Detailed geochemical map of Upper Silesia

1:25 000

Sheet **SIEWIERZ**

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INTRODUCTION

A general geochemical study of Poland (Lis, Pasieczna, 1995a, b) has shown that the highest environmental contamination of soils, aquatic sediments, and surface waters occurs in the Silesian region. In 1996, work on the Detailed Geochemical Map of Upper Silesia, scale 1: 25,000, began in this area, starting with the development of the pilot sheet Sławków M-34-63-B-b (Lis, Pasieczna, 1999). Geochemical studies in the Siewierz M-34-51-C-b map sheet area are a continuation of detailed mapping work conducted systematically by the Polish Geological Institute – National Research Institute and financed by the National Fund for Environmental Protection and Water Management after approval of the Ministry of Climate and Environment.

The map sheet area is located in the central part of the Silesian Voivodeship. It covers mostly the area of the town and municipality of Siewierz. The town of Siewierz is a commercial centre and an important road junction. A short distance away (towards the west), beyond the borders of the sheet area, is the International Airport "Katowice" at Pyrzowice. At the northern boundary of the map sheet (near Bacholin–Kazimierówka) there are opencast mines of dolomites – Górnicze Zakłady Dolomitowe SA and TRIBAG SA Dolomite Mine "Nowa Wioska", and just beyond its northern boundary, there is a dolomite mine of Przedsiębiorstwo Wielobranżowe PROMAG Sp. z o.o. Other deposits of mineral raw materials (Zn-Pb ores, iron ores, dolomites and sands) are also present in the study area and its vicinity. Galena deposits in Diplopora dolomites (Czarnocki, 1931) were extracted in the Siewierz region as early as the 12th century. During World War I, small-scale mining was carried out by the German occupation authorities at Brudzowice, beyond the northern boundary of the map sheet (Grzechnik, 1978). On the western outskirts of Siewierz, the zinc ore mine "Wiktor Emanuel" operated until the 1930s (Preidl, Wójcik, 2014).

A significant part of the study area is covered by forests. The Przeczyce-Siewierz reservoir (Przeczyce reservoir), of natural undeveloped shores, is located in its central part, currently fulfilling flood control, tourist and recreational functions. In the past also being a source of drinking water for the cities of the Upper Silesian Industrial District (in Polish Górnośląski Okręg Przemysłowy – GOP) (Rzętała, 2008).

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

The information gathered may be useful in the preparation of planning documents, including, in particular, ecophysiographic studies that are normally produced prior to the drafting of local spatial development plans and/or studies on conditions and directions of spatial development. Geochemical data may also be used to prepare strategic and sectoral documents, including environmental protection programmes, revitalization programmes (in the part presenting the 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, 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:

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CHARACTERISTICS OF THE MAP SHEET AREA

Geographical and administrative location. According to the physico-geographical division, the southern part of the Siewierz sheet is included in the Silesian Upland macroregion that spans two mesoregions: Jaworzno Knolls and Tarnogóra Hummock Northern part of the map sheet is occupied by the Woźniki–Wieluń Upland macroregion that includes three lower-order units: Woźniki Rock Step, Upper Mała Panew Depression and Siewierz Basin (Richling *et al*., 2021).

Administratively, a significant part of the study area is located in the Będzin district. It includes the town and municipality of Siewierz and part of the municipality of Psary. The south-eastern extreme of the map sheet is occupied by Trzebiesławice, which is a town district of Dąbrowa Górnicza with *powiat* rights.

Surface relief, geomorphology and hydrography. Southern part of the map sheet, where the bedrock is composed of Triassic limestones and dolomites (Plate 1), is represented by gentle hills separated by valleys of rivers and minor watercourses. The western part, included in the Tarnogóra Hummock is separated from the eastern one, forming part of the Jaworzno Knolls, by the Przemsza (Czarna Przemsza) River valley. The highest elevated point in this part of the sheet is located in Twardowice. It is Ostra Góra hill exceeding 355 m a.s.l. (Richling *et al*., 2021). The north-eastern part belonging mostly to the Siewierz Basin is a plain reaching a maximum elevation of 306 m a.s.l. The area extending at the northern edge of the map sheet, within the Woźniki Rock Step, attains a maximum elevation of 365 m a.s.l. The lowest point within the sheet area, about 275 m a.s.l., is located in the Przemsza River channel, at the point where the river leaves the study area.

The Siewierz sheet area lies within the Vistula River basin, in the 3rd order catchment of the Przemsza River. The hydrographic network of the area consists mainly of the Przemsza River and its tributaries, numerous drainage ditches, fishponds, and an anthropogenic water body (Przeczyce-Siewierz reservoir). In the western part of the study area, the Czeczówka Stream rises. Paludified areas locally occur.

Land development and land use. The map sheet area is dominated by low-rise single-family housing. Villages with buildings located along the main road predominate; it is the so-called linear settlement ("ulicówka" in Polish). The town of Siewierz is an area of urban development. Industrial buildings are located to the north of the town, where production plants are situated, and in the areas of dolomite extraction. Along the shores of the artificial reservoir, there are tourist infrastructure facilities such as: cottages, camping sites, bathing beaches, restaurants, car parks, etc. The land use type varies between different parts of the study area: most of the area is of an agricultural-forest nature. Agricultural land (arable fields and meadows) and forests occupy 27 and 37% of the map sheet, respectively (Plates 2–3). North-western part of the sheet is covered with forests. Most of the forest land is represented by State Forests managed by the Siewierz Forest District, while the remaining forested areas are private properties, mostly belonging to the Company for the Development of the Forest and Land Community in Siewierz (Spółka dla Zagospodarowania Wspólnoty Leśno-Gruntowej w Siewierzu). Southern part of the map sheet is covered predominantly by arable land, meadows and wasteland. In the eastern part of the map sheet, an ecological site called „W dolinie Przemszy" has been created, covering an oxbow lake area of the Przemsza River, 0.43 ha in size (Uchwała, 2018).

The Siewierz sheet area is crossed from south to north by the national road (DK) 91. A section of expressway S1 runs across its south-western part. Road DK 78 and the revitalized railway route No. 182 run from west to east, allowing direct access to the "Katowice" Airport.

Economy. Economic activity in the map sheet area was related for many centuries mainly to mining and iron ore processing, as well as to agriculture and animal husbandry. The oldest industrial centre is Siewierz. Already since the Middle Ages, it has had industrial and agricultural functions (Malikowski, 2011). In the 13th and 14th centuries, silver and lead were mined by the open-cast method and smelted in this area (Strategia, 2016). During that period, also iron production began at forges that were built along rivers to harness their energy (Noga, 1993). The iron ore occurs at shallow depths from 1 to 10 m, and in some places down to merely 4 m (Piesowicz, 1961). Between the 15th and 18th centuries, iron forges operated in Piwonia and Sulików, using local ore resources (exploitation of ores from the Piwoński's manor area until 1668, and in the following years from Mierzęcice and Wojkowice Kościelne, located outside the map sheet). Furthermore, over a slightly shorter period, i.e. until the late 17th century, the St. John's forges operated, and a plant in Przeczyce was active until the mid-17th century, on the site of which a paper mill was established and operated until 1675 (Noga, 1993). In addition to the extraction and processing of raw materials, milling was also an important industrial function during that period. In Siewierz, in the late 16th century through the 17th century, there were eight mills built on the Przemsza River. Mills also operated at Boguchwałowice, Przeczyce and Warężyno. Mills located at Kuźnica Świętojańska and Sulików used energy from the Mitręga River (Noga, 1993).

Extraction of raw materials in the map sheet area has been carried out to a limited extent until modern times. In the inter-war period (the 1920s and 1930s), the "Wiktor Emanuel" calamine mine operated on the western outskirts of Siewierz. The deposit was represented by an impregnation of galena and cerussite in Diplopora dolomites, with a lead content of 5–6%. The mineral deposit was 4 m thick (Czarnocki, 1931), and the raw material was mined from two levels separated by an interbed of about 2 m in thickness. The mining reached a depth of 9 m. Since 1970, a landfill had operated in the northern part of the former mine, and subsequently was remediated in the late 1990s (Sołtysik, 2008). Currently, the southern bypass of Siewierz (DK 78) runs through this area. In the northern and north-eastern part of the map sheet, dolomite, sand and sand-gravelly deposits were extracted (Central Geological Database – https://dm.pgi.gov.pl/ [access 19/12/2023]).

Current economic development in the map sheet area is related mainly to micro-enterprises (up to nine employees) and, to a lesser extent, to the small and medium enterprise sector. The dominant industries are trade and services, manufacturing and construction (Uchwała, 2021b; Raport, 2023). Businesses that are important to the local economy in terms of the number of people employed include: Górnicze Zakłady Dolomitowe SA, Elektrolux Poland Sp. z o.o., Tribag Sp. z o.o., Air Products Sp. z o.o., Mechanic System Sp. z o.o., Paks'd Sp. z o.o., and TOPCON Polska Sp. z o.o. (Uchwała, 2021a).

GEOLOGICAL STRUCTURE AND MINERAL DEPOSITS

The Siewierz map sheet area is situated in the extreme northern part of the Upper Silesian Foredeep, which is part of the exposed basement of the Variscan platform (Pożaryski *et al*., 1992), within the northern margin of the Upper Silesian Coal Basin (USCB) (Jureczka *et al*., 2005). The north-eastern boundary of the USCB, which is the limit of Upper Carboniferous coal-bearing formations, runs through the extreme south-western part of the map sheet. The northern margin of the USCB is latitudinally crossed by a tectonic graben filled with Late Variscan molasse formations of Permian age, several hundred metres thick, belonging to a major unit – the Sławków Graben (Kotas, 1985; Kiersnowski, 1991).

The oldest sediments in the Siewierz map sheet area are Middle **Devonian** (Givetian) rocks represented by dark grey, greenish-grey, compact, crystalline dolomites with obliterated primary structures. On the surface, they are exposed at Kazimierzówka in the north-eastern part of the map sheet. These layers dip southwards under Triassic deposits, are tectonically underlain by Lower Carboniferous rocks, and their thickness may reach 1000 m (Biernat, 1955 [updated by Wilanowski, Żaba, 2010]; Buła *et al*., 2002; Wilanowski, Żaba, 2016).

Above in the section are **Carboniferous** deposits represented by Lower Carboniferous and fragmentary Upper Carboniferous coal-bearing formations. The Lower Carboniferous (Visean) deposits are composed of greywacke sandstones, mudstones, claystones and conglomerates, included in the lower Malinowice Beds. They are not exposed at the surface and occur mostly beneath the Permian succession and partly beneath Carboniferous coal-bearing and Triassic rocks. These are alternating layers of sandstones, mudstones and claystones, showing cyclicity characteristic of flysch sequences (Culm facies). The Culm deposits occur throughout the area and are approximately 800 m thick (Jureczka *et al*., 2005; Wilanowski, Żaba, 2016).

Upper Carboniferous coal-bearing deposits occur only in a small portion of the map sheet in its south-western part. They are up to 50 m thick and included in the Paralic Series (Namurian A) that is composed of sandy (fine- and medium-grained sandstones) and clay-muddy deposits with thin coal interbeds (Jureczka *et al*., 2005; Wilanowski, Żaba, 2016).

Permian sandstones, conglomerates, claystones and mudstones occupy most of the map sheet area, filling a tectonic graben located in the Tarnowskie Góry Trough (Sławków Graben). They overlie Carboniferous deposits and are covered by Triassic rocks. At the top, they are represented mainly by red clays with green spots, and subordinate conglomeratic sandstones and conglomerates containing small clasts. Beneath, red-green conglomerates with infrequent interbeds of sandstones, mudstones and claystones are found. Lower in the section, the series is represented exclusively by conglomerates composed of porphyry clasts, with minor clasts of carbonates and quartz, cemented by clay, containing thin intergrowths of conglomeratic sandstones. These deposits occur at depths of 40–170 m and can reach 400–450 m in thickness (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

Triassic deposits occupy a relatively compact area in the southern part of the map sheet, forming extensive, highly dismembered outcrops, while in the north they mostly underlie Quaternary sediments. The thickness of the Triassic succession is commonly 70–170 m and is constrained by the tectonics and relief of the top of Carboniferous and Permian formations (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

The Świerklaniec Beds, included in the Lower Triassic (Scythian, spanning the Induan and Olenekian stages), erosionally overlie Permian, Lower Carboniferous and locally Devonian deposits. They are represented by several metres thick terrestrial sands, clays, sandstones and subordinate conglomerates, passing into mudstones and claystones at the top, and are overlain by Middle Triassic carbonates (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

The Świerklaniec Beds are overlain unconformably by Middle Triassic (Lower Anisian) rocks, formerly referred to as the Röt (Wagner, 2008). The succession shows a fairly well-marked bipartition. The lower part of the section is composed mainly of grey dolomites with interbeds of limestones and marls and locally marly dolomites and dolomitic limestones. The upper part of the Świerklaniec Beds is represented by light yellow and grey dolomites with more frequent interbeds of grey or grey-brown, coarse-crystalline, compact limestones with small caverns. Locally, a series of cavernous limestones characterized by numerous caverns of varying diameters, exceeding 2 cm in places, may occur at the top of these deposits. The thickness of the above-described rocks is about 40 m and their minor outcrops are located in the extreme south-western part of the map sheet in the Toporowice and Przeczyce regions (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

This rock complex is overlain by limestones of the Gogolin Beds. In the map sheet area, they compose most of the hills in its western part, within a strip stretching between Niwiska, Boguchwałowice and Toporowice. The lower part of the Gogolin Beds is represented predominantly by platy limestones, while the upper part is dominated by wavy limestones, mostly silty and marly. The platy limestones are thinly to moderately bedded, micritic, grey and yellow in colour, and greenish in places. Locally, conglomerates and laminated marly dolomites with crinoids are also present in the Gogolin Beds. The thickness of the unit ranges from 35 to 60 m (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

The Gogolin Beds are overlain by ore-bearing dolomites. This is a complex of medium-bedded, dark grey, finely crystalline compacted and cavernous-porous dolomites, locally silicified, which are covered by thickly bedded, coarsely crystalline, highly porous grey dolomites. At the top of this complex, there are grey and yellow cavernous-porous, finely and medium-crystalline, medium- and thickly bedded dolomites. Numerous pre-dolomitization relics – traces of bedding, lamination and shell casts of bivalves and gastropods – are found in the sections of ore-bearing dolomites. However, the succession of lithotypes within the ore-bearing dolomites is locally modified depending on the specific conditions of dolomitization. The ore-bearing dolomites are characterized by mineralization with zinc and lead sulphides, particularly abundant near the base of the complex. According to the proposal of Kotlicki (1995), these strata should be included in the metasomatic Bytom Formation. The thickness of the ore-bearing dolomites is about 25 m in the study area, but they have been extensively depleted in many places. These deposits occur in the slopes and at the tops of several hills of approximately 315 m a.s.l. near Boguchwałowice and Podwarpie (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

The ore-bearing dolomite complex locally contains limestones and marls of the Gorażdże, Terebratula and Karchowice beds. Only limestones of the Karchowice Beds are exposed on the surface, forming a minor outcrop near Boguchwałowice. The Gorażdże, Terebratula and Karchowice Beds in the Siewierz region are characterized by a high lithological variability, which usually makes it impossible to reliably distinguish between these individual units. Their original thickness may have been around 50 m, but in the preserved fragments, it is much lower and amounts to 10–30 m (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

Upper in the Middle Triassic (Anisian) section, there are Diplopora dolomites of the Jemielnica Beds, which are exposed on the surface in the vicinity of Podwarp and Siewierz. The lower Diplopora Beds are represented by yellow and grey-yellow, medium- to thick-bedded, finely crystalline dolomites containing sparse fragments of crinoids. Above, there are thinly bedded marly dolomites, horizontally and wavy laminated, with diverse faunal and floral fossils that are damaged and mostly indeterminable. Manganese and limonite dendrites are common, and some fissures and minor caverns are filled with calcite crystals. The Diplopora Beds reach about 55 m (?) in thickness near Siewierz (north-eastern part of the map sheet) (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

