metal determined, ranging between 0.82 and 2.10 µg/dm^3. The concentration of iron in the catchment waters is usually in the range of <0.01–0.10 mg/dm^3 (median 0.05 mg/dm^3). Its maximum content (2.25 mg/dm^3) was found near Cieluchowce, in a sample taken from an unnamed stream. The catchment's highest concentration of manganese (3.823 mg/dm^3) is also recorded at that location.

Catchment of the Czarna Przemsza River from the Przeczyce reservoir dam to the Brynica River. The pH value of the catchment waters varies between 6.45 and 8.86, and the specific electrolytic conductivity is between 0.29 and 2.05 mS/cm. Concentrations of the elements analysed do not exceed the normative levels (Rozporządzenie..., 2021; Tab. 5).

Water with an EC value of more than 1 mS/cm is found in streams of forested areas near the eastern boundary of the map sheet. The elevated EC in these watercourses is due mainly to the concentrations of boron (0.13–0.70 mg/dm^3), calcium (114.0–270.8 mg/dm^3), magnesium (20.0–105.5 mg/dm^3), sodium (21.1–130.0 mg/dm^3) and sulphate (97–587 mg/dm^3). Also of note is the concentration of some elements in the water over a short, concreted section of the Psarka Stream and in a nearby ditch, near the eastern boundary of the map sheet. It contains 2.074–2.839 mg/dm^3 of manganese, 13.48–19.42 µg/dm^3 of cobalt, 0.87–7.04 mg/dm^3 of iron, and 20.6–24.9 µg/dm^3 of nickel.

Catchment of the Brynica River from the Szarlejka Stream to the Rawa Stream. In the catchment area, the pH values vary between 6.80 and 8.53, and the specific electrolytic conductivity is between 0.36 and 1.90 mS/cm. The Brynica River is characterized by a slight variation in EC, ranging from 1.09 mS/cm to 1.90 mS/cm. The elevated EC (>1 mS/cm) in the catchment area is mainly due to the concentrations of sodium (57.7–137.8 mg/dm^3), lithium (12.3–231.7 µg/dm^3), calcium (76.2–198.1 mg/dm^3) and magnesium (37.2–109.1 mg/dm^3).

The levels of some constituents in the Brynica River waters are clearly influenced by its tributaries in the section of the watercourse in the adjacent area beyond the western boundary of the map sheet. The source of sodium is the waters of the Szarlejka Stream, as concentrations of this element were found downstream of its mouth at a level of 120–240 mg/dm^3. Downstream of the mouth of the Rów z Orła Białego ditch, 380–990 mg/dm^3 of sulphate and 1.55–6.41 µg/dm^3 of thallium were meassured in the Brynica River (Pasieczna, Konon, 2021). The present study of the Brynica River waters upstream of the confluence of the Jaworznik Stream with the Brynica River shows similar concentrations of sodium (114–118 mg/dm^3), sulphate (515–558 mg/dm^3) and thallium (1.84–2.34 µg/dm^3).

Water samples from the catchment area are characterized by lower levels of most of the elements analysed compared to the limits set for surface water quality classes I and II. As for thallium, zinc and antimony, higher levels are observed only in a few cases (Rozporządzenie..., 2021; Tab. 5). Cadmium is below the limit of quantification in most of the waters studied, lead does not exceed 9.05 µg/dm^3 (median 0.23 µg/dm^3) and nickel 12.0 µg/dm^3 (median 5.6 µg/dm^3).

SUMMARY AND CONCLUSIONS

1. In the study area, the anthropogenic sources of contamination of the natural environment are the historical exploitation of zinc-lead ores, the mining of coal and construction raw materials, and urbanization (residential, service and commercial housing). Contaminants coming from neighbouring heavily industrialized and urbanized areas also have a significant impact.
2. The lithology of the parent rock of the soils is reflected in their grain size composition. Soils that developed mainly on Quaternary glaciofluvial sands and gravels are rich in the sand fraction, while those formed mainly on outcrops of Triassic carbonates and on Carboniferous deposits are rich in the silt and clay fractions.
3. The median contents of the elements studied in the topsoil layer are higher than the geochemical background values for the Silesian-Cracow region. The only exception is mercury. The highest exceedances of the background levels (about five times) were found for cadmium and zinc
4. Soils that are clearly enriched in cadmium and zinc are observed in areas of Triassic carbonates.
5. Exceedances of the PEC thresholds for arsenic, cadmium, lead and zinc were found in aquatic sediments from all catchments within the map sheet boundaries.
6. The surface waters are characterized by variability in chemical element content, pH, and specific electrolytic conductivity. They are mainly neutral and alkaline in pH. High EC (>1 mS/cm) is observed in the waters of the Brynica River and its tributaries and of some watercourses, in wooded areas, in the north-western and south-eastern parts of the map sheet.

REFERENCES

ANALIZA, 2016 – Analiza stanu gospodarki odpadami komunalnymi na terenie gminy Wojkowice; https://wojkowice.bip.net.pl/?a=1367 (dostęp: 6.02.2024).

BEDNAREK R., DZIADOWIEC H., POKOJSKA U., PRUSINKIEWICZ Z., 2004 – Badania ekologiczno-gleboznawcze. PWN, Warszawa.

BIERNAT S., 1955 – Szczegółowa Mapa Geologiczna Polski 1:50 000, ark. Wojkowice. Inst. Geol., Warszawa.

BN-78/9180-11 – Gleby i utwory mineralne. Podział na frakcje i grupy granulometryczne. Norma branżowa, 1978. PKN, Warszawa.

BUŁA Z., KOTAS A. (red.), 1994 – Atlas geologiczny GZW w skali 1:100 000 cz. III. Mapa geologiczno-strukturalna utworów karbonu produktywnego. Państw. Inst. Geol., Warszawa.

CIEPIELA B., 2006 – Zlikwidowane zagłębiowskie kopalnie węgla w fotografii. Magic, Grodziec.

CIEPIELA B., 2016a – Ciechanowscy – zasłużeni dla górnictwa w Grodźcu – założyciele „Przeglądu Górniczo-Hutniczego". *Przegląd Górniczy*, **11**: 81–85.

CIEPIELA B., 2016b – Szyby górnicze na terenie ziemi psarskiej. Komunikat. Budownictwo Górnicze i Tunelowe, 3: 27–32; https://sbc.org.pl/Content/280259/PDF/BGiT_2016_R000_003.pdf (dostęp: 25.01.2024).

CIEPIELA B., 2016c – Z historii zwanych zagłębiowskich kopalń węgla (III). Kopalnie na terenie ziemi psarskiej. *Przegląd Górniczy*, **10**: 68–77.

CIEPIELA B., TRZCIONKA T., 2017 – Historia kopalń węgla kamiennego w Strzyżowicach. Komunikat. Wiadomości Górnicze, 3: 153–159; https://sbc.org.pl/Content/293875/PDF/WiadGornicze_2017_R068_003.pdf (dostęp: 25.01.2024).

DURJASZ-MAJEWSKA I., DURKA-KAMIŃSKA N., NOWAKOWSKA A., PAJĄK A., 2017 – Aktualizacja opracowania ekofizjograficznego dla gminy Wojkowice, obejmującej teren działek o numerze geodezyjnym 1079, obręb Żychcice. EKO EKOID, Katowice; http://wojkowice.bip.net.pl (dostęp: 6.02.2024).

DURKA-KAMIŃSKA R., 2020 – Zmiana studium uwarunkowań i kierunków zagospodarowania przestrzennego miasta Siemianowice Śląskie. Etap I – opracowanie ekofizjografii; https://bip.msiemianowicesl.finn.pl/res/serwisy/pliki/32064797?version=1.0 (dostęp: 23.11.2023).

DYBOVÁ S., JACHOWICZ A., 1957 – Mikrospory górnośląskiego karbonu produktywnego. *Pr. Inst. Geol*., **33**.