The Upper Triassic is represented by clays, claystones and mudstones with interbeds of the Lisów breccia and Woźniki limestones, red, brown or variegated (red-green) in colour, usually slightly marly. In places at the base, there are numerous clay-marly layers with irregular calcareous and calcareous-clayey aggregations, partly showing the nature of pseudoolites and calcareous-oolitic conglutinates, or oolitic breccias. Much more frequently, cream-coloured, compact, nodular pelitic limestones and crystalline limestones, often conglomeratic, with coalified flora remains, are also reported mainly at the top of the section. They are known as the Woźniki limestones. Subordinate sandstones and lignite up to 20 cm thick are also found in the Upper Triassic (Siewierz region). On the ground surface, these rocks occur at Krzanów, where they form a hill 356 m a.s.l. The thickness of the Upper Triassic in the study area is up to 25 m (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

Lower **Jurassic** deposits occur mainly in the northern and central-eastern parts of the map sheet area, near Siewierz, where they generally form minor outcrops. The section is dominated by light grey mudstones interbedded with fine-grained sandstones and claystones. The locally occurring, predominantly gravelly formations and the underlying kaolin clays have been extensively depleted. The thickness of the Jurassic succession ranges typically from a dozen to about 22 m (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

The Palaeogene–Neogene deposits, represented by loams, muds, clays and sands, occur at the surface or under a thin cover of Quaternary sediments. Their minor outcrops are found mainly in the central-western part of the Siewierz map sheet. These deposits accumulated predominantly in karst funnels and sinkholes developed at the top of Triassic carbonates, especially in outcrop zones of the Gogolin Limestones and ore-bearing dolomites. Locally, ochre-colour silty loams and white fine-grained sands, as well as celadon-grey muds with variable admixtures of quartz gravels, predominate. These sediments, predominantly muddy-clayey with subordinate sands and refractory clays, were previously included in the Lower Jurassic, but more recent studies of karst regoliths in the Silesian Upland indicate their Oligocene–Miocene age (Lewandowski, Ciesielczuk, 1997). The thickness of the deposits ranges from several to a few tens of metres (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

The **Quaternary** sediments cover about 70% of the map sheet area with a layer ranging in thickness from a few to several metres, and up to approximately 30 m in fossil valleys. The typical thickness of the Quaternary cover is about 15 m. Their lithology is constrained by the relief of the sub-Quaternary bedrock, and their areal extent and thickness increase towards the north. Over most of the study area, these sediments overlie Middle Triassic and occasionally Miocene rocks (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

In zones of the Quaternary covers reaching considerable thicknesses, sediments of the South Polish Glaciations underlie fluvial or glaciofluvial sediments of the

Odranian Glaciation. These include occasional glacial tills overlying Triassic rocks, glaciofluvial sands and gravels, and glacial lake clays and muds filling the bottoms of fossil valleys of watercourses, and they estimated thickness is below 10 m. The fossil valley of the Czarna Przemsza River is filled with fluvial sands and gravels of the Great Interglacial. These are usually variably grained sands with an admixture of fine-grained gravels, about 20 m in thickness (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

Sediments of the Middle Polish Glaciations are found on the surface in the majority of the central and northern parts of the map sheet. The oldest sediments of these glaciations in the map sheet are yellow and yellow-brown glacial tills, generally sandy-silty, or sandy at the top, with a thickness ranging from 3 to 6 m. Above, in depressions of the till surface, glacial lake clays and muds (upper) are locally observed, deposited during the Odranian ice-sheet recession. These are grey sandy clays and muds, ranging from strongly sandy to slightly clayey, 2–3 m thick. There are also glaciofluvial (upper) sands and gravels deposited during the standstill and recession of the Odranian ice sheet, which cover about 40% of the map sheet area. These are light to dark yellow medium-grained or variably grained sands with an admixture of fine-grained gravels, about 5 m in thickness, locally up to 10 m. Glacial sands and gravels occur on the surface in the central part of the map sheet, in the Siewierz region, where they compose the upper parts of the slopes of minor gentle hills. They are represented by are variably grained sands with a significant admixture of gravels and single boulders, locally with loamy interbeds, attaining a thickness of 4 m (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

Sediments of the North Polish Glaciations are represented by fluvial sands and gravels of overflood (accumulation) terraces. They occur in the Przemsza River (Czarna Przemsza) valley. These are mostly medium- and fine-grained sands, locally with a relatively high admixture of fine-grained gravels, generally not exceeding 15 m in thickness (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

Undivided Quaternary deposits occupy a small part of the map sheet area. They are represented by slope wash loams, sands and gravels found at the foothills and lower slopes of hills composed of Triassic deposits in the southern part of the study area. These are washed loamy-sandy sediments containing a small number of gravel grains and clasts of local rocks, about 2–4 m thick, locally up to 6 m. Slope wash-fluvial sands, gravels and muds fill numerous short valleys cutting mainly the hillslopes composed of Triassic deposits in the southern and central-eastern parts of the map sheet. These are variably grained sands with varying admixtures of fine-grained gravels and numerous lenses of sandy muds and occasional fragments of local rocks, about 2–4 m in thickness. Aeolian sands and those forming dunes occur in a belt extending between Gamrot and Siewierz. The deposits were accumulated towards the end of the Vistulian Glaciation and at the beginning of the Holocene. The dunes are generally small in size and cover an area of up to a dozen or so hectares, attaining a height of 5 to 10 m (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

Holocene sediments occur only in the river valleys of the Czarna Przemsza, Szeligowiec, Czeczówka, Dopływ z Sadowia, Mitręga and other minor watercourses. These are mainly fluvial sands, gravels and muds of floodplain terraces, attaining a thickness of up to 8 m, as well as fluvial muds of valley bottoms (sandy muds with a large amount of humic matter), 1.5 to 3.0 m thick (Biernat, 1955, updated by Wilanowski, Żaba, 2010; Wilanowski, Żaba, 2016).

Mineral deposits. The map sheet area is a region of long mining tradition associated with the extraction of iron, silver and lead ores, and lignite. Iron ore deposits have been known since the early Middle Ages and supplied raw material for ironworks and smelters operating in the area, located on the rivers that provided necessary energy. The 18th century saw the development of iron ore mining (which was linked with the introduction of new metallurgical processing methods), as well as the use of hard coal for metallurgical processes. In the map sheet area, iron ore was mined at that time near the Bishop's village of Mierzęcice (the so-called Mierzęcice ore). These mineral deposits occurred in a nested form on outcrops of Middle Triassic carbonates and originated from regolith forms composed of residual loams and sands, developed probably as a result of karst activity in Oligocene–Miocene times (Lewandowski, Ciesielczuk, 1997). These deposits were extracted from shallow workings (so-called "ore pits"), up to 25 m deep. In addition, the iron ore was also mined in the 19th century using a multi-pit system in small underground mines.

Mining of zinc-lead ores in the Siewierz region was developing from the 13th to 19th centuries. The ores were initially mined using the open-pit method, and silver and lead were as well produced as a result of the smelting process. In the 1920s, Lower Jurassic brown coal was also mined. A coal mine was active near Mierzęcice, the so-called Blanowice coal mine, which was operated by the Polish-American Coal Company. In this area, coal-bearing deposits occur at variable depths from 4 to about 35 m in the form of lenses, but their thickness is small and does not exceed 1.1 m (Wójcik, Preidl, 2014).

As of December 31, 2022, 10 mineral deposits were proved to occur in the Siewierz map sheet area: zinc and lead ores, dolomites, clay ceramic raw materials, and sands and gravels (Szuflicki *et al*., 2023). Information on the parameters of the mineral deposits and the quality parameters of the mineral product is quoted after geological documentations of the individual mineral deposits and the System of Management and Protecting of Polish Mineral Raw Materials (MIDAS – http://geoportal.pgi.gov.pl/midas-web [access 14/11/2024]).

Two **zinc and lead** ore deposits of „Siewierz" and „Gołuchowice" are documented in the map sheet area. They are associated with the occurrence of Middle Triassic ore-bearing dolomites. The "Siewierz" deposit, covering an area of 650 ha, is located in the north-eastern part of the map. This ore deposit was assessed preliminarily (category D), and the approved resources are 317,000 tonnes of ore containing 18,000 tonnes of lead and 9,000 tonnes of zinc. The average thickness of the overburden (limestone and dolomite) is about 160 m, and the thickness of the mineral deposit itself varies from 1.1 to 14.1 m. The quality parameters of the mineral deposit are as follows: zinc content ranges from 0.8 to 10.0%, lead content is from 0.5 to 50.4%, and the average silver concentration is 523.9 g/t. The "Gołuchowice" deposit is documented over an area of 627.7 ha. Most of the area is located on the adjacent map sheet. The resources of the zinc and lead ore are 16.9 million tonnes, incuding metallic zinc of 562,000 tonnes, and lead of 149,000 tonnes. The average zinc content in the ore is 3.4%, and the lead content is 1.1%. Both zinc and lead ore deposits remain undeveloped.

The study area provides mineral deposits of the following **rock raw materials**: carbonates (dolomites), clay ceramic raw materials (loams, clays, clay shales), and sands.

In the north-eastern part of the map sheet, the "Brudzowice" mineral deposit is located, covering an area of 106.8 ha. Triassic (ore-bearing and Diplopora dolomites) and Devonian dolomites, varying in thickness from 20 to 91.8 m, are documented directly on the terrain surface or under a slight overburden of about 4.5 m thick. The average contents of CaO and MgO in the mineral deposit are 28.9% and 18.0%, respectively. The content of harmful admixtures is negligible. This raw material is used in metallurgy as a flux, in the construction industry as crushed stone aggregate, and in the production of carbonate-magnesium fertilizers. The "Brudzowice" mineral deposit has been mined since 1976, resulting in an extensive excavation of several tens of hectares. Exploitation is carried out by a multi-bench system on several levels, using explosives. The mineral resources of the deposit are significant amounting to 132.8 million tonnes, including 73.2 million tonnes of industrial resources.

To the east of the "Brudzowice" deposit, this rock complex includes the "Nowa Wioska" crushed and dimension stone deposit covering an area of 49.51 ha. The deposit bed is 28.1 to 75.9 m thick and its overburden has an average thickness of about 5 m. The quality parameters of the mineral product are as follows: the air-dry compressive strength ranges between 27.5 and 99.1 MPa, average water absorption is 2.5%, and the density varies between 2.8 and 3.0 g/cm^3. The mineral deposit is documented as a raw material for the road construction industry and for the production of crushed stone aggregate, with the resources of 50.3 million tonnes. The "Nowa Wioska" mineral deposit has been extracted since 1968, and the post-mining pit area is several hectares in size.

The "Podwarpie" mineral deposit of crushed and dimension stone is located in the central-eastern part of the map sheet within the outcrops of ore-bearing and Diplopora dolomites. It covers an area of 62.3 ha. The useful raw material here is dolomite that occurs under a thin (average 3.7 m) overburden of soil, till and dolomite rubble. The thickness of the mineral deposit varies from 21.8 to 64.7 m. The dolomites are characterized by a compressive strength of 101.9 MPa and a water absorption rate of 4.33%, while the result of Deval abrasion test is 7.86%. The deposit remains undeveloped.

In the north-western part of the map sheet, the **Quaternary sand** deposits "Szeligowiec" and "Szeligowiec II" are located adjacent to each other, 12.31 ha and 39.27 ha in area, respectively. The deposit bed is represented by fine-grained sand ranging in thickness from 2.0 to 10.3 m, occurring under a thin, 0.1–0.4 m overburden. The sand point of the aggregate is 100%, the mineral dust contents are low (averaging 3.4% and 4.47%, respectively), and the aggregate contains no extraneous impurities. It can be used for construction purposes and for the production of concrete and plaster mortar. Both deposits had been exploited in the past and the concessions expired at the end of 2022.

Three mineral deposits, "Siewierz M", "Siewierz II" and "Piwoń", are located within glaciofluvial sands in the north-eastern part of the map sheet. The "Siewierz M" and "Siewierz II" deposits cover small areas of 2.7 ha and 1.57 ha, respectively. Their thickness is about 7 m and the overburden is thin, attaining 0.1–0.5 m. It is a natural aggregate with a high sand point in excess of 99% and a low mineral dust content of 1.4–2%. The mineral deposits are free of foreign and organic impurities. The "Siewierz M" deposit has been abandoned, while the "Siewierz II" deposit remains undeveloped. The "Piwoń" deposit covers an area of 15.76 ha and its thickness varies from 8.4 m to 16.7 m. The overburden is represented by soil with an average thickness of 0.4 m. The sand point of the aggregate is 99.5%, the mineral dust content is negligible and reaches a maximum of 1.4%, and there are no foreign or organic impurities. It is an undeveloped deposit.

East of Siewierz, over an area of 4.35 hectares, the "Siewierz E" mineral deposit of **clay raw materials for the ceramics industry** – Jurassic (Liassic) clays and clay shales and Quaternary tills and silty tills – is documented. The thickness of the deposit varies between 4.24 and 15.0 m and it is covered by a 0.3–5.7 m thick overburden. The raw material contains 48.6–78.1% SiO_2, 8.9–25.4% Al_2O_3, and 3.67–6.59% of marl. Exploitation of the deposit took place between 1910 and 1994. The raw material was used for the production of solid bricks fired in a nearby brickyard.

HUMAN IMPACT (ANTHROPOPRESSION)

The relief of the study area has been only slightly transformed anthropogenically. Changes in the natural landforms took place in the areas of modern extraction of mineral deposits (dolomites, crushed stones, sands and gravels) at the northern boundary of the map sheet and in its south-eastern part, where small-scale historical mining of Zn-Pb ores occurred, after which post-mining depressions in the ground surface remained. The creation of the Przeczyce-Siewierz reservoir has resulted in changes to the hydrographic network and landscape.

Atmospheric air. The factors that shape the aerosanitary conditions in the map sheet area are emissions from the municipal and domestic sector (so-called low emissions), emissions from industrial and service sectors, and linear emissions. Emissions from local boiler houses and individual household furnaces show seasonal variability. They intensify during the heating season and are associated with the release of mainly particulate matter, sulphur and nitrogen dioxides, and carbon monoxide into the air. The type and quantity of emitted contaminants depend not only on the condition of the equipment, but also on the energy sources used. Sources of dust and gaseous contaminants emitted into the air by industrial and service facilities include Air Products Sp. z o.o., Electrolux Poland Sp. z o.o., Górnicze Zakłady Dolomitowe SA, TRIBAG SA, and Przedsiębiorstwo Wielobranżowe PROMAG Sp. z o.o. The activities of these entities generate, inter alia, emissions of PM10, carbon monoxide, sulphur dioxide, hydrocarbons, sulphuric acid, as well as other harmful substances (Majka *et al*., 2013; Majka, 2020). As regards traffic (linear) emissions, the sources of contamination are the products both of the abrasion of vehicle consumables (*e.g.* tyres) and of the combustion of fuels. These produce hydrocarbons, nitrogen dioxide, carbon oxides, and lead compounds (Adamiec *et al*., 2016). The greatest impact of linear emissions is observed along heavy traffic roads that, in the study area, include the S1, DK 78, DK 86 and DK 91 roads.

The map sheet area is part of the Silesian zone, for which evaluation of levels of substances in the air is carried out annually as part of the national environmental monitoring system (Ustawa..., 2001). Data provided by the measurement stations located outside the boundaries of the map sheet indicate that excessive concentrations of particulate matter (both PM10 and PM2.5) and benzo(a)pyrene contained in PM10 dust are recorded in this zone. Measurements of particulate matter (PM1, PM2.5, PM10) in the air have also been carried out since March 2019 as part of the municipal air monitoring system operating in the Siewierz municipality. Data on the concentrations of contaminants are provided continuously by nine sensors installed in different parts of the municipality. Analysis of the obtained results indicates that the worst air quality is recorded during the heating season, under conditions of windless weather and low temperatures, in areas of compact buildings where there is no free flow of air masses (Analiza jakości powietrza..., 2023).

Surface water and groundwater. The main hydrographic axis in the map sheet area is the Przemsza River that flows from the north-east to south across its area. On the river, near Siewierz, Przeczyce and Boguchwałowice (administratively belonging to the town and municipality of Siewierz and to the municipality of Mierzęcice), the Przeczyce-Siewierz reservoir has been created. Downstream to the Przeczyce-Siewierz reservoir, the Przemsza River flows in a natural, often meandering channel (Deryło, 2000). Its left-bank tributaries are the Mitręga Stream and the Dopływ w Kuźnicy Sulikowskiej stream, which feed the river in its course upstream of the Przeczyce-Siewierz reservoir. The right-bank tributaries are the Jordan Stream (its headwaters are outside the map sheet area) that meets the river upstream of the reservoir, and the Dopływ z Sadowia (its headwaters are located near Sławniów) – downstream of the reservoir (Wójcik, 2024). After flowing out of the reservoir, the river runs through a wide valley with numerous wetlands and ditches (Studium, 2021).