FAJFER J., KRIEGER W., ROLKA M., ANTOLAK O., 2010 – Opracowanie metodyki wykonania spisu zamkniętych obiektów unieszkodliwiania odpadów wydobywczych oraz opuszczonych obiektów unieszkodliwiania odpadów wydobywczych, które wywierają negatywny wpływ na środowisko. Państw. Inst. Geol. – Państw. Inst. Badaw., Warszawa [niepubl.].

GMINNY PROGRAM OPIEKI NAD ZABYTKAMI MIASTA BĘDZINA NA LATA 2021–2024 – Uchwała Nr XXXIII/259/2021 Rady Miejskiej Będzina z dnia 29 kwietnia 2021 r. w sprawie uchwalenia „Gminnego Programu Opieki nad Zabytkami Miasta Będzina na lata 2020–2030" (Dz. Urz. Woj. Śl., poz. 3398); https://dzienniki.slask.eu/WDU_S/2021/3398/akt.pdf (dostęp: 06.02.02024).

GOSZCZ R., KUZIO B., KUZIO S., GRUDZIEŃ I., HELJASZ I., HERTLEIN A., LABRYGA B., LIBERSKI W., MUSIAŁ H., NOSZCZYK M., RYCHCIK K., STRASZ R., 2004a – Program Ochrony Środowiska dla miasta Wojkowice na lata 2004–2015. AGOS-GEMES Sp. z o.o; http://archiwum.wojkowice.bip.net.pl/_pliki/upload/200701041114241p52hpehmehl.pdf (dostęp: 24.01.2024).

GOSZCZ R., KUZIO B., KUZIO S., GRUDZIEŃ I., HELJASZ I., HERTLEIN A., LABRYGA B., LIBERSKI W., MUSIAŁ H., NOSZCZYK M., RYCHCIK K., STRASZ R., 2004b – Program Ochrony Środowiska dla miasta Będzina na lata 2004–2015. AGOS-GEMES Sp. z o.o; https://bedzin.bip.info.pl/dokument_druk.php?iddok=592&idmp=37&r=r (dostęp: 24.01.2024).

GOSZCZ R., HERTLEIN A., LIBERSKI W., STRASZ R., TROJANOWSKI M., 2008 – Aktualizacja Programu Ochrony Środowiska dla powiatu będzińskiego na lata 2008–2020. AGOS-GEMES Sp. z o.o; https://www.bip.powiat.bedzin.pl/bipkod/010/002/024/004 (dostęp: 25.01.2024).

GÓRA S., 2012 – Podatność wód podziemnych na zanieczyszczenia w warunkach płytkiego górnictwa węglowego i zatapiania kopalń w północno-wschodniej część Górnośląskiego Zagłębia Węglowego [pr. doktor.]. AGH, Kraków; https://winntbg.bg.agh.edu.pl/rozprawy2/10598/full10598.pdf (dostęp: 07.02.2024).

GÓRECKA Ł., 1962 – Związek przemysłu cementowego w Polsce ze środowiskiem geograficznym. Dokumentacja Geograficzna, z. 4. Polska Akademia Nauk, Inst. Geogr., Warszawa; https://rcin.org.pl/Content/42252/WA51_50364_r1963-z4_Dokumentacja-Geogr.pdf (dostęp: 5.02.2024).

INWENTARYZACJA, 2014 – Inwentaryzacja i waloryzacja przyrodnicza terenów położonych w granicach administracyjnych gminy Wojkowice; http://wojkowice.bip.net.pl (dostęp: 5.02.2024).

JAROS J., 1984 – Słownik historyczny kopalń węgla na ziemiach polskich. Wyd. II poprawione i zaktualizowane. Śląski Inst. Nauk., Katowice.

JECHNA K., GALLUS A., 2010 – Program Ochrony Środowiska dla Miasta Wojkowice do roku 2013 z uwzględnieniem perspektywy do roku 2018. ATMOTERM SA; http://archiwum.wojkowice.bip.net.pl/index_idg14_id290_x510.html (dostęp: 31.01.2024).