Created in 1963 on the Przemsza River, the Przeczyce-Siewierz reservoir has an area of 414.7 ha (at normal water level) and an average depth of 4.4 m. It is a multipurpose facility with the following functions:

- compensation – storing water for drinking and industrial purposes and providing an inviolable flow below the dam, as well as increasing low flows in the river;
- flood control – reducing flood waves and protecting downstream areas;
- recreation – tourism and angling (Aktualizacja, 2020).

It is an elongated ice-dammed reservoir whose bottom is filled with Quaternary sediments – fluvial muds, sands and gravels (Kaziuk, Lewandowski, 1978), underlain by fractured Cretaceous rocks. Water from the reservoir infiltrates into aquifers. As the result, hydrogeological conditions change, manifesting themselves as an increase in the groundwater table level. The reservoir's head dam is located at km 53+420 of the Przemsza River. The reservoir also has a lateral dyke in the Boguchwałowice region, built to protect polder areas. Due to its low average depth and large water surface area, it is susceptible to atmospheric disturbances (Machowski, Rzętała, 2020). The reservoir is fed directly by the waters of the Szeligowiec Stream and the Dopływ w Boguchwałowicach stream (Wójcik, 2024).

The quality status of surface waters flowing across the map sheet area is assessed as poor. The waters are characterized by ecological status less than good, and by poor ecological potential, with the exception of the Przeczyce-Siewierz reservoir which is assessed to have moderate ecological potential (Prognoza, 2023; Rozporządzenie…, 2022). The poor water quality status is due to runoff from agricultural areas, discharges of treated wastewater from treatment plants operating in the area, surface runoff of rainwater from paved areas, i.e.: roads, squares, car parks, and roof surfaces, as well as due to deposition of contaminants (mainly benzo(a)pyrene) from motorized transport (Rozporządzenie…, 2022). Confirmation of the poor water condition is also provided by the environmental assessment carried out for the four fluvial Surface Water Bodies located within the map sheet limits. All the water bodies are considered to be at risk of failing to meet the environmental objectives set out for the Vistula River Basin Management Plan (Rozporządzenie…, 2022).

The map sheet area is situated in the Silesian Triassic hydrogeological region (XII) (Paczyński, Sadurski, 2007), and within the boundaries of GWB 111 (north-western area of the map sheet) and GWB 112 (covering the whole area of the sheet except for its north-west), according to the characterization of the Groundwater Bodies (Central Geological Database – https://dm.pgi.gov.pl/ [access 19/12/2023]). Usable groundwater is found in Middle and Lower Triassic marly-dolomitic and calcareous deposits represented by the Muschelkalk and Röt. These are fractured-karst aquifers that merge over large areas into the aquifer complex of Triassic carbonates. Of local use is the Quaternary and Lower Jurassic (Liassic) pore aquifer in Siewierz and the lower Buntsandstein (Lower Triassic – Świerklaniec Beds) aquifer in the Ożarowice–Mierzęcice–Dąbie–Siemonia region (Różkowski, 1997). The quality of the waters is assessed as good, except for the north-western region of the map sheet, where the general condition of waters is considered poor. The poor water quality status is due to the agricultural activities carried out in the area (http://karty.apgw.gov.pl:4200/jcw-podziemne [access 07/12/2023]).

The map sheet area is located within the range of two Major Groundwater Reservoirs: MGR No. 454 (Olkusz–Zawiercie) and MGR No. 327 (Lubliniec–Myszków). MGR No. 454 covers the whole study area, excluding its north-western part. It is composed of Lower and Middle Triassic calcareous, dolomitic and marly rocks included in the Muschelkalk, Röt, and Middle and Lower Buntsandstein (these deposits occur on a local scale and are of little economic significance). The reservoir has no established protection zones, but there is a designated degraded water area of 167 km². Due to the strong transformation of physico-chemical properties of the Triassic aquifer system waters in this area, they are not suitable for drinking purposes. Most of the reservoir's waters are of 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 (Mikolajków, Sadurski, 2017). At the north-western edge of the map sheet, there is a small part of MGR No. 327. It is composed of Middle Triassic (Muschelkalk) dolomite-limestone rocks containing water in fractured-karst aquifers. Within the map sheet boundaries the aquifer is unconfined. The reservoir has no established protection areas. Most of its waters are of quality classes II and III. The potential threat to water quality comes mainly from economic activities carried out outside the boundaries of the map sheet, notably in the Tarnowskie Góry region. Adverse impacts also result from intense agricultural production (Mikołajków, Sadurski, 2017).

Treatment plants. In the map sheet area, there is the municipal sewage treatment plant "Północ" located within the administrative boundaries of the Siewierz municipality. It is a mechanical-biological installation with an average capacity of 996 m³/d. Its wastewater is discharged to the Przemsza River (km 58+280). Due to both the unsatisfactory technical conditions of the treatment plant and the expansion of the sewerage network, modernization of the facility is planned. Ultimately, the investment is to be completed in 2026, and its measurable effects are expected to include the improvement of technological processes and ensuring adequate quality of wastewater discharged to the Przemsza River (Uchwała, 2021b). Domestic wastewater from the Lung Disease Hospital in Siewierz and from Air Products Sp. z o.o. is transferred to the "Północ" treatment plant via the sewage network. Previously, both these entities operated their own wastewater treatment facilities.

The Siewierz Forestry District and Górnicze Zakłady Dolomitowe SA still run their own treatment plants. The former operates a biological treatment plant for domestic wastewater, with a capacity of 9 m³/d, while the latter operates an on-site "Bioblok" wastewater treatment plant with a capacity of 50 m³/d (Majka, 2020). Industrial wastewater from Górnicze Zakłady Dolomitowe SA, which is a mixture of pre-treated rainwater from paved areas, those treated in a domestic treatment plant, as well as *technological wastewater* from a car wash, is discharged through the existing outlet No. 2 into the "Ptasznik" canal and further into the Przemsza River (Informacja, 2023).

Soils. In urbanized, industrial and post-industrial expanses, anthropogenic soils cover not very extensive areas. Mechanical transformation of soil profiles is most commonly observed, which is manifested by the disappearance of genetic horizons, their mixing with each other or with foreign material, as well as by backfilling and compaction. Mechanical transformation of soils is the result of land development, hardening and compacting of the ground, removal of the soil cover, and excavation, embankment and levelling operations.

In addition to geogenic factors, the soil chemistry is influenced by dust emission from mining plants and by disturbances in hydrogeological conditions (observed, among others, in the Przeczyce-Siewierz reservoir area). Precipitation of contaminants emitted into the air, intensive urbanization, and excessive chemicalization of agriculture also play an important role.

Information on soil contamination in the map sheet area is scarce. Monitoring studies conducted in 2015 and 2020 by the Institute of Soil Science and Plant Cultivation – State Research Institute at a research and measurement point near Sulików showed 10.85 and 9.48 mg/kg of cadmium, 856.6 and 2,100 mg/kg of lead, and 1,458.8 and 281 mg/kg of zinc, respectively (Monitoring, 2020).

RESEARCH SCOPE AND METHODS

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

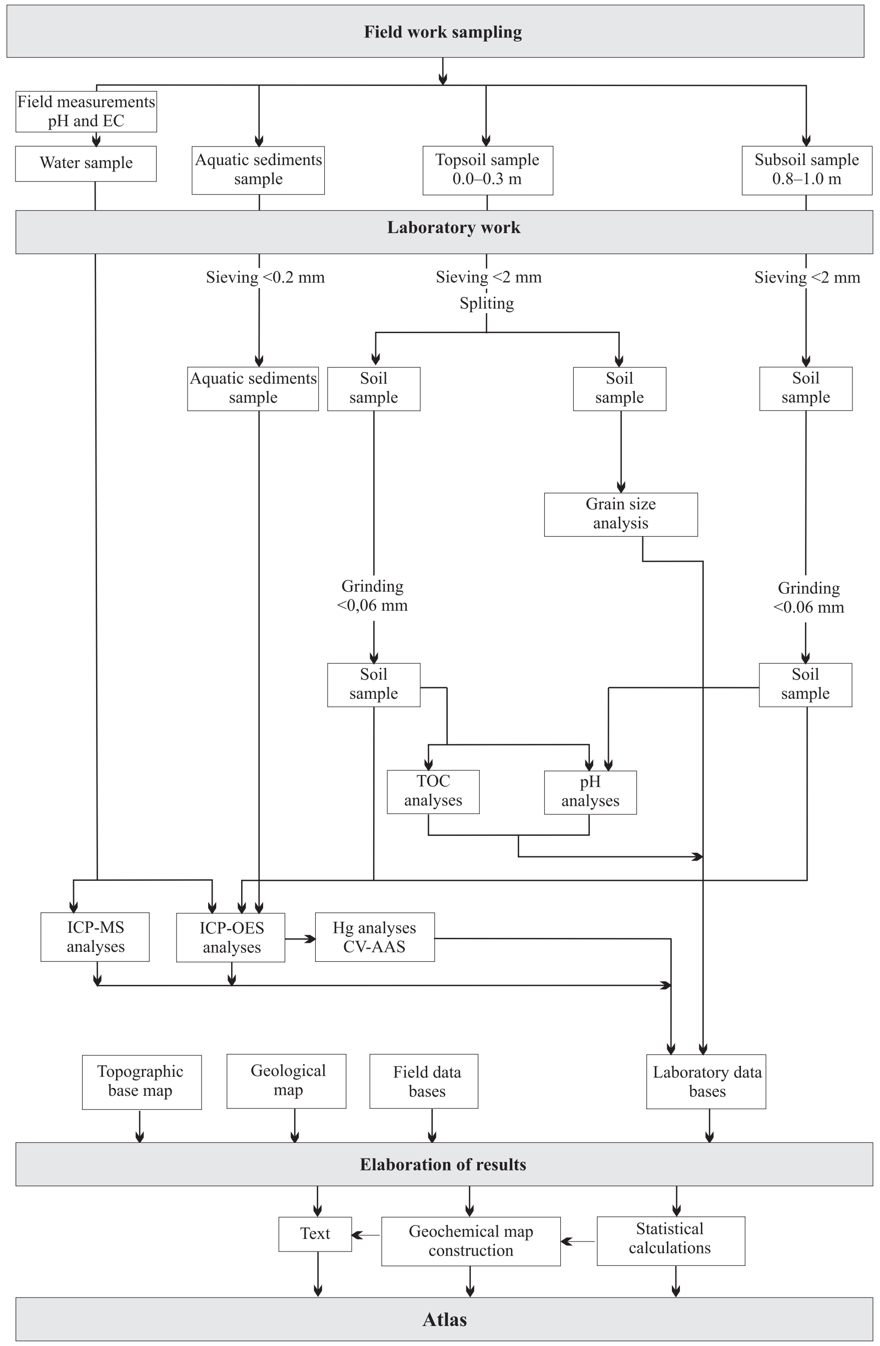

Fig. 1. Scheme of the work performed

FIELDWORK

Soils were sampled using a 60 mm diameter hand auger in a regular 250 × 250 m grid (16 samples/km^2). The location of sampling sites is documented by maps showing both the housing type and land use (Plates 2–3). A total of 1289 samples were collected from a depth of 0.0–0.3 m, and 1263 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 (266 and 256 samples, respectively) were taken at the same locations from rivers, streams, ditches, canals, lakes, and settling and natural ponds. The differences in the number of samples collected were dependent on the possibility to sample them (lack of material resulting, for example, from the periodic drying up of watercourses or the concreting of their channels). The distance between the sampling sites in the watercourses and water bodies was approximately 250 m. The locations of the sampling sites corresponds to those presented in the plates (starting with Plates 7 and 9, respectively), showing the content of individual elements in surface waters and aquatic sediments.

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

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

LABORATORY WORK

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

Sample preparation. After transport to the laboratory, soil samples were dried at room temperature and sieved through 2 mm mesh nylon sieves. Each soil sample from a depth of 0.0–0.3 m (topsoil), after sieving and quartering, was divided into two subsamples: one for chemical analysis and the other for grain size analysis. Each soil sample from a depth of 0.8–1.0 m (subsoil), after sieving and quartering, was destined for chemical analysis (Fig. 1). Soil samples prepared for chemical analysis were grinded to a <0.06 mm fraction in agate ball mills. 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 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 sediments were performed by inductively coupled plasma optical emission spectrometry (ICP-OES). Analyses of Hg content in soil and sediment samples were carried out by cold vapour atomic absorption spectrometry (CV-AAS) in a flow-injection system. The pH was determined by a potentiometric method in 1:5 (weight fraction) suspension of soil in water (pH–H_2O), and the total organic carbon (TOC) content of soils was determined by high-temperature combustion with IR detection. Determinations of B, Ba, Ca, Cr, Fe, K, Mg, Mn, Na, P, Si, S, Sr, Ti and Zn in surface waters were carried out by inductively coupled plasma atomic emission spectrometry (ICP-OES), while the contents of Ag, Al, As,

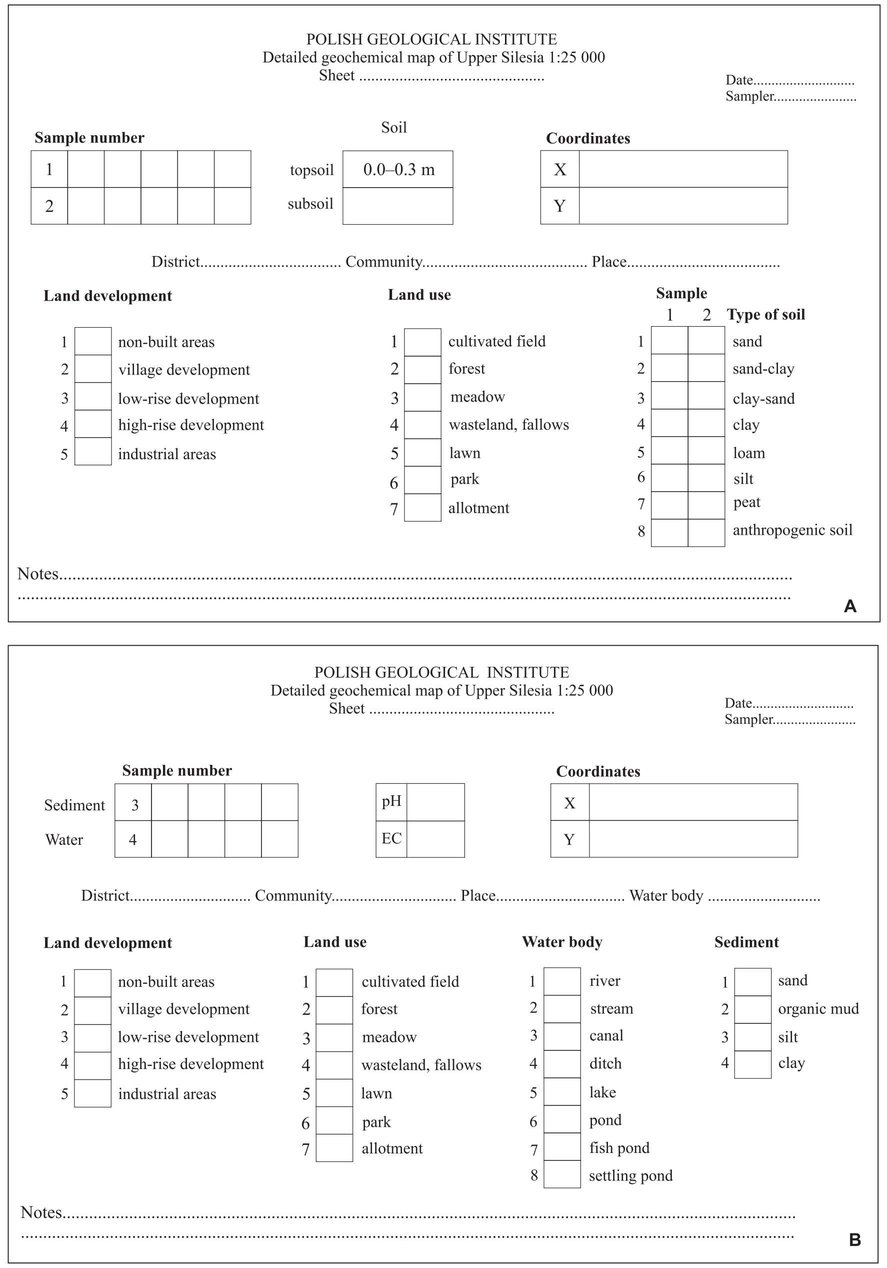

Fig. 2. Field sampling sheets for soils (A) and sediments and surface waters (B)