JOCHEMCZYK L., KRZANOWSKA A., LIS J., OLSZEWSKA K., PASIECZNA A., WOŁKOWICZ S., STRZELECKI R., GAŁKA M., STRZEMIŃSKA K., KRIEGER W., 2004 – Objaśnienia do Mapy geośrodowiskowej Polski 1: 50 000, arkusz Wojkowice (911). Państw. Inst. Geol., Warszawa; https://bazadata.pgi.gov.pl/data/mgsp/txt/mgsp0911.pdf (dostęp: 06.02.2024).

JURECZKA J., DOPITA M., GAŁKA M., KRIEGER W., KWARCIŃSKI J., MARTINEC P., 2005 – Atlas geologiczno-złożowy polskiej i czeskiej części Górnośląskiego Zagłębia Węglowego. Państw. Inst. Geol., Warszawa.

KABATA-PENDIAS A., MUKHERJEE A., 2007 – Trace Elements from Soil to Human. Springer-Verlag, Berlin Heidelberg.

KABATA-PENDIAS A., PENDIAS H., 1999 – Biogeochemia pierwiastków śladowych. Wydaw. Nauk. PWN, Warszawa.

KARCZEWSKA A., LEWIŃSKA K., AGATA M., KRYSIAK A., 2010 – Soil Pollution by Arsenic within the Allotment Gardens in Zloty Stok. *Ecol. Chem. Enineering A*, **17**, 8: 927–933.

KIERSNOWSKI H., 1991 — Litostratygrafia permu północno-wschodniego obrzeżenia Górnośląskiego Zagłębia Węglowego – nowa propozycja. *Przegląd Geologiczny*, **39**, 4: 198–203.

KLASYFIKACJA UZIARNIENIA GLEB I UTWORÓW MINERALNYCH, 2008. Polskie Towarzystwo Gleboznawcze; https://www1.up.poznan.pl/glinbar/wp-content/uploads/2015/03/Uziarnienie_PTG_2008.pdf (dostęp: 10.06.2024).

KOBIELA K., MOCZULSKI M., POLUS M., ZARZYCKI J., 2012 – Plan gospodarki odpadami dla województwa śląskiego 2014. ATMOTERM S.A. Zespół Studiów i Analiz Środowiskowych w Katowicach; https://www.slaskie.pl/content/1346329324_2012-08-30 (dostęp: 02.02.2024).

KOTAS A., MALCZYK W., 1972 – Seria paraliczna piętra namuru dolnego Górnośląskiego Zagłębia Węglowego. [W]: Karbon Górnośląskiego Zagłębia Węglowego. *Pr. Inst. Geol*., **61**.

KOTLICKI S., 1995 – Badania nad litostratygrafią triasu Górnego Śląska. Cetralne Archiwum Geologiczne PIG-PIB, Oddział Górnośląski, Sosnowiec.

LEWANDOWSKI J., CIESIELCZUK J., 1997 – Przyczynek do poznania regolitów krasowych Wyżyny Śląskiej. *Pr. Nauk. Uniw. Śl., Geologia*, **14**: 139–152.

LIS J., PASIECZNA A., 1995a – Atlas geochemiczny Polski w skali 1:2 500 000. Państw. Inst. Geol., Warszawa.

LIS J., PASIECZNA A., 1995b – Atlas geochemiczny Górnego Śląska w skali 1:200 000. Państw. Inst. Geol., Warszawa.

LIS J., PASIECZNA A., 1997 – Anomalie geochemiczne Pb-Zn-Cd w glebach na Górnym Śląsku. *Przegląd Geologiczny*, **45**, 2: 182–189.

LIS J., PASIECZNA A., 1999 – Szczegółowa mapa geochemiczna Górnego Śląska w skali 1:25 000, ark. Sławków. Państw. Inst. Geol., Warszawa.

LOMBI E., SLETTEN R.S., WENZEL W.W., 2000 – Sequentially extracted arsenic from different size fractions of contaminated soils. *Water Air Soil Poll*., **124**: 319–332.