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/dm^3, 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,
- 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 subsets of soils, sediments, and surface waters provided they numbered 10 or more samples. If the contents of elements were lower than their limits of quantification of the analytical method, a value equal to half of this limit was taken for statistical calculations. The arithmetic mean, geometric mean, and median were calculated and the minimum and maximum values were presented. In case of elements for which the percentage of results below the limit of quantification exceeded 50%, the calculation of selected measures of descriptive statistics was abandoned and only the minimum and maximum values were presented. Statistical parameters for individual elements and indices are summarized in Tables 2–5 and shown in the geochemical maps (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 Siewierz sheet (Plates 2–63):
- land development;
- land use;
- content of total organic carbon, and of the sand, silt and clay fractions in soils at a depth of 0.0–0.3 m;
- pH in soils at depths of 0.0–0.3 and 0.8–1.0 m;
- contents of Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, Mg, Mn, Ni, P, Pb, S, Sr, Ti, V and Zn in soils at depths of 0.0–0.3 and 0.8–1.0 m, and in 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

Tabela 1 / *Table 1*

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

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 *Total soils* n = 1263	a	<1	0,02	<3	6	0,09	<0,01	<0,5	<1	<1	<1	0,01	<0,02	<0,01	<2	<1	<0,002	3	<0,003	<1	<5	<1	4	3,59
	b	37	2,06	258	469	49,20	19,68	55,1	31	119	148	8,47	0,28	9,74	4052	43	0,210	8453	0,309	208	405	149	7888	9,37
	c	–	0,36	6	45	2,67	0,52	3,1	2	6	8	0,64	0,03	0,18	351	5	0,025	149	0,021	8	42	9	300	6,53
	d	–	0,28	4	37	1,46	0,11	1,8	1	4	6	0,42	0,02	0,04	125	3	0,020	82	0,014	5	38	6	133	6,40
	e	–	0,28	4	38	1,33	0,09	1,8	1	4	6	0,40	0,02	0,03	196	3	0,023	80	0,014	4	40	6	128	6,67
Tereny bez zabudowy *Non-built-up areas* n = 1034	a	<1	0,02	<3	6	0,09	<0,01	<0,5	<1	<1	<1	0,01	<0,02	<0,01	<2	<1	<0,002	3	<0,003	<1	<5	<1	4	3,59
	b	37	2,06	258	273	49,20	16,42	55,1	13	119	148	5,38	0,28	8,40	4052	26	0,210	8453	0,309	208	240	149	6573	9,37
	c	–	0,35	6	44	2,95	0,44	3,2	2	6	7	0,61	0,03	0,16	342	4	0,025	154	0,022	7	40	8	290	6,33
	d	–	0,27	4	36	1,56	0,09	1,8	1	4	5	0,39	0,02	0,03	110	3	0,020	82	0,015	4	37	6	124	6,20
	e	–	0,27	4	37	1,38	0,07	1,8	1	4	5	0,37	0,02	0,03	172	3	0,022	80	0,013	4	39	6	115	6,43
Tereny z zabudową wiejską *Village areas* n = 117	a	<1	0,12	<3	11	0,09	<0,01	<0,5	<1	2	2	0,13	<0,02	0,01	17	1	0,003	12	0,003	1	21	2	24	4,93
	b	2	2,06	82	242	7,71	19,68	23,0	31	31	85	8,47	0,12	9,74	2513	43	0,118	2240	0,095	92	164	99	2863	8,95
	c	–	0,44	8	52	1,50	0,91	3,5	3	8	11	0,90	0,03	0,28	464	7	0,033	159	0,019	14	51	11	388	7,30
	d	–	0,38	5	45	1,25	0,27	2,4	2	6	8	0,68	0,02	0,09	306	5	0,029	101	0,016	8	47	9	232	7,25
	e	–	0,35	5	44	1,24	0,25	2,4	2	6	8	0,63	0,02	0,07	317	5	0,029	93	0,015	7	46	8	211	7,54
Tereny z zabudową miejską *Urban areas* n = 88	a	<1	0,11	<3	9	0,09	0,03	<0,5	<1	1	1	0,12	<0,02	<0,01	15	<1	0,003	5	<0,003	1	12	2	16	5,97
	b	3	1,10	45	469	8,38	7,21	45,6	16	19	126	4,05	0,16	4,00	2263	30	0,103	629	0,084	165	405	32	7888	8,91
	c	–	0,33	5	45	1,35	0,70	2,7	2	6	11	0,66	0,03	0,28	293	5	0,028	115	0,017	11	51	7	355	7,58
	d	–	0,29	3	36	1,02	0,27	1,5	1	5	7	0,46	0,02	0,09	160	4	0,022	72	0,013	7	44	6	163	7,55
	e	–	0,27	3	37	1,16	0,25	1,6	1	4	7	0,39	0,02	0,08	164	3	0,025	73	0,015	7	41	6	142	7,74
Tereny przemysłowe *Industrial areas* n = 24	a	<1	0,08	<3	12	0,13	0,04	<0,5	<1	1	<1	0,07	<0,02	0,01	14	<1	0,005	7	<0,003	2	16	2	33	5,65
	b	<1	0,91	8	107	5,64	19,10	3,0	3	12	20	2,05	0,05	9,14	2042	10	0,056	146	0,044	55	119	22	230	8,81
	c	–	0,27	–	37	1,05	1,34	0,9	–	4	6	0,48	–	0,65	355	3	0,018	52	0,011	8	42	7	102	7,58
	d	–	0,23	–	30	0,75	0,27	0,7	–	3	5	0,35	–	0,10	138	2	0,014	42	0,009	5	39	5	86	7,54
	e	–	0,20	–	27	0,86	0,19	0,7	–	3	5	0,31	–	0,07	148	2	0,014	39	0,009	5	38	5	79	7,77
Pola uprawne *Cultivated fields* n = 119	a	<1	0,08	<3	16	0,20	<0,01	<0,5	<1	1	3	0,15	<0,02	<0,01	47	<1	0,008	13	0,003	1	19	2	24	5,55
	b	2	1,33	61	115	2,89	12,93	42,2	9	27	18	3,74	0,10	7,00	3676	22	0,072	858	0,051	208	164	27	4798	9,00
	c	–	0,48	8	49	1,22	0,87	5,3	3	8	8	0,99	0,03	0,35	702	7	0,034	181	0,017	11	50	13	579	7,32
	d	–	0,43	6	45	1,10	0,27	3,4	2	7	8	0,82	0,02	0,11	516	6	0,032	132	0,015	7	48	11	353	7,29
	e	–	0,42	6	47	1,18	0,21	3,3	2	7	8	0,80	0,03	0,08	536	5	0,032	121	0,016	6	49	11	369	7,51
Lasy *Forests* n = 465	a	<1	0,02	<3	6	0,16	<0,01	<0,5	<1	<1	<1	0,01	<0,02	<0,01	<2	<1	<0,002	3	<0,003	<1	<5	<1	4	3,59
	b	37	1,55	70	244	49,20	6,11	55,1	12	23	84	3,07	0,28	3,19	2510	23	0,116	8453	0,235	35	96	47	4695	8,55
	c	–	0,23	4	40	4,34	0,14	2,1	–	3	5	0,30	0,03	0,07	128	2	0,017	135	0,022	3	35	5	133	5,40
	d	–	0,18	3	31	1,98	0,03	1,1	–	2	4	0,21	0,02	0,01	31	1	0,013	61	0,013	2	33	3	56	5,30
	e	–	0,17	3	31	1,68	0,02	1,1	–	2	4	0,21	0,02	0,01	23	1	0,013	63	0,011	2	34	3	47	5,23
Łąki *Meadows* n = 223	a	<1	0,06	<3	8	0,33	<0,01	<0,5	<1	<1	1	0,04	<0,02	<0,01	4	<1	0,005	9	0,004	1	6	<1	18	4,82
	b	1	2,06	41	242	30,68	12,31	24,7	31	31	148	8,47	0,27	5,64	4052	43	0,210	3521	0,261	204	105	99	3622	8,50
	c	–	0,49	7	49	2,03	0,57	3,3	3	8	9	0,88	0,03	0,14	435	7	0,034	147	0,024	12	40	12	289	6,85
	d	–	0,40	5	43	1,50	0,19	2,3	2	6	7	0,65	0,02	0,06	272	5	0,030	86	0,018	7	37	9	188	6,81
	e	–	0,37	5	44	1,41	0,18	2,4	2	6	6	0,65	0,03	0,06	344	5	0,030	81	0,017	7	41	9	196	6,81
Nieużytki, ugory *Wasteland, fallows* n = 360	a	<1	0,04	<3	6	0,09	0,01	<0,5	<1	<1	<1	0,01	<0,02	<0,01	3	<1	0,002	5	<0,003	<1	12	<1	10	4,70
	b	5	1,68	258	469	34,20	19,10	31,8	16	119	126	5,38	0,26	9,14	3555	30	0,176	2270	0,309	165	405	149	6573	9,37
	c	–	0,41	7	47	1,75	0,71	3,6	2	7	9	0,81	0,03	0,26	477	6	0,029	166	0,021	10	46	10	399	7,19
	d	–	0,35	4	39	1,20	0,21	2,2	2	5	7	0,58	0,02	0,07	263	4	0,025	99	0,015	6	41	8	215	7,15
	e	–	0,34	4	39	1,16	0,18	2,2	2	5	7	0,58	0,03	0,06	332	4	0,026	98	0,014	6	43	8	205	7,27
Trawniki *Lawns* n = 89	a	<1	0,12	<3	9	0,09	0,02	<0,5	<1	1	2	0,11	<0,02	0,01	13	<1	0,003	5	<0,003	1	19	1	16	5,65
	b	3	1,21	84	192	8,14	19,68	45,6	25	29	85	2,88	0,16	9,74	2263	27	0,077	685	0,163	73	161	25	7888	8,95
	c	–	0,34	6	45	1,34	1,11	3,3	2	7	11	0,66	–	0,43	335	5	0,026	126	0,018	12	54	8	442	7,84
	d	–	0,30	4	39	1,00	0,41	1,7	1	5	8	0,52	–	0,14	200	4	0,022	82	0,013	8	49	7	201	7,83
	e	–	0,28	4	39	1,17	0,38	1,9	1	5	8	0,52	–	0,12	219	4	0,025	88	0,015	8	46	6	196	7,87

Tabela 2 **cd.**
Table 2 *cont.*

Gleby *Soils*	Parametry *Parameters*	Ag	Al	As	Ba	C_{org}	Ca	Cd	Co	Cr	Cu	Fe	Hg	Mg	Mn	Ni	P	Pb	S	Sr	Ti	V	Zn	pH
		[mg/kg]	[%]	[mg/kg]		[%]		[mg/kg]				[%]	[mg/kg]	[%]	[mg/kg]		[%]	[mg/kg]	[%]	[mg/kg]				[–]
	Granica oznaczalności *Determination limit*	1	0,01	3	1	0,02	0,01	0,5	1	1	1	0,01	0,02	0,01	2	1	0,002	2	0,003	1	5	1	1	2,00
Gleby piaszczyste *Sandy soils* n = 887	a	<1	0,02	<3	6	0,09	<0,01	<0,5	<1	<1	<1	0,01	<0,02	<0,01	<2	<1	<0,002	3	<0,003	<1	6	<1	4	3,59
	b	2	2,06	45	242	44,46	14,88	42,2	31	56	148	8,47	0,18	8,40	4052	43	0,118	1239	0,136	156	129	99	4798	9,00
	c	–	0,29	5	38	1,86	0,31	2,5	–	5	6	0,51	0,03	0,12	291	4	0,022	105	0,016	6	39	7	224	6,30
	d	–	0,24	4	33	1,36	0,07	1,5	–	3	5	0,34	0,02	0,03	96	2	0,018	72	0,013	4	37	5	107	6,18
	e	–	0,24	4	34	1,29	0,05	1,6	–	3	5	0,31	0,02	0,02	135	2	0,020	75	0,012	3	39	5	98	6,38
Gleby gliniaste *Clay soils* n = 217	a	<1	0,11	<3	8	0,16	0,01	<0,5	<1	1	1	0,04	<0,02	<0,01	3	<1	0,005	8	<0,003	<1	10	1	19	4,56
	b	37	1,71	70	187	10,77	12,93	41,9	25	38	85	4,05	0,24	3,19	3535	27	0,076	8453	0,082	208	164	47	4854	9,37
	c	–	0,56	8	52	1,59	0,71	4,5	3	9	9	1,07	0,04	0,23	600	7	0,031	275	0,019	12	43	13	482	7,10
	d	–	0,47	5	45	1,32	0,24	2,4	2	7	8	0,77	0,03	0,09	329	5	0,028	106	0,016	7	39	11	221	7,05
	e	–	0,50	6	49	1,31	0,22	2,1	3	8	8	0,91	0,03	0,09	441	6	0,029	94	0,017	8	41	12	198	7,21
Gleby torfiaste *Peaty soils* n = 46	a	<1	0,08	<3	14	2,06	0,01	<0,5	<1	1	3	0,06	<0,02	<0,01	4	<1	0,008	17	0,014	1	<5	<1	18	3,77
	b	6	2,06	53	273	49,20	6,11	55,1	6	24	47	3,42	0,28	2,90	1828	19	0,210	5163	0,309	64	90	149	4695	7,40
	c	–	0,59	10	110	26,11	0,50	6,7	–	7	15	0,63	0,13	0,12	134	5	0,058	422	0,130	15	33	14	354	4,72
	d	–	0,47	6	91	19,54	0,16	4,4	–	6	12	0,38	0,10	0,02	35	4	0,044	180	0,102	10	27	9	166	4,62
	e	–	0,55	6	102	28,41	0,13	5,0	–	6	15	0,36	0,13	0,02	24	5	0,045	187	0,145	9	31	9	151	4,23
Gleby antropogeniczne *Anthropogenic soils* n = 113	a	<1	0,12	<3	9	0,09	0,02	<0,5	<1	1	2	0,13	<0,02	0,01	15	1	0,003	5	<0,003	1	20	2	16	5,65
	b	6	1,31	258	469	8,38	19,68	45,6	11	119	77	5,38	0,12	9,74	3555	30	0,103	1015	0,267	165	405	34	7888	9,00
	c	–	0,39	9	54	1,55	1,77	3,7	2	10	13	0,83	0,03	0,62	426	7	0,028	148	0,023	19	62	10	529	7,96
	d	–	0,35	4	44	1,12	0,69	2,0	2	7	10	0,63	0,02	0,20	251	5	0,023	94	0,016	11	54	8	246	7,94
	e	–	0,34	4	43	1,24	0,83	2,3	2	7	9	0,64	0,02	0,19	304	5	0,024	107	0,016	13	52	8	262	8,00
Tło geochemiczne/*Geochemical background*																								
Gleby Europy [1] *Soils of Europe*	e	0,27 n = 840	5,82 n = 845	6,00 n = 837*	65,0 n = 837*	1,73 n = 819	0,659 n = 845	0,145 n = 840	7,00 n = 837*	22,00 n = 837*	12,0 n = 837*	1,96 n = 837*	0,037 n = 833	0,46 n = 845	382 n = 837*	14,0 n = 837*	0,056 n = 845	15,0 n = 837*	0,023 n = 837*	89,0 n = 845	3426 n = 845	33,0 n = 837*	48,0 n = 837*	5,51 n = 818
Gleby Polski [2] *Soils of Poland* n = 10 840**	e	<1	nd.	<5	32	nd.	0,18	<0,5	2	4	5	0,51	<0,05	0,06	217	4	0,034	13	0,012	8	26	7	35	6,1
Gleby regionu śląsko-krakowskiego [3] *Soils of Cracow-Silesia Region* n = 1564**	e	<1	nd.	<5	54	nd.	0,22	1,3	3	5	7	0,63	0,08	0,07	257	5	0,030	44	0,015	10	28	9	104	6,7
Dopuszczalne zawartości 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
Gleby ogółem *Total soils* n = 1180	a	<1	0,03	<3	3	<0,01	<0,5	<1	<1	<1	0,01	<0,02	<0,01	<2	<1	<0,002	<2	<0,003	<1	7	<1	1	4,21
	b	9	2,39	171	367	22,98	139,7	81	273	40	14,08	1,68	10,36	7220	197	0,122	3970	1,106	367	199	63	14770	9,58
	c	–	0,43	–	27	1,15	–	–	7	6	0,79	–	0,37	326	7	0,012	71	0,008	12	46	10	264	7,35
	d	–	0,31	–	20	0,06	–	–	4	4	0,34	–	0,05	69	3	0,008	12	0,004	3	41	5	43	7,29
	e	–	0,25	–	17	0,03	–	–	3	3	0,26	–	0,03	55	2	0,008	10	0,004	2	41	4	29	7,48
Tereny bez zabudowy *Non-built-up areas* n = 968	a	<1	0,03	<3	3	<0,01	<0,5	<1	<1	<1	0,01	<0,02	<0,01	<2	<1	<0,002	<2	<0,003	<1	7	<1	1	4,21
	b	9	2,39	17	367	22,98	139,7	81	273	40	9,61	0,19	10,36	7220	197	0,121	3970	1,106	367	199	63	14770	9,58
	c	–	0,44	–	27	1,23	–	–	7	6	0,79	–	0,39	330	7	0,011	70	0,008	12	47	10	255	7,24
	d	–	0,31	–	19	0,06	–	–	4	3	0,33	–	0,04	65	3	0,008	11	0,004	3	41	5	40	7,17
	e	–	0,25	–	17	0,03	–	–	3	3	0,25	–	0,02	49	2	0,007	8	0,004	2	41	4	24	7,33
Tereny z zabudową wiejską *Village areas* n = 108	a	<1	0,07	<3	6	<0,01	<0,5	<1	<1	<1	0,04	<0,02	<0,01	9	<1	<0,002	<2	<0,003	<1	13	<1	7	6,57
	b	4	1,85	89	170	9,62	62,5	13	36	33	7,32	0,17	5,50	5485	46	0,101	1249	0,043	140	109	46	9662	8,74
	c	–	0,48	–	30	0,96	–	3	8	7	0,93	–	0,28	393	8	0,016	84	0,006	12	49	11	353	7,80
	d	–	0,36	–	23	0,13	–	2	5	5	0,51	–	0,06	146	5	0,012	24	0,004	5	45	7	83	7,79
	e	–	0,34	–	21	0,09	–	2	4	4	0,43	–	0,05	150	4	0,012	21	0,003	4	46	6	66	7,88
Tereny z zabudową miejską *Urban areas* n = 84	a	<1	0,05	<3	7	<0,01	<0,5	<1	<1	<1	0,05	<0,02	<0,01	4	<1	0,002	<2	<0,003	<1	10	1	4	5,90
	b	2	1,25	105	106	12,33	37,3	24	26	36	14,08	1,68	1,66	2894	52	0,122	1057	0,094	200	110	43	5965	9,05
	c	–	0,33	–	24	0,58	–	–	5	6	0,77	–	0,14	231	5	0,017	75	0,006	10	43	7	314	7,89
	d	–	0,25	–	20	0,10	–	–	3	4	0,30	–	0,05	64	2	0,011	18	0,004	4	38	4	48	7,87
	e	–	0,21	–	17	0,07	–	–	3	4	0,23	–	0,03	46	2	0,011	19	0,004	3	38	4	37	7,97
Tereny przemysłowe *Industrial areas* n = 20	a	<1	0,04	<3	7	0,01	<0,5	<1	<1	1	0,04	<0,02	<0,01	4	<1	0,002	<2	<0,003	1	10	<1	4	7,02
	b	0,5	0,82	12	102	15,83	2,9	6	16	10	1,52	0,06	7,82	1315	14	0,022	152	0,018	51	92	22	288	8,90
	c	–	0,26	–	23	1,17	–	–	4	4	0,40	–	0,60	184	3	0,008	21	–	6	39	5	51	7,94
	d	–	0,20	–	16	0,07	–	–	2	4	0,21	–	0,04	39	2	0,006	6	–	3	34	3	20	7,92
	e	–	0,18	–	12	0,04	–	–	2	4	0,16	–	0,02	19	1	0,007	4	–	2	34	3	13	7,99
Pola uprawne *Cultivated fields* n = 102	a	<1	0,10	<3	8	<0,01	<0,5	<1	<1	1	0,09	<0,02	<0,01	10	<1	0,003	3	<0,003	<1	13	2	7	5,59
	b	8	1,94	89	165	18,32	95,8	18	40	35	5,38	0,16	10,36	4968	49	0,040	2386	0,026	223	199	63	9417	9,26
	c	–	0,69	8	37	2,42	5,3	4	12	9	1,44	0,04	0,86	655	12	0,015	127	0,007	22	59	17	640	7,93
	d	–	0,54	5	30	0,38	1,3	3	9	6	0,98	0,03	0,18	337	8	0,013	47	0,005	9	54	13	185	7,89
	e	–	0,55	6	33	0,29	1,1	3	9	7	1,16	0,03	0,16	357	9	0,015	41	0,005	8	57	15	154	8,05
Lasy *Forests* n = 457	a	<1	0,04	<3	3	<0,01	<0,5	<1	<1	<1	0,01	<0,02	<0,01	<2	<1	<0,002	<2	<0,003	<1	7	<1	1	4,21
	b	9	2,29	40	367	13,57	139,7	18	41	30	5,67	0,19	6,24	3548	51	0,121	2343	0,148	37	160	52	14770	9,30
	c	–	0,27	–	17	–	–	–	3	3	0,33	–	0,07	105	3	0,007	24	–	2	41	5	84	6,61
	d	–	0,21	–	13	–	–	–	2	2	0,16	–	0,02	20	1	0,005	4	–	1	36	3	15	6,55
	e	–	0,19	–	11	–	–	–	2	2	0,14	–	0,01	15	1	0,005	2	–	1	34	2	11	6,68
Łąki *Meadows* n = 211	a	<1	0,05	<3	7	<0,01	<0,5	<1	<1	<1	0,02	<0,02	<0,01	4	<1	<0,002	<2	<0,003	1	11	<1	3	5,07
	b	1	2,39	171,0	182	22,87	61,8	34	51	40	7,65	0,14	10,08	7220	48	0,103	2160	0,123	367	161	59	5364	9,20
	c	–	0,62	6,7	36	2,11	–	4	11	8	1,19	0,03	0,43	422	12	0,017	68	0,008	24	48	15	237	7,72
	d	–	0,44	3,8	27	0,21	–	2	6	5	0,59	0,02	0,08	142	6	0,011	18	0,005	7	43	9	65	7,69
	e	–	0,55	4,0	28	0,14	–	3	8	6	0,69	0,02	0,09	226	7	0,012	19	0,004	6	43	13	50	7,73
Nieużytki, ugory *Wasteland, fallows* n = 319	a	<1	0,03	<3	5	<0,01	<0,5	<1	<1	<1	0,01	<0,02	<0,01	3	<1	<0,002	<2	<0,003	<1	10	<1	3	5,43
	b	4	1,99	105	244	22,98	76,6	81	273	38	14,08	0,30	10,21	4863	197	0,122	3970	1,106	185	155	57	9662	9,58
	c	–	0,47	–	33	1,62	–	3	8	7	1,01	–	0,62	477	8	0,014	119	0,012	13	49	11	420	7,78
	d	–	0,34	–	24	0,16	–	2	5	4	0,47	–	0,08	132	4	0,010	27	0,005	5	44	7	83	7,75
	e	–	0,31	–	21	0,07	–	2	4	5	0,51	–	0,05	155	4	0,010	26	0,004	4	45	7	75	7,82

Tabela 3 cd.
Table 3 cont.

Gleby *Soils*	Parametry *Parameters*	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	Hg	Mg	Mn	Ni	P	Pb	S	Sr	Ti	V	Zn	pH
		[mg/kg]	[%]	[mg/kg]		[%]	[mg/kg]				[%]	[mg/kg]	[%]	[mg/kg]		[%]	[mg/kg]	[%]	[mg/kg]				[–]
	Granica oznaczalności *Determination limit*	1	0,01	3	1	0,01	0,5	1	1	1	0,01	0,02	0,01	2	1	0,002	2	0,003	1	5	1	1	2,00
Trawniki *Lawns* n = 84	a	<1	0,07	<3	8	<0,01	<0,5	<1	<1	<1	0,04	<0,02	<0,01	10	<1	0,002	<2	<0,003	1	18	<1	5	6,25
	b	2	1,53	51	170	12,33	62,5	11	48	33	7,32	1,68	5,50	5485	39	0,056	1161	0,033	200	110	46	5817	9,05
	c	–	0,40	–	31	0,96	2,4	2	7	6	0,74	–	0,27	332	6	0,016	79	0,007	13	50	9	273	8,09
	d	–	0,31	–	24	0,19	0,7	1	4	5	0,41	–	0,08	113	4	0,013	28	0,004	5	45	6	80	8,07
	e	–	0,27	–	22	0,16	0,6	1	4	4	0,38	–	0,07	111	3	0,013	31	0,004	5	45	5	72	8,12
Gleby piaszczyste *Sandy soils* n = 761	a	<1	0,03	<3	3	<0,01	<0,5	<1	<1	<1	0,01	<0,02	<0,01	<2	<1	<0,002	<2	<0,003	<1	10	<1	1	4,59
	b	3	1,85	44	367	22,87	95,8	34	36	28	5,67	0,30	10,36	3854	35	0,072	984	0,158	358	128	44	9417	9,30
	c	–	0,22	–	15	0,30	–	–	3	3	0,27	–	0,14	115	2	0,007	23	–	3	38	4	91	7,08
	d	–	0,19	–	13	0,02	–	–	2	2	0,16	–	0,02	27	1	0,005	5	–	1	35	3	19	7,03
	e	–	0,19	–	12	0,01	–	–	2	2	0,15	–	0,02	21	2	0,005	4	–	1	34	3	13	7,15
Gleby gliniaste *Clay soils* n = 356	a	<1	0,16	<3	8	<0,01	<0,5	<1	2	2	0,12	<0,02	0,02	6	<1	0,003	4	<0,003	1	10	3	9	4,70
	b	9	2,39	171	244	22,98	139,7	81	51	40	14,08	0,19	10,08	7220	197	0,103	2457	0,214	367	199	63	14770	9,20
	c	–	0,89	10	50	2,94	5,0	6	16	12	1,92	0,05	0,83	779	17	0,021	153	0,010	28	63	22	625	7,83
	d	–	0,79	7	42	0,73	1,4	5	13	10	1,52	0,04	0,24	442	13	0,017	57	0,007	14	58	20	205	7,78
	e	–	0,83	7	43	0,64	1,3	5	14	10	1,54	0,04	0,18	483	14	0,017	57	0,008	12	61	21	210	8,08
Gleby antropogeniczne *Anthropogenic soils* n = 54	a	<1	0,13	<3	7	0,03	<0,5	<1	1	2	0,13	<0,02	0,01	14	<1	0,005	<2	<0,003	1	19	2	8	4,83
	b	2	1,39	63	191	15,83	21,9	7	273	35	2,75	1,68	7,82	2548	18	0,122	852	0,094	107	155	37	1735	9,58
	c	–	0,41	6	46	1,53	2,3	2	13	10	0,74	0,07	0,47	368	6	0,023	131	0,015	18	53	10	268	8,20
	d	–	0,35	4	36	0,57	1,3	2	6	7	0,56	0,03	0,16	198	5	0,018	71	0,010	10	49	8	157	8,16
	e	–	0,33	4	33	0,63	1,4	2	6	7	0,61	0,03	0,15	251	5	0,019	76	0,009	11	48	9	153	8,25