LUSZKA A., CZUCZWARA P., MATUSIAK K., MIŁOWSKI T., NIŻBORSKI M., MILLER A., 2013 – Studium Uwarunkowań i Kierunków Zagospodarowania Przestrzennego Miasta Będzina, Załącznik Nr 1. do Uchwały Nr XLII/398/2013 Rady Miejskiej Będzina z dnia 30 września 2013 r.; http://www.przetargi.um.bedzin.pl/SUiKZP_Bedzin_2013/studium/zal_01_tekst_studium_bedzin.pdf (dostęp: 02.02.2024)

MACDONALD D.D., INGERSOL C.G., BERGER T.A., 2000 – Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. *Arch. Environ. Contam. Toxicol*., **39**: 20–31; doi: 10.1007/s002440010075.

MACHOWSKI R., RZĘTAŁA M., 2023 – Zbiorniki Rogoźnik. [W:] Encyklopedia Województwa Śląskiego (red. R. Kaczmarek i in.). T. 10. Instytut Badań Regionalnych Biblioteki Śląskiej; https://ibrbs.pl/index.php/Zbiorniki_Rogo%C5%BAnik (dostęp: 07.02.2024).

MAJORCZYK R., 1985 – Historia górnictwa kruszcowego w rejonie Bytomia. ZUP Piekary Śl. zam. 1138/85, Bytom; https://www.sbc.org.pl/dlibra/publication//230429/edition/217785 (dostęp: 31.01.2024).

MIKOŁAJKÓW J., SADURSKI A. (red.), 2017 – Charakterystyka głównych i lokalnych zbiorników wód podziemnych. Państw. Inst. Geol. – Państw. Inst. Badaw., Warszawa; https://www.pgi.gov.pl/psh/materialy-informacyjne-psh/informatory-psh/4719-informator-psh-2017-gzwp/file.html (dostęp: 07.02.2024).

MOCEK A., DRZYMAŁA S., MASZNER P., 2000 – Geneza, analiza i klasyfikacja gleb. Wydaw. Akademia Rolnicza, Poznań.

NOWICKI Z. (red.), 2007 – Wody podziemne miast Polski. Miasta powyżej 50 000 mieszkańców – Siemianowice Śląskie. Informator PSH: 365–380. Państ. Int. Geol., Warszawa; https://www.pgi.gov.pl/dokumenty-pig-pib-all/psh/psh-materialy-informacyjne-psh/informatory-psh/4144-wody-podziemne-miast-wojewodzkich-polski-1/file.html (dostęp: 07.02.2024).

ORZECZENIE NR 54 Ministra Przemysłu i Handlu z dnia 28 sierpnia 1948 roku o przejęciu przedsiębiorstw na własność Państwa, (M. P. z 1948 r., nr 70, poz. 599); https://isap.sejm.gov.pl/isap.nsf/download.xsp/WMP19480700599/O/M19480599.pdf (dostęp: 07.02.2024).

PACZYŃSKI B. (red.), 1995 – Atlas hydrogeologiczny Polski, 1:500 000. Cz. II. Zasoby, jakość i ochrona zwykłych wód podziemnych. Państw. Inst. Geol., Warszawa.

PASIECZNA A., 2008 – Wpływ przemysłu na środowisko przyrodnicze regionu śląsko-krakowskiego. *Gosp. Sur. Miner*., **24**, 2: 67–82.

PASIECZNA A., KONON A. (red.), 2021 – Szczegółowa mapa geochemiczna Górnego Śląska w skali 1:25 000, ark. Piekary Śląskie. Panstw. Inst. Geol. – Państw. Inst. Badaw., Warszawa; https://mapgeochem.pgi.gov.pl/atlasy-szczegolowe/piekary-slaskie-2/ (dostęp: 25.01.2024).

PIOTRKIEWICZ A., WOJCIECHOWSKA B., 2016 – Program Ochrony Środowiska dla Gminy Bobrowniki na lata 2017–2020 z uwzględnieniem perspektywy na lata 2021–2024; https://archiwum-bobrowniki.bip.net.pl/c1676.html (dostęp: 25.01.2024).