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) *Aquatic sediments (all samples)* n = 256	a	<1	0,05	<3	3	<0,01	<0,5	<1	1	<1	0,05	<0,02	<0,01	3	<1	0,004	3	<0,003	<1	8	1	10
	b	2	4,45	174	1096	13,10	124,0	29	115	130	23,00	0,40	5,72	2835	45	4,577	1861	2,557	235	224	251	2826
	c	–	0,54	11	61	0,77	4,8	2	7	12	1,00	–	0,19	188	6	0,063	132	0,167	12	44	13	340
	d	–	0,32	4	38	0,28	2,1	1	6	7	0,48	–	0,06	71	4	0,029	75	0,086	8	39	7	195
	e	–	0,26	3	40	0,25	2,2	1	6	7	0,43	–	0,05	73	4	0,030	82	0,083	8	37	6	179
Strumienie i rowy (bez nazwy) *Streams and ditches (no name)* n = 115	a	<1	0,06	<3	3	<0,01	<0,5	<1	1	<1	0,05	<0,02	0,01	5	<1	0,004	3	<0,003	<1	8	1	10
	b	2	4,19	174	1096	13,10	124,0	29	115	130	16,55	0,40	5,72	1831	45	4,577	1861	0,746	235	224	118	2826
	c	–	0,80	16	85	0,55	7,3	3	9	17	1,19	0,08	0,15	151	7	0,096	166	0,183	14	44	16	428
	d	–	0,52	8	53	0,21	3,8	2	7	10	0,52	0,05	0,05	54	5	0,040	97	0,108	9	37	11	252
	e	–	0,56	8	59	0,21	4,5	2	8	12	0,45	0,06	0,04	42	5	0,045	107	0,137	10	36	11	256
Sadzawki *Small water pools* n = 10	a	<1	0,12	<3	11	0,05	<0,5	<1	2	1	0,15	<0,02	<0,01	9	2	0,007	26	0,005	2	12	3	75
	b	<1	1,05	25	134	1,09	21,2	6	14	27	0,91	0,21	0,18	541	13	0,104	397	0,945	24	49	22	686
	c	–	0,44	–	57	0,30	6,8	2	7	13	0,38	0,07	0,04	88	6	0,044	178	0,303	10	36	8	346
	d	–	0,34	–	41	0,19	2,9	1	5	9	0,33	0,04	0,03	42	5	0,028	115	0,141	8	33	7	255
	e	–	0,34	–	43	0,19	3,5	1	6	10	0,35	0,04	0,03	39	6	0,038	99	0,293	9	38	7	314
Zlewnia Brynicy do zb. Kozłowa Góra *Catchment of the Brynica River to the Kozłowa Góra reservoir* n = 43	a	<1	0,15	<3	4	<0,01	<0,5	<1	2	<1	0,06	<0,02	0,01	6	1	0,004	3	0,015	<1	9	3	18
	b	1	3,07	103	399	1,15	124,0	5	24	58	1,94	0,40	0,48	311	18	0,129	601	0,746	28	101	47	1964
	c	–	1,03	17	97	0,24	11,3	1	9	18	0,42	0,14	0,05	42	5	0,065	189	0,310	12	43	16	381
	d	–	0,84	11	71	0,15	6,5	1	8	13	0,30	0,11	0,03	26	4	0,053	123	0,232	9	38	13	277
	e	–	0,84	10	79	0,18	6,8	1	9	14	0,35	0,13	0,03	23	5	0,066	146	0,291	11	37	13	325
Zlewnia Dopływu w Boguchwałowicach *Catchment of the Dopływ w Boguchwałowicach Stream* n = 29	a	<1	0,15	<3	3	<0,01	<0,5	<1	2	3	0,05	<0,02	<0,01	3	<1	0,004	4	0,018	<1	8	2	10
	b	<1	4,45	136	240	1,07	24,7	29	23	83	23,00	0,17	0,34	2835	30	0,333	373	0,563	34	105	251	2040
	c	–	1,20	29	69	0,24	6,4	4	9	21	3,39	0,07	0,05	222	9	0,054	113	0,205	11	48	39	496
	d	–	0,73	12	44	0,12	4,1	2	7	15	0,89	0,04	0,03	30	6	0,035	79	0,138	7	41	17	268
	e	–	0,67	13	56	0,16	5,6	2	10	19	0,83	0,08	0,02	16	6	0,043	104	0,173	8	44	16	349
Dopływ w Boguchwałowicach *Dopływ w Boguchwałowicach Stream* n = 12	a	<1	0,18	<3	6	0,01	<0,5	<1	2	3	0,08	<0,02	<0,01	3	2	0,010	14	0,020	1	21	3	24
	b	<1	4,45	136	111	0,67	11,0	13	23	83	23,00	0,11	0,34	2835	27	0,333	373	0,563	24	105	251	1314
	c	–	1,16	37	63	0,19	6,0	4	10	28	3,98	0,06	0,05	399	10	0,065	120	0,231	11	57	55	482
	d	–	0,72	16	46	0,11	4,3	2	8	19	1,03	0,04	0,02	32	7	0,040	87	0,154	8	52	22	278
	e	–	0,63	14	78	0,16	6,0	2	11	22	0,90	0,08	0,02	15	7	0,046	115	0,188	9	53	16	236
Zlewnia Szeligowca *Catchment of the Szeligowiec Stream* n = 44	a	<1	0,05	<3	6	0,02	<0,5	<1	1	<1	0,09	<0,02	0,01	6	<1	0,006	11	0,008	1	12	1	28
	b	1	2,45	174	1096	1,37	19,4	17	115	130	8,78	0,16	0,23	1474	45	4,577	304	0,470	235	151	118	2826
	c	–	0,60	13	77	0,27	4,8	3	9	17	1,22	0,05	0,06	177	6	0,160	87	0,138	15	36	12	372
	d	–	0,40	6	38	0,17	2,7	2	5	8	0,55	0,03	0,04	61	4	0,040	60	0,086	7	31	7	221
	e	–	0,40	6	43	0,17	3,2	2	6	8	0,45	0,04	0,04	45	4	0,039	72	0,096	8	30	8	192
Szeligowiec *Szeligowiec Stream* n = 12	a	<1	0,05	<3	6	0,04	0,5	<1	1	1	0,11	<0,02	0,01	9	<1	0,006	11	0,014	1	22	1	67
	b	<1	1,26	12	127	0,55	12,0	15	11	28	2,28	0,07	0,15	1474	11	0,122	223	0,309	21	48	15	1030
	c	–	0,34	–	30	0,20	3,4	–	4	6	0,56	–	0,06	153	3	0,032	51	0,108	6	30	6	273
	d	–	0,22	–	19	0,13	1,7	–	3	4	0,34	–	0,04	32	2	0,019	30	0,073	4	29	4	165
	e	–	0,19	–	14	0,10	1,1	–	3	3	0,30	–	0,03	21	2	0,014	18	0,076	4	26	3	115
Przemsza (Czarna Przemsza) *Przemsza (Czarna Przemsza) River* n = 32	a	<1	0,06	<3	8	0,04	<0,5	<1	2	1	0,24	<0,02	0,02	52	1	0,008	9	0,012	1	22	2	29
	b	1	0,87	11	408	4,35	3,6	9	27	23	2,26	0,19	0,53	1585	19	0,220	293	0,257	47	73	18	344
	c	–	0,16	–	49	0,53	0,9	2	5	5	0,58	–	0,11	351	4	0,038	70	0,068	7	39	4	125
	d	–	0,14	–	33	0,26	0,6	2	4	4	0,49	–	0,08	222	3	0,026	48	0,048	5	38	4	109
	e	–	0,12	–	29	0,22	0,8	2	4	3	0,46	–	0,08	178	3	0,023	56	0,055	5	36	4	111
Zlewnia Czarnej Przemszy do zb. Przeczyce *Catchment of the Czarna Przemsza River to the Przeczyce reservoir* n = 37	a	<1	0,06	<3	5	0,02	<0,5	<1	1	<1	0,12	<0,02	0,01	8	1	0,004	5	0,005	1	25	2	18
	b	1	0,87	25	118	13,10	6,4	10	27	28	2,26	0,19	5,72	1142	24	0,171	722	0,232	45	130	20	1895
	c	–	0,23	–	31	1,40	1,2	3	6	7	0,62	–	0,61	234	6	0,027	90	0,061	9	43	6	260
	d	–	0,19	–	23	0,34	0,7	2	5	4	0,44	–	0,15	129	4	0,017	41	0,037	6	39	5	135
	e	–	0,16	–	21	0,22	0,7	2	4	4	0,41	–	0,10	140	4	0,016	27	0,035	4	34	4	113

Tabela 4 cd.
Table 4 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
Zlewnia zb. Przeczyce *Catchment of the Przeczyce reservoir* n = 67	a	<1	0,06	<3	7	0,04	<0,5	<1	2	<1	0,09	<0,02	0,01	5	<1	0,005	8	0,012	<1	11	2	18
	b	1	1,12	20	159	6,78	26,7	8	28	47	2,40	0,30	2,92	770	20	0,297	959	2,557	57	96	29	1847
	c	–	0,25	–	37	1,06	2,5	2	6	7	0,60	–	0,15	138	5	0,035	116	0,191	12	43	6	259
	d	–	0,20	–	27	0,43	1,1	1	5	4	0,45	–	0,07	83	3	0,022	66	0,086	7	40	5	147
	e	–	0,18	–	29	0,33	1,0	1	5	4	0,47	–	0,05	100	3	0,019	61	0,069	6	39	5	131
Zalew Przeczycko-Siewierski (zb. Przeczyce) *Przeczycko-Siewierski (Przeczyce) reservoir* n = 46	a	<1	0,06	<3	7	0,04	<0,5	<1	2	<1	0,09	<0,02	0,01	5	<1	0,005	8	0,012	<1	26	2	18
	b	1	0,99	11	159	6,78	26,7	8	28	47	2,40	0,30	2,92	770	20	0,297	959	2,557	53	96	29	1847
	c	–	0,24	–	37	1,34	3,0	2	6	7	0,58	–	0,19	134	5	0,036	112	0,220	13	45	6	290
	d	–	0,20	–	27	0,62	1,2	1	5	4	0,41	–	0,08	76	3	0,021	60	0,093	8	43	5	148
	e	–	0,19	–	32	0,66	1,1	1	5	4	0,39	–	0,07	91	3	0,018	56	0,085	10	43	5	129
Zlewnia Czarnej Przemszy od zapory zb. Przeczyce do Brynicy *Catchment of the Czarna Przemsza River from the Przeczyce reservoir dam to the Brynica River* n = 36	a	<1	0,06	<3	9	0,07	<0,5	<1	1	<1	0,12	<0,02	0,02	23	<1	0,004	13	<0,003	2	14	1	28
	b	2	0,93	51	408	4,35	27,0	11	26	46	2,32	0,11	1,01	1831	19	0,220	1861	0,257	55	224	23	1918
	c	–	0,21	–	72	1,29	3,9	2	6	8	0,62	–	0,25	397	4	0,038	206	0,064	16	55	7	356
	d	–	0,16	–	53	0,87	2,2	2	5	5	0,49	–	0,17	237	3	0,023	122	0,041	12	46	5	211
	e	–	0,14	–	52	1,01	1,9	2	5	5	0,41	–	0,15	236	3	0,021	113	0,045	11	43	5	154
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/dm^3]			[mg/dm^3]		[µg/dm^3]	[mg/dm^3]	[µg/dm^3]		[mg/dm^3]	[µg/dm^3]	[mg/dm^3]		[µg/dm^3]	[mg/dm^3]		[µg/dm^3]	[mg/dm^3]	[µg/dm^3]	[mg/dm^3]	[µg/dm^3]	[mg/dm^3]	[µg/dm^3]		[mg/dm^3]			[µg/dm^3]			[mg/dm^3]
	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	0,06	3,45	<0,05	0,6	<2	<0,01	0,013	<0,05	3,5	<0,05	<0,05	<0,003	0,22	<0,01	<0,5	<0,3	0,4	<0,001	<0,05	<0,5	<0,5	<0,05	<0,05	3	<0,05	<2	0,6	0,011	<0,002	<0,05	<0,05	<1	<0,003
Surface water (all samples)	b	1,23	9,27	<0,05	12295,8	118	0,29	0,771	2,50	123,3	49,42	41,56	0,006	5,08	36,01	11,1	32,5	40,4	1,655	2,01	120,5	42,7	1,95	226,36	140	6,00	<2	27,6	0,360	0,018	0,63	1,69	23	2,968
n = 266	c	0,43	6,86	–	705,3	–	0,05	0,082	–	44,1	1,75	2,33	–	1,16	1,02	2,9	4,0	12,9	0,129	0,40	11,0	3,8	–	4,68	42	0,38	–	9,8	0,105	–	0,10	0,37	–	0,264
	d	0,36	6,63	–	46,4	–	0,04	0,068	–	32,6	0,16	0,36	–	0,92	0,14	2,2	2,8	8,4	0,048	0,23	6,7	2,3	–	0,75	36	0,26	–	8,6	0,091	–	0,06	0,18	–	0,035
	e	0,45	7,44	–	18,8	–	0,05	0,060	–	44,8	0,05	0,20	–	0,77	0,09	2,2	3,8	14,4	0,068	0,29	9,9	1,9	–	0,41	45	0,31	–	8,7	0,111	–	0,06	0,39	–	0,027
Strumienie i rowy bez nazwy	a	0,08	3,60	<0,05	0,6	<2	<0,01	0,013	<0,05	3,7	<0,05	<0,05	<0,003	0,46	<0,01	<0,5	<0,3	0,6	<0,001	<0,05	<0,5	<0,5	<0,05	<0,05	3	<0,05	<2	1,2	0,011	<0,002	<0,05	<0,05	<1	<0,003
Streams and ditches no name	b	1,23	9,25	<0,05	12295,8	118	0,29	0,277	2,50	123,3	49,42	41,56	0,004	5,08	11,95	10,5	32,5	38,1	1,292	2,01	120,5	42,7	1,95	130,69	140	6,00	<2	27,6	0,360	0,017	0,45	1,60	23	2,968
n = 116	c	0,34	5,89	–	1280,8	–	0,04	0,094	0,26	33,9	3,53	4,05	–	1,68	1,34	1,8	4,2	8,4	0,141	0,27	7,7	5,4	0,06	6,17	39	0,49	–	11,7	0,094	–	0,13	–	–	0,482
	d	0,27	5,69	–	240,4	–	0,04	0,081	0,11	22,7	0,72	0,85	–	1,40	0,34	1,4	2,4	4,9	0,052	0,14	3,8	3,0	0,03	2,09	31	0,30	–	10,2	0,077	–	0,09	–	–	0,151
	e	0,23	5,98	–	732,2	–	0,04	0,076	0,13	20,0	0,85	1,96	–	1,46	0,67	1,4	2,9	4,6	0,104	0,13	2,6	2,5	0,03	2,76	38	0,37	–	10,5	0,072	–	0,11	–	–	0,250
Sadzawki	a	0,06	3,99	<0,05	3,5	<2	0,01	0,021	<0,05	3,5	<0,05	0,08	<0,003	0,24	<0,01	<0,5	<0,3	0,4	0,005	<0,05	<0,5	<0,5	<0,05	<0,05	6	0,05	<2	2,3	0,016	<0,002	<0,05	<0,05	<1	<0,003
Small water pools	b	1,00	8,97	<0,05	2657,9	6	0,12	0,222	0,33	119,1	7,90	8,22	<0,003	3,88	3,48	6,8	6,9	38,1	1,408	0,62	96,4	8,1	0,13	226,36	82	1,35	<2	12,2	0,256	0,010	0,63	0,86	4	1,396
n = 10	c	0,31	6,10	–	568,8	3	0,04	0,090	0,13	31,0	2,10	1,96	–	1,50	1,09	2,0	3,1	7,5	0,401	0,19	12,4	2,9	–	41,09	31	0,47	–	5,8	0,072	–	0,16	0,19	–	0,307
	d	0,17	5,94	–	163,5	2	0,03	0,068	0,08	14,3	0,36	0,73	–	1,00	0,43	1,4	1,8	2,7	0,135	0,12	2,6	1,8	–	4,81	21	0,33	–	5,0	0,048	–	0,08	0,07	–	0,081
	e	0,11	6,20	–	265,9	3	0,03	0,064	0,09	9,1	0,37	1,14	–	0,75	0,54	1,9	2,9	1,9	0,177	0,15	1,9	2,5	–	4,00	18	0,36	–	5,2	0,040	–	0,08	0,04	–	0,070
Zlewnia Brynicy do zb. Kozłowa Góra	a	0,06	3,60	<0,05	81,6	<2	0,02	0,032	<0,05	3,5	<0,05	0,09	<0,003	0,46	0,04	<0,5	<0,3	0,4	<0,001	<0,05	<0,5	1,0	<0,05	0,32	5	0,20	<2	3,4	0,016	<0,002	<0,05	<0,05	<1	0,009
Catchment of the Brynica River	b	0,58	7,30	<0,05	4459,5	118	0,11	0,277	0,65	71,5	15,99	8,73	0,003	5,08	11,95	6,7	11,2	18,0	0,398	0,90	18,2	11,7	0,38	39,11	60	1,10	<2	27,6	0,181	0,017	0,63	0,85	23	1,422
to the Kozłowa Góra reservoir	c	0,20	4,78	–	2029,6	9	0,05	0,095	0,26	15,8	4,36	2,54	–	1,89	1,79	1,7	5,2	3,8	0,128	0,18	3,1	4,0	–	9,29	30	0,50	–	14,9	0,058	0,005	0,18	–	4	0,611
n = 45	d	0,17	4,68	–	1396,8	5	0,04	0,086	0,19	11,7	2,40	1,88	–	1,66	1,06	1,3	4,0	2,5	0,097	0,12	2,1	3,5	–	5,76	26	0,46	–	13,6	0,051	0,004	0,13	–	3	0,407
	e	0,17	4,50	–	1940,5	5	0,04	0,084	0,26	10,0	3,53	2,36	–	1,62	1,23	1,2	4,6	2,4	0,114	0,13	2,1	3,1	–	7,11	27	0,45	–	13,6	0,051	0,004	0,15	–	3	0,569
Zlewnia Dopływu w Boguchwałowicach	a	0,08	3,45	<0,05	4,7	<2	0,02	0,022	<0,05	3,80	<0,05	<0,05	<0,003	0,57	0,03	0,6	<0,3	1,0	0,003	<0,05	1,0	<0,5	<0,05	0,11	5	0,10	<2	0,6	0,016	<0,002	<0,05	<0,05	<1	0,009
Catchment of the Dopływ	b	0,55	7,25	<0,05	12295,8	13	0,07	0,188	1,39	62,7	35,52	41,56	0,006	3,20	36,01	11,1	16,5	12,7	1,655	1,39	23,4	42,7	0,15	21,67	86	1,03	<2	24,3	0,159	0,018	0,42	0,44	15	2,968
w Boguchwałowicach Stream	c	0,24	5,00	–	2284,8	3	0,04	0,078	0,51	18,4	4,47	10,54	–	1,53	4,33	2,3	5,9	3,8	0,220	0,16	4,0	11,8	–	5,10	42	0,34	–	13,7	0,071	–	0,14	–	3	0,831
n = 29	d	0,21	4,88	–	869,5	2	0,04	0,070	0,28	14,0	1,65	4,13	–	1,38	1,61	1,9	3,6	2,9	0,114	0,08	2,9	6,5	–	3,05	34	0,30	–	11,5	0,061	–	0,10	–	2	0,388
	e	0,21	4,60	–	1748,6	2	0,04	0,066	0,38	12,9	2,68	8,48	–	1,27	2,37	1,8	6,3	2,5	0,128	0,07	2,5	8,9	–	4,61	41	0,31	–	15,9	0,062	–	0,11	–	1	0,652
Dopływ w Boguchwałowicach	a	0,10	3,45	<0,05	4,7	<2	0,02	0,041	<0,05	3,8	0,18	<0,05	<0,003	0,72	0,03	0,9	<0,3	1,0	0,053	<0,05	1,8	1,2	<0,05	0,11	15	0,12	<2	5,6	0,023	<0,002	<0,05	<0,05	<1	0,019
Dopływ w Boguchwałowicach Stream	b	0,55	7,25	<0,05	5535,4	13	0,07	0,147	0,99	62,7	5,01	19,45	0,006	1,84	36,01	11,1	10,4	12,7	1,655	1,39	23,4	21,1	0,15	9,96	60	1,03	<2	20,0	0,134	0,018	0,19	0,44	15	1,163
n = 12	c	0,29	4,82	–	2113,4	4	0,04	0,068	0,48	20,3	2,05	8,55	–	1,10	6,91	3,0	5,4	4,1	0,253	0,23	5,8	9,6	–	4,06	43	0,33	–	14,4	0,070	–	0,11	0,11	3	0,582
	d	0,25	4,68	–	580,4	3	0,03	0,064	0,26	12,8	1,28	4,11	–	1,06	2,68	2,2	2,9	2,7	0,125	0,10	3,8	6,8	–	2,24	39	0,26	–	13,2	0,060	–	0,08	0,06	2	0,309
	e	0,23	4,25	–	1932,4	3	0,04	0,058	0,44	9,9	2,35	9,16	–	1,09	4,65	1,9	6,5	2,1	0,088	0,11	2,7	11,0	–	4,45	46	0,24	–	16,4	0,062	–	0,12	0,04	1	0,630
Zlewnia Szeligowca	a	0,06	3,96	<0,05	8,2	<2	<0,01	0,013	<0,05	4,7	<0,05	<0,05	<0,003	0,24	0,06	<0,5	<0,3	0,8	0,003	<0,05	<0,5	<0,5	<0,05	0,09	3	0,13	<2	0,8	0,011	<0,002	<0,05	<0,05	<1	<0,003
Catchment of the Szeligowiec Stream	b	1,23	7,91	<0,05	2527,1	25	0,29	0,159	0,83	72,5	7,32	21,67	<0,003	3,99	6,47	3,0	5,9	36,8	0,374	0,72	120,5	27,3	0,12	23,44	136	6,00	<2	14,2	0,276	0,008	0,28	0,73	5	1,364
n = 43	c	0,34	6,53	–	507,1	–	0,03	0,055	–	30,9	1,22	2,42	–	1,48	0,84	1,4	1,8	9,7	0,104	0,15	10,7	3,4	–	2,12	31	0,69	–	7,6	0,082	–	–	0,17	–	0,226
	d	0,27	6,41	–	124,8	–	0,02	0,050	–	23,1	0,27	0,54	–	1,16	0,40	1,2	1,2	5,9	0,065	0,09	4,0	1,9	–	0,82	23	0,39	–	6,5	0,069	–	–	0,09	–	0,064
	e	0,28	7,11	–	69,6	–	0,02	0,057	–	31,3	0,20	0,36	–	1,27	0,26	1,3	1,6	6,9	0,074	0,09	2,6	1,6	–	0,60	27	0,35	–	8,5	0,068	–	–	0,08	–	0,054
Szeligowiec	a	0,22	6,88	<0,05	6,4	<2	0,02	0,040	<0,05	20,1	<0,05	0,06	<0,003	0,28	0,08	1,0	<0,3	6,4	0,025	<0,05	2,6	0,8	<0,05	0,06	10	0,05	<2	0,8	0,062	<0,002	<0,05	<0,05	<1	<0,003
Szeligowiec Stream	b	0,73	7,91	<0,05	104,2	<2	0,04	0,081	0,10	50,1	1,17	0,92	<0,003	0,88	1,51	3,0	1,9	25,0	0,223	0,20	53,8	1,6	<0,05	0,60	52	0,43	<2	11,0	0,107	<0,002	0,08	0,68	<1	0,099
n = 13	c	0,42	7,31	–	41,2	–	0,02	0,058	–	38,0	–	0,40	–	0,52	0,67	1,8	1,4	16,9	0,104	0,08	13,9	1,0	–	0,30	31	0,22	–	8,2	0,081	–	–	0,23	–	0,031
	d	0,40	7,30	–	28,1	–	0,02	0,056	–	36,6	–	0,32	–	0,49	0,46	1,7	1,2	15,8	0,078	0,06	9,9	1,0	–	0,25	29	0,20	–	7,1	0,080	–	–	0,12	–	0,014
	e	0,39	7,37	–	32,3	–	0,02	0,053	–	41,7	–	0,31	–	0,45	0,62	1,5	1,6	14,4	0,071	0,06	6,9	1,0	–	0,24	30	0,21	–	9,8	0,075	–	–	0,09	–	0,015
Przemsza (Czarna Przemsza)	a	0,53	7,13	<0,05	1,1	<2	0,05	0,038	<0,05	48,6	<0,05	<0,05	<0,003	0,43	0,02	3,4	2,8	9,9	0,039	0,57	13,2	1,4	<0,05	<0,05	39	0,17	<2	7,3	0,109	<0,002	<0,05	0,38	<1	<0,003
Przemsza (Czarna Przemsza) River	b	0,69	8,91	<0,05	12,6	<2	0,14	0,119	<0,05	75,9	0,17	0,27	<0,003	2,04	0,12	7,7	6,3	30,3	0,373	0,87	25,2	5,4	0,10	0,56	57	0,45	<2	11,6	0,179	<0,002	0,27	0,75	<1	0,033
n = 34	c	0,61	7,84	–	6,0	–	0,08	0,071	–	67,2	–	0,15	–	0,75	0,06	5,4	4,6	17,4	0,124	0,69	18,2	2,2	–	0,16	51	0,26	–	9,2	0,146	–	0,08	0,58	–	0,016
	d	0,61	7,83	–	5,0	–	0,08	0,066	–	66,9	–	0,11	–	0,71	0,06	5,2	4,4	16,7	0,110	0,68	17,9	2,1	–	0,13	51	0,25	–	9,1	0,146	–	0,06	0,57	–	0,013
	e	0,61	7,68	–	6,8	–	0,08	0,060	–	67,6	–	0,16	–	0,77	0,06	5,8	5,0	17,6	0,133	0,69	19,3	2,4	–	0,13	52	0,26	–	9,8	0,146	–	0,07	0,61	–	0,017
Zlewnia Czarnej Przemszy do zb. Przeczyce	a	0,20	5,86	<0,05	1,0	<2	0,01	0,018	<0,05	19,7	<0,05	<0,05	<0,003	0,22	<0,01	0,8	<0,3	4,3	0,003	<0,05	3,4	0,7	<0,05	<0,05	9	0,06	<2	1,7	0,055	<0,002	<0,05	<0,05	<1	<0,003
Catchment of the Czarna Przemsza	b	0,72	9,25	<0,05	1781,7	4	0,14	0,090	0,29	75,9	2,95	8,66	<0,003	2,02	4,23	8,0	8,9	40,4	0,774	0,81	35,5	6,5	0,56	4,04	61	0,47	<2	20,4	0,179	0,005	0,31	0,90	8	0,375
River to the Przeczyce reservoir	c	0,59	7,88	–	85,7	–	0,05	0,063	–	59,1	–	0,70	–	0,73	0,33	4,1	4,2	22,8	0,117	0,46	14,9	2,4	–	1,00	48	0,29	–	8,3	0,112	–	0,15	0,51	–	0,053
n = 38	d	0,57	7,85	–	10,8	–	0,04	0,060	–	55,6	–	0,21	–	0,66	0,03	3,4	3,5	18,3	0,040	0,29	12,9	2,2	–	0,38	43	0,25	–	7,6	0,105	–	0,09	0,31	–	0,025
	e	0,65	7,92	–	6,8	–	0,06	0,070	–	67,5	–	0,18	–	0,65	0,03	3,8	3,7	20,3	0,059	0,60	12,1	2,4	–	0,42	55	0,28	–	7,5	0,115	–	0,11	0,57	–	0,030