PIWOWAR A., CIUK E., 1936 – Przyczynek do znajomości rud manganowych w północnej części Zagłębia Dąbrowskiego. *Annales Societatis Geologorum Poloniae*, **12**: 276–293.
PLAN, 2004 – Plan Gospodarki Odpadami dla miasta Wojkowice na lata 2004–2015; http://archiwum.wojkowice.bip.net.pl/_pliki/upload/20070104111259opk4dg9k9qbb.pdf (dostęp: 24.01.2024).
PN-B-04481:1988 – Grunty budowlane. Badania próbek gruntu [norma wycofana].
PROGNOZA, 2020 – Prognoza oddziaływania na środowisko miejscowego planu zagospodarowania przestrzennego dla terenów położonych w sołectwach: Strzyżowice, Malinowice, Preczów, Sarnów, Gołąsza, Brzękowice, Dąbie. Gmina Psary. Pracownia Urbanistyczno-Architektoniczna Jan Knura; https://www.psary.pl/images/galeria/2020/2020-10-14-plan_zagospodarowania/Prognoza_Psary_VI2020.pdf (dostęp 04.11.2024).
PROGRAM, 2021 – Program Ochrony Środowiska na lata 2021–2025, z perspektywą na lata 2026–2030 dla Miasta Wojkowice; https://wojkowice.bip.net.pl/?a=3651 (dostęp: 13.02.2024).
RICHLING A., SOLON J., MACIAS A., BALON J., BORZYSZKOWSKI J., KISTOWSKI M. (red.), 2021 – Regionalna geografia fizyczna Polski. Bogucki Wydaw. Naukowe, Poznań.
ROCZNA OCENA, 2023 – Roczna ocena jakości powietrza w województwie śląskim. Raport wojewódzki za rok 2022. Główny inspektorat ochrony Środowiska, Departament Monitoringu Środowiska. Regionalny Wydział Monitoringu Środowiska w Katowicach, Katowice, 2023; https://powietrze.gios.gov.pl/pjp/rwms/publications/card/1877 (dostęp: 05.12.2023).
ROZPORZĄDZENIE MINISTRA INFRASTRUKTURY Z DNIA 25 czerwca 2021 r. w sprawie klasyfikacji stanu ekologicznego, potencjału ekologicznego i stanu chemicznego oraz sposobu klasyfikacji stanu jednolitych części wód powierzchniowych, a także środowiskowych norm jakości dla substancji priorytetowych. Dz.U. 2021 poz. 1745.
ROZPORZĄDZENIE MINISTRA INFRASTRUKTURY Z DNIA 4 listopada 2022 r. w sprawie Planu gospodarowania wodami na obszarze dorzecza Wisły (Dz.U. z 2023 r., poz. 300).
ROZPORZĄDZENIE MINISTRA ŚRODOWISKA Z DNIA 1 września 2016 r. w sprawie sposobu prowadzenia oceny zanieczyszczenia powierzchni ziemi. (Dz.U. z 2016 poz. 1395).
ROZPORZĄDZENIE RADY MINISTRÓW Z DNIA 26 czerwca 2017 r. w sprawie utworzenia w województwie śląskim związku metropolitalnego pod nazwą „Górnośląsko-Zagłębiowska Metropolia" (Dz.U. 2017 poz. 1290).
RÓŻKOWSKA A., PTAK B., 1995 – Bar w węglach kamiennych Górnego Śląska. *Przegląd Geologiczny*, **43**, 3: 223–226
RYŻAK M., BARTMIŃSKI P., BIEGANOWSKI A., 2009 – Metody wyznaczania rozkładu granulometrycznego gleb mineralnych. *Acta Agrophysica*, **175**: 1–79.
SALMINEN R. (red.), 2005 – Geochemical Atlas of Europe, Part I. Geological Survey of Finland, Espoo.
STANGIEL M., 2020 – Założenia do koncepcji zagospodarowania terenu pokopalnianego w Wojkowicach – działka o numerze geodezyjnym 1079. Etap III – koncepcja po uwzględnieniu wyników konsultacji społecznych. Część opisowa; https://wojkowice.bip.net.pl/?a=2836 (dostęp: 01.02.2024).
STUDIUM, 2019 – Zmiana studium uwarunkowań i kierunków zagospodarowania przestrzennego Gminy Bobrowniki. Załącznik Nr 1 do Uchwały Nr XIII/130/19 Rady Gminy Bobrowniki z dnia 25 września 2019 r. w sprawie uchwalenia zmiany studium uwarunkowań i kierunków zagospodarowania przestrzennego Gminy Bobrowniki; https://bip.bobrowniki.pl/kategorie/89-obowiazujace/artykuly/143-uchwala-nr-xiii13019-rady-gminy-bobrowniki-z-dnia-25-wrzesnia-2019-r-w-sprawie-uchwalenia-zmiany-studium-uwarunkowan-i-kierunkow-zagospodarowania-przestrzennego-gminy-bobrowniki?lang=PL (dostęp: 13.02.2024).
STUDIUM, 2021 – Studium uwarunkowań i kierunków zagospodarowania przestrzennego gminy Wojkowice; https://wojkowice.bip.net.pl/?p=document&action=show&id=8169&bar_id=3337 (dostęp: 31.01.2024).
STUDIUM, 2022 – Studium uwarunkowań i kierunków zagospodarowania przestrzennego gminy Psary. Załącznik nr 1 do Uchwały Nr XLVIII/498/2022 Rady Gminy Psary z dnia 27 października 2022 r. w sprawie uchwalenia Zmiany nr 4 studium uwarunkowań i kierunków zagospodarowania przestrzennego gminy Psary; http://bip.psary.pl/11779/dokument/37439 (dostęp: 13.02.2024).
SZUFLICKI M., MALON A., TYMIŃSKI M. (red.), 2023 – Bilans zasobów złóż kopalin w Polsce wg stanu na 31 XII 2022 r. Państw. Inst. Geol. – Państw. Inst. Badaw., Warszawa.
UCHWAŁA, 2019 – Uchwała Nr XIII/130/19 Rady Gminy Bobrowniki z dnia 25 września 2019 r. w sprawie uchwalenia zmiany studium uwarunkowań i kierunków zagospodarowania przestrzennego Gminy Bobrowniki; https://bip.bobrowniki.pl/kategorie/89-obowiazujace/artykuly/143-uchwala-nr-xiii13019-rady-gminy-bobrowniki-z-dnia-25-wrzesnia-2019-r-w-sprawie-uchwalenia-zmiany-studium-uwarunkowan-i-kierunkow-zagospodarowania-przestrzennego-gminy-bobrowniki?lang=PL (dostęp: 25.01.2024).
UCHWAŁA, 2020a – Uchwała Nr XXIX/339/20 Rady Miasta Piekary Śląskie z dnia 17 grudnia 2020 r. w sprawie wyznaczenia obszaru i granic aglomeracji Piekary Śląskie Południe (Dz. Urz. Woj. Śl. z 2020 r., poz. 9489); https://dzienniki.slask.eu/eli/POL_WOJ_SL/2020/9489/ogl/pol/pdf (dostęp: 31.01.2024).
UCHWAŁA, 2020b – Uchwała Nr XXXI/229/20 Rady Gminy Bobrowniki z dnia 17 grudnia 2020 r. w sprawie wyznaczenia obszaru i granic aglomeracji Bobrowniki (Dz. Urz. Woj. Śl. z 2020 r., poz. 9456); https://dzienniki.slask.eu/eli/POL_WOJ_SL/2020/9456/ogl/pol/pdf (dostęp: 31.01.2024).
UCHWAŁA, 2020c – Uchwała Nr XXIV.225.2020 Rady Miasta Wojkowice z dnia 21 grudnia 2020 r. w sprawie wyznaczenia obszaru i granic aglomeracji Wojkowice (Dz. Urz. Woj. Śl. z 2020 r., poz. 9587); https://dzienniki.slask.eu/eli/POL_WOJ_SL/2020/9587/ogl/pol/pdf (dostęp: 31.01.2024).