Tabela 5 cd.
Table 5 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
Zlewnia zb. Przeczyce	a	0,11	4,47	<0,05	2,1	<2	0,01	0,029	<0,05	11,7	<0,05	<0,05	<0,003	0,31	0,01	<0,5	<0,3	1,5	0,002	<0,05	1,5	0,7	<0,05	<0,05	19	0,05	<2	2,9	0,031	<0,002	<0,05	<0,05	<1	<0,003
Catchment of the Przeczyce reservoir	b	1,00	9,27	<0,05	2445,7	4	0,27	0,771	2,50	119,1	49,42	25,22	<0,003	4,49	3,48	6,8	32,5	24,6	1,408	0,90	96,4	34,2	0,31	226,36	140	1,35	<2	15,6	0,256	0,008	0,44	0,71	4	2,715
n = 72	c	0,50	8,14	–	65,3	–	0,08	0,069	–	52,3	–	0,92	–	0,79	0,19	4,5	4,7	15,9	0,147	0,62	16,3	2,6	–	7,07	49	0,31	–	8,0	0,122	–	–	0,50	–	–
	d	0,49	8,09	–	8,6	–	0,08	0,053	–	50,5	–	0,18	–	0,67	0,06	4,2	3,7	15,1	0,043	0,54	14,4	1,9	–	0,23	47	0,27	–	7,5	0,118	–	–	0,43	–	–
	e	0,47	8,29	–	6,5	–	0,08	0,045	–	47,4	–	0,13	–	0,62	0,04	4,8	4,2	15,5	0,039	0,71	15,4	1,8	–	0,19	46	0,31	–	8,3	0,117	–	–	0,55	–	–
Zalew Przeczycko-Siewierski (zb. Przeczyce)	a	0,41	7,54	<0,05	2,1	<2	0,01	0,029	<0,05	40,1	<0,05	<0,05	<0,003	0,41	0,01	<0,5	<0,5	14,0	0,002	0,22	5,3	0,7	<0,05	<0,05	30	0,06	<2	2,9	0,031	<0,002	<0,05	0,20	<1	<0,003
Przeczycko-Siewierski (Przeczyce) reservoir	b	0,62	9,27	<0,05	28,9	2	0,27	0,771	<0,05	80,8	1,32	0,66	<0,003	1,81	0,55	5,1	4,9	24,6	0,768	0,90	20,3	2,4	0,31	0,42	53	0,41	<2	14,1	0,148	<0,002	0,25	0,62	1	0,596
n = 52	c	0,47	8,39	–	8,6	–	0,09	0,066	–	47,9	–	0,14	–	0,63	0,05	4,5	3,9	15,8	0,065	0,71	15,3	1,7	–	0,21	45	0,31	–	7,3	0,114	–	–	0,52	–	–
	d	0,47	8,37	–	6,3	–	0,08	0,048	–	47,4	–	0,13	–	0,61	0,04	4,3	3,6	15,7	0,024	0,69	15,1	1,6	–	0,18	45	0,29	–	6,9	0,112	–	–	0,51	–	–
	e	0,47	8,42	–	5,1	–	0,08	0,043	–	46,8	–	0,12	–	0,61	0,04	4,7	4,1	15,3	0,024	0,72	15,3	1,8	–	0,20	45	0,32	–	7,9	0,116	–	–	0,54	–	–
Zlewnia Czarnej Przemszy od zapory zb. Przeczyce do Brynicy	a	0,38	7,13	<0,05	0,6	<2	<0,01	0,044	<0,05	43,4	<0,05	<0,05	<0,003	0,43	<0,01	<0,5	1,2	6,9	<0,001	0,11	6,6	0,7	<0,05	<0,05	5	<0,05	<2	6,7	0,069	<0,002	<0,05	0,13	<1	<0,003
Catchment of the Czarna Przemsza River from the Przeczyce reservoir dam to the Brynica River	b	0,84	8,16	<0,05	74,9	3	0,17	0,235	<0,05	123,3	0,33	0,67	0,004	4,18	0,80	10,5	3,7	26,8	0,373	2,01	61,6	2,7	1,95	8,71	74	0,59	<2	18,6	0,360	0,003	0,20	1,69	2	0,116
n = 39	c	0,66	7,60	–	6,1	–	0,04	0,140	–	81,0	–	–	–	0,77	0,08	2,5	2,3	18,8	0,071	0,63	12,3	1,3	–	1,06	52	0,13	–	8,3	0,174	–	0,06	0,79	–	0,019
	d	0,65	7,60	–	3,2	–	0,04	0,133	–	77,7	–	–	–	0,67	0,02	2,0	2,1	18,1	0,012	0,49	11,1	1,3	–	0,38	47	0,08	–	8,1	0,168	–	0,05	0,71	–	0,012
	e	0,66	7,60	–	2,7	–	0,03	0,133	–	69,5	–	–	–	0,55	0,01	2,2	1,7	16,3	0,008	0,68	11,1	1,3	–	0,26	52	0,07	–	7,5	0,172	–	0,06	0,77	–	0,012
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)

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 Siewierz 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

Apart from natural soil-forming factors such as bedrock, climate, vegetation, water conditions, and topography, the quality of soils is affected by anthropogenic processes that result in changes in their physico-chemical properties and disturb the soil profile structure. In small zones within industrial housing areas, in river valleys, in urbanized areas and near transport routes, much of the soils are contaminated with metals (Klojzy-Karczmarczyk, Mazurek, 2017; Liu *et al*., 2019; Sager, 2020).

Grain size composition. The percentage of particles of specified diameters in a soil is called its mechanical composition, particle size distribution, grain-size (granulometric) composition or granulometric distribution. The granulometric distribution does not change as a result of the processes taking place within soils. Furthermore, it is considered one of the basic physical characteristics of soils, as many soil properties are related to it (Mocek *et al*., 2000; Ryżak *et al*., 2009).

The study adopted the division of soil particles into grain size fractions according to the standard BN-78/9180-11, which was in force until 2008, because the project is a continuation of a serial study performed for several years continuously in accordance with the instruction to the geochemical map at the scale of 1:25,000. The results of grain size analyses are presented for 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 the previously obtained and published data.

The grain size composition of the investigated soils is clearly related to the lithology of the parent material. In the study area, sand fraction-rich soils predominate. In its northern part, covered mainly by Quaternary glaciofluvial sands and gravels, and in areas of slope wash loams, sands and gravels, and slope wash/fluvial sands, gravels and muds, the proportion of this fraction is >75% (Plate 4). Areas of the most sandy and least silty-clayey soils (frequently <10% of the clay and silt fractions) of the north-western part of the map sheet are overgrown by forests. In contrast, soils that developed mainly on the outcrops of Triassic carbonates are clearly enriched in the silt fraction (0.1–0.02 mm) and clay fraction (<0.02 mm). The silt fraction content varies mostly between 10% and 25%, while the clay fraction is between 10% and 50%. The clay fraction consists mainly of the products of weathering of primary minerals of the kaolinite, illite and montmorillonite group, but is also composed of humus colloids and organic-mineral associations (Ryżak *et al*., 2009). Soils containing a high proportion of clay minerals, i.e. those of high sorption capacity for cations, and soils containing high amounts of organic matter, are characterized by ability to strongly bind chemical elements and retain them in the surface layers. They can accumulate significant amounts of some elements, and the degree of their uptake by plants and capability of leaching into groundwater and surface water is lower than in acidic sandy soils (Kabata-Pendias, Pendias, 1999).

The pH. The pH of soils depends on the bedrock lithology, the way they are used, and anthropogenic factors. Both the topsoil (0.0–0.3 m) and subsoil (0.8–1.0 m) layers are characterized largely by neutral (pH 6.8–7.4) and alkaline (pH > 7.4) pH. Alkaline soils are found in the north-eastern and southern parts of the map sheet. In the subsoil layer, the proportion of soils with a pH > 7.4 is about 30%; in the subsoil layer it is 53%. The higher proportion of alkaline pH soils at a depth of 0.8–1.0 m indicates that their alkalinization can be linked primarily to the presence of Triassic carbonates. A very acidic (<5.0) to acidic (5.0–6.0) pH (Plates 7 and 8) is typical of soils from the north-western part of the map sheet, which is covered mostly by forests, with a stronger acidification of topsoil (median pH 6.67) compared to subsoil (median pH 7.48) (Tabs. 2 and 3).

Geochemistry. The distribution of the contents of major and trace elements in the soils is constrained by the chemical composition of the bedrock and by anthropogenic factors. In the areas of insignificant anthropogenic pressure (north-western part of the sheet), and depending on the physico-chemical conditions of the environment, soil-forming processes have led to changes in the chemical composition of the soils in relation to the parent rocks, but most often the basic geochemical characteristics of the original rocks are preserved. In the south-eastern part of the study area, there are soils enriched in, among others, calcium and manganese, and contaminated with some metals as a result of historical mining and processing of Zn-Pb and Fe ores. Relatively high contents of these elements were found in this area already at the time of compilation of the Geochemical Atlas of Upper Silesia (Lis, Pasieczna, 1995b, 1997).