UCHWAŁA, 2021a – Uchwała Nr XXXIV/353/2021 Rady Gminy Psary z dnia 26 sierpnia 2021 r. w sprawie uchwalenia Zmiany nr 3 studium uwarunkowań i kierunków zagospodarowania przestrzennego gminy Psary; http://bip.psary.pl/11779/dokument/34945 (dostęp: 25.01.2024).
UCHWAŁA, 2021b – Uchwała Nr XXXI.253.2021 z dnia 12 kwietnia 2021r. w sprawie uchwalenia Studium uwarunkowań i kierunków zagospodarowania przestrzennego Gminy Wojkowice; https://wojkowice.bip.net.pl/?a=3337 (dostęp: 25.01.2024).
UCHWAŁA, 2021c – Uchwała Nr XXXIII/381/21 Rady Miasta Piekary Śląskie z dnia 25 marca 2021 r. w sprawie uchwalenia „Programu ochrony środowiska dla Miasta Piekary Śląskie na lata 2021–2024 z uwzględnieniem perspektywy do roku 2028"; https://piekaryslaskie.bip.net.pl/?a=42602 (dostęp: 19.02.2024).
UCHWAŁA, 2023 – Uchwała Nr VI/62/8/2023 Sejmiku Województwa Śląskiego z dnia 20 listopada 2023 r. w sprawie przyjęcia aktualizacji „Programu ochrony powietrza dla województwa śląskiego" przyjętego uchwałą Nr VI/21/12/2020 Sejmiku Województwa Śląskiego z dnia 22 czerwca 2020 roku (Dz. Urz. Woj. Śl. z 2023 r., poz. 8625); https://dzienniki.slask.eu/WDU_S/2023/8625/akt.pdf (dostęp: 12.02.2024).
USTAWA, 2001 – Ustawa z dnia 27 kwietnia 2001 r. Prawo ochrony środowiska (Dz.U. z 2024 poz. 54 t.j.).
WAGNER R. (red.), 2008 – Tabela stratygraficzna Polski. Państw. Inst. Geol., Warszawa.
WIERZCHOŃ A., 2015 – Kryteria delimitacji obszarów krawędziowych poprzemysłowych zespołów urbanistycznych. [W:] Przestrzeń. Ekonomia. Społeczeństwo. Czasopismo Naukowe Sopockiej Szkoły Wyższej, 8/11: 45–62; https://sopocka.edu.pl/wp-content/uploads/2023/03/SANS_Czasopismo_8_II_2015_caly_numer.pdf (dostęp: 26.01.2024).
WILANOWSKI S., ŻABA M., 2010 – Szczegółowa Mapa Geologiczna Polski 1:50 000, ark. Wojkowice (911), reambulacja. Państw. Inst. Geol.– Państw. Inst. Badaw., Warszawa.
WILANOWSKI S., ŻABA M., 2016 – Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1:50000, ark. Wojkowice (911). Państw. Inst. Geol. – Państw. Inst. Badaw., Warszawa.
WOŹNICA A., ABSALON D., CIEPLOK A., KRODKIEWSKA M., LIBERA M., ŁOZOWSKI B., MATYSIK M., NOWAK T., PASIERBINSKI A., PSZCZELNIK Ł., SIUDY A., ULAŃCZYK R., 2018 – Kompleksowa analiza stanu zbiornika Rogoźnik I wraz z przedstawieniem propozycji rozwiązań naprawczych. Raport końcowy; https://archiwum-bobrowniki.bip.net.pl/c1946.html (dostęp: 25.01.2024).
WÓJCIK A., 2008 – Działalność górnicza i geologiczna Józefa Cieszkowskiego w Okręgu Zachodnim Królestwa Polskiego w pierwszej połowie XIX w. *Analecta*, **17** (1/2): 87–102.
WÓJCIK A. J., SIEMBAB M., 2020 – Górnictwo triasowych rud żelaza w Księstwie Siewierskim w XVIII wieku. *Hereditas Minariorum*, **6**: 115–124.
ZUZAŃSKA-ZYŚKO E., SITEK S., PIĄTEK J., 2017 – Lokalny Program Rewitalizacji Miasta Wojkowice na lata 2017–2023 (Uchwała Nr XXXVIII.468.2017 z dnia 23 października 2017r.); https://wojkowice.bip.net.pl/?a=1403 (dostęp: 25.01.2024).