Soils that developed mainly on Quaternary glaciofluvial sands and gravels, characterized by the sandy fraction exceeding 75%, generally contain the lowest concentrations of analysed elements in both soil levels. The low contents of the elements in these soils can be associated with the poor chemical composition of the bedrock and the acidic pH, which favours leaching of many elements. Soils that developed on Triassic carbonates tend to be enriched in most of the elements studied. They are conspicuous by relatively high amounts of calcium, whose content reaches a maximum of 19.68% in topsoil, and 22.98% in subsoil, and are also rich in magnesium and manganese.

The median contents of silver, arsenic, barium, calcium, cobalt, chromium, copper, iron, mercury, magnesium, manganese, nickel, phosphorus, sulphur, strontium and vanadium in the topsoil layer are lower or close to the geochemical background values of these elements in the Silesian-Cracow region (Tab. 2). In contrast, slightly higher contents of cadmium and zinc, and a marked enrichment (about twofold) in lead and titanium are observed.

The aluminium content in soils that developed on Triassic carbonates is usually in the range of 0.40%–0.80% (max. 2.06%) in topsoil and 0.40–1.60% (max. 2.39%) in subsoil. In forest areas (mainly in the northern part of the map sheet), composed of glaciofluvial sands and gravels, soils are poorer in aluminium (<0.40%). The mobility of aluminium in soils depends significantly on the combinations with organic matter and the degree of soil's acidity (*e.g.* Kabata-Pendias, Mukherjee, 2007). Soil's acidity is presumably the main factor that affects the mobilization and presence of aluminium in the waters, and consequently its concentration in the sediments, which is particularly well marked in the watercourses of the north-western part of the map sheet area (Plates 11 and 12).

The total organic carbon content in the topsoil layer varies from 0.09 to 49.20% (median 1.33%). The highest level of organic carbon (>12%) is found in soils of wet valleys of watercourses in the north-western and north-eastern parts of the map sheet, filled with alluvial muds and peats. The maximum content (49.20%) is recorded in soils of the Szeligowiec Stream valley. Soils containing more than 24% of carbon are simultaneously enriched in aluminium (>0.40 mg/kg), arsenic (>5 mg/kg), barium (>60 mg/kg), cadmium (>4.0 mg/kg), copper (>10 mg/kg), mercury (>0.10 mg/kg), nickel (>5 m/kg), phosphorus (>0.030%), lead (>100 mg/kg) and sulphur (>0.160%). The presence of sediments showing high sorption capacity (silts, peats, clays) can strongly contribute to the increase in the concentration of the analysed chemical elements. Organic carbon content of soils is also dependent on the way they are used. The median total organic carbon content in cultivated field soils is 1.18%, in forest soils it is 1.68%, and in industrial soils – 0.86% (Tab. 2).

In most of the soils, the sulphur content does not exceed 0.080% in both the topsoil and subsoil layers. Contents higher than 0.160% were found in peaty soils of wetlands, which are also rich in total organic carbon.

The phosphorus content of the soils is dependent on both the chemical composition of parent rocks and the way they are used. The median content of phosphorus in the topsoil layer (0.023%) is almost three times higher than its median in subsoil (0.008%). Soils from both depth intervals, that are derived from carbonate parent rocks, are richer in phosphorus compared to those developed on sandy sediments (>0.015% and <0.015%, respectively). The lowest levels of phosphorus (in both topsoil and subsoil) are found in acidic soils of forests (medians: 0.013% and 0.005%, respectively). In the topsoil layer, increased contents of phosphorus are measured in soils of cultivated fields (median 0.032%), rural areas (median 0.029%) and urban areas (median 0.025%), which is probably related to its excessive accumulation as a result of phosphorus fertilizer application and introduction in the form of waste and sewage.

Both topsoil and subsoil in areas composed of carbonates have naturally high concentrations of calcium (>1.00%), magnesium (>0.50%), manganese (>400 mg/kg) and strontium (>40 mg/kg). The distribution of these elements, reflecting the relationship with the bedrock chemistry, is more pronounced in subsoil and coincides with the outcrops of Triassic limestones and dolomites. Soils enriched in calcium, magnesium, manganese and strontium cover mainly the southern part of the map sheet. They also occur in the Polichno–Kazimierówka region near the northern boundary of the study area (where there are opencast dolomite mines), in the Boguchwałowice region (n the central part of the sheet), and in the area of Siewierz (in its eastern part). These soils are also conspicuous by elevated contents of iron, cobalt, chromium, nickel, vanadium and titanium, which presumably points to the bedrock as their primary source.

The barium concentration in both soil horizons rarely exceeds 120 mg/kg. Figures above 200 mg/kg in topsoil are found in some peaty soils, while the highest barium concentration (469 mg/kg) is observed in anthropogenic soil in the area of Siewierz. In the subsoil layer, relatively high concentrations of barium are limited to much smaller areas, and its maximum content (367 mg/kg) in this layer is found in the Szeligowiec Stream valley.

Cadmium, lead and zinc are associated with the presence of zinc-lead ores in carbonate rocks and with mining and metallurgical activities. Their geochemical anomalies occupy more extensive areas in topsoil (Plates 22, 46 and 61) compared to subsoil (Plates 23, 47 and 62). The cadmium and zinc anomalies are more intense in the deeper soil layers. The spatial distributions of cadmium, lead and zinc are similar, which is more pronounced in subsoil.

As regards both soil depth layers, the highest concentrations of cadmium (>8.0 mg/kg), lead (>250 mg/kg) and zinc (>1,000 mg/kg) are found in the Boguchwałowice–Tuliszów–Zawarpie–Trzebiesławice region. Distinct geochemical anomalies of these elements are also observed in the south-western part of the map sheet near Sławniów Gaj and Targoszyce, and at its northern boundary in the Polichno region. A high lead concentration (up to 2,457 mg/kg) in subsoil is also recorded in the eastern part of the map sheet in Siewierz. The map sheet area has a long tradition of mining and iron ore processing. Hence, there are traces of historical ore mining in many localities, including among others the Trzebiesławice and Podwarpie regions (Łabęcki, 1841; https://www.siewierz.pl/miasto/historia-miasta-i-gminy-siewierz [access 18/07/2024]). On the western outskirts of Siewierz, the zinc ore mine "Wiktor Emanuel" operated (Sołtysik, 2008; Preidl, Wójcik, 2014). It may be assumed that the main source of the apparent geochemical anomalies is the outcrops of ore-bearing and Diplopora dolomites and associated zinc-lead ore deposits. The anomalies may be a result of the shallow historical mining of Zn-Pb and Fe ores and the past activity of forges for smelting metals.

At the southern boundary of the map sheet, in the Zarzecze-Zawodzie region, high concentrations of lead, cadmium and zinc are observed in the soils of wetland valleys of watercourses, filled with alluvial muds and peats. The maximum concentrations of these elements in topsoil and subsoil are, respectively: for lead 3,521 mg/kg and 3,970 mg/kg, for cadmium 24.7 mg/kg and 42.8 mg/kg, and for zinc 2,023 mg/kg and 5,060 mg/kg.

Analyses of agricultural land soils, carried out in 2006, showed high levels of metal contamination. In the municipality of Mierzęcice, in the map sheet area, the maximum concentrations were as follows: 8.11 mg/kg of cadmium, 358.16 mg/kg of lead, and 1,124.63 mg/kg of zinc (Przeczyce-Boguchwałowice region), whereas in the town and municipality of Siewierz, these were up to: 1,918.66 mg/kg lead, 35.47 mg/kg cadmium, and 2,613.50 zinc (Wykaz, 2006).

In the area of anomalous contents of cadmium, zinc and lead, there are also high concentrations of arsenic (Plates 13 and 14). Its maximum concentration (258 mg/kg) was measured in the topsoil layer of anthropogenic soil in the western part of the map sheet near Komorne. At this site, the cadmium concentration is 24.6 mg/kg, lead 885 mg/kg, and zinc 6,573 mg/kg.

A local anomaly in silver concentration (>4 mg/kg) is observed in both depth intervals near Zawarpie, on the outcrops of Diplopora and ore-bearing dolomites (Plates 9 and 10). In this area, the soils are also enriched in calcium, cadmium, mercury, magnesium, manganese, lead and zinc, which may indicate a relationship between these elements and the bedrock geology.

The copper concentration in most of the topsoil and subsoil layers does not exceed 10 mg/kg (Plates 28 and 29). The highest concentration of this element (148 mg/kg) is found in a topsoil sample collected from meadows in the south-western part of the map sheet near the village of Gostów. High copper concentrations (126 mg/kg) are also observed in wasteland soil of the north-eastern part of the map sheet, in the area of Siewierz. Copper may be introduced into the soils with mineral and organic fertilizers, with plant protection preparations, and with municipal waste (*e.g.* Kabata-Pendias, Pendias, 1999). The copper geochemical anomalies in the study area are probably of anthropogenic origin, which is further evidenced by the fact that they do not occur in deeper zones of the soil profile at these locations.

In the topsoil layer of Europe, the median mercury concentration is 0.037 mg/kg (Salminen, 2005). In Poland, the concentration of this element in soils varies from <0.05 to 7.55 mg/kg (median <0.05 mg/kg) (Lis, Pasieczna, 1995a). In the map sheet area, the mercury concentration in most of the studied soils ranges from <0.02 mg/kg to 0.05 mg/kg (Plates 32 and 33). The exceptions are some peaty soils in the valleys of watercourses, where the concentrations in the topsoil layer are in the range of 0.05–0.28 mg/kg. In the subsoil layer, higher mercury concentrations (0.30–1.68 mg/kg) are recorded over a small area in anthropogenic soils of the urban expanse of Siewierz. Mercury's strong affinity for organic substances and compounds with sulphur, as well as its high volatility in elemental form, is among the most important geochemical properties that determine the content of this metal in soils. Mercury vapour is readily sorbed by organic matter and clay minerals leading to its accumulation in soils, especially in topsoil. The amount of mercury bound by organic matter is greater in acidic soils (*e.g.* Kabata-Pendias, Pendias, 1999).

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). Contamination by arsenic affects a negligible area of soils. Its high levels (>100 mg/kg) were found in an area occupied by 0.08% of the soil surface in the topsoil layer and by 0.17% in the subsoil layer. The proportion of area occupied by soils contaminated by cadmium in the topsoil layer (>15 mg/kg) is 3.09%, by lead (>600 mg/kg) 2.93%, and by zinc (>2,000 mg/kg) 2.13%. At a depth of 0.8–1.0 m, the proportion of soils contaminated with these metals is 2.97% for cadmium, 2.29% for lead, and 2.80% for zinc. It therefore follows that, despite the occurrence of geochemical anomalies in the study area, the areas occupied by them are not large and do not exceed 3.5%.

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, recreation and leisure areas) were met by 98.42% to 100% of the analysed soil samples. The contents of most elements (in 99.52–100% of soil samples) met the requirements for group II (arable land, orchards, meadows and permanent pastures, land under ponds and ditches, allotment gardens). The exceptions were arsenic, zinc, cadmium and lead, for which the percentage of samples was lower (55.74%–89.55%). Between 94.30% and 100% of the soil samples met the requirements for group III (forests, wooded and shrubby land including cultivated land, wasteland, recreation and leisure areas, ecological sites, miscellaneous land) (Tab. 7), which is significant because the land use in the map sheet area is largely agriculture and forestry An example of the assessment of soil pollution (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 (Plate 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 [km²]	0,0–0,3 m [%]*	0,8–1,0 m [km²]	0,8–1,0 m [%]*
As	<10	73,87	89,55	74,88	90,77
	10–25	7,32	8,87	6,22	7,54
	25–50	0,91	1,10	0,77	0,93
	50–100	0,33	0,40	0,49	0,59
	>100	0,07	0,08	0,14	0,17
Cd	<2	45,98	55,74	69,35	84,07
	2–5	25,54	30,95	6,57	7,96
	5–10	6,60	8,00	2,94	3,56
	10–15	1,83	2,22	1,19	1,44
	>15	2,55	3,09	2,45	2,97
Pb	<100	51,47	62,39	70,96	86,01
	100–200	19,40	23,52	5,59	6,78
	200–500	8,69	10,53	3,64	4,41
	500–600	0,52	0,63	0,42	0,51
	>600	2,42	2,93	1,89	2,29
Zn	<300	61,60	74,67	68,66	83,22
	300–500	9,60	11,64	4,33	5,25
	500–1000	6,60	8,00	5,24	6,35
	1000–2000	2,94	3,56	1,96	2,38
	>2000	1,76	2,13	2,31	2,80

* 82,5 km² = 100%

AQUATIC SEDIMENTS

Within the map sheet boundaries, sediments of watercourses and standing water bodies were studied within the following catchments: Brynica River to the Kozłowa Góra reservoir, Dopływ w Boguchwałowicach stream, Szeligowiec Stream, Czarna Przemsza River to the Przeczyce reservoir, Przeczyce reservoir, and Czarna Przemsza River from the Przeczyce dam to the Brynica River (Fig. 3).

The ranges and statistical parameters of the elemental contents in the individual catchments are presented in Table 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.

In sediments of rivers and streams of Poland, the median content of arsenic is <5 mg/kg, cadmium <0.5 mg/kg, lead 13 mg/kg, and zinc 62 mg/kg (Lis, Pasieczna, 1995a). In the catchments of the watercourses studied within the map sheet boundaries, the concentrations of these elements are many times higher, which is particularly well pronounced in the north-western part of the sheet.

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	1243	1131	1257	1262	0
	3	98,42%	89,55%	99,52%	99,92%	0,00%
Ba	1	<400	<200	<1000	<1500	>1500
	2	1262	1257	1263	1263	0
	3	99,92%	99,52%	100,00%	100,00%	0,00%
Cr	1	<200	<150	<500	<1000	>1000
	2	1263	1263	1263	1263	0
	3	100,00%	100,00	100,00	100,00	0,00
Zn	1	<500	<300	<1000	<2000	>2000
	2	1090	943	1191	1236	27
	3	86,30%	74,66%	94,30%	97,86%	2,14%
Cd	1	<2	<2	<10	<15	>15
	2	704	704	1196	1224	39
	3	55,74%	55,74%	94,70%	96,91%	3,09%
Co	1	<50	<20	<100	<200	>200
	2	1263	1261	1263	1263	0
	3	100,00%	99,84%	100,00%	100,00%	0,00%
Cu	1	<200	<100	<300	<600	>600
	2	1263	1261	1263	1263	0
	3	100,00%	99,84%	100,00%	100,00%	0,00%
Ni	1	<150	<100	<300	<500	>500
	2	1263	1263	1263	1263	0
	3	100,00%	100,00%	100,00%	100,00%	0,00%
Pb	1	<200	<100	<500	<600	>600
	2	1085	788	1218	1226	37
	3	85,91%	62,39%	96,44%	97,07%	2,93%
Hg	1	<5	<2	<10	<30	>30
	2	1263	1263	1263	1263	0
	3	100,00%	100,00%	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

Catchment of the Brynica River to the Kozłowa Góra reservoir. The catchment is located in the north-western part of the Siewierz map sheet and covers forested areas. Most of the aquatic sediment samples were taken from unnamed ditches and streams.

The median contents of barium, chromium, phosphorus, cobalt, copper, iron, manganese, nickel, strontium and titanium in the sediments is lower or close to the values defined as the geochemical background in the Silesian-Cracow region. The median concentrations of calcium and magnesium are many times lower than the geochemical background values, probably because the catchment area is covered by glaciofluvial sands and gravels dominated by quartz. The median vanadium content is slightly higher. Considerable exceedances of the regional background values are found for arsenic, cadmium, mercury, lead, sulphur and zinc (Tab. 4).

In the catchment, sediments of the watercourses draining alluvial muds deposited in their valleys show accumulations of arsenic (up to 103 mg/kg), cadmium (up to 124.0 mg/kg), mercury (up to 0.40 mg/kg), lead (up to 601 mg/kg), sulphur (up to 0.746%) and zinc (up to 1,964 mg/kg). The highest concentrations of cadmium and mercury represent the maximum levels recorded in the map sheet. Exceedances of the PEC threshold value in some samples were recorded for arsenic, cadmium, lead and zinc, but the greatest number of samples (more than half) showed exceedances of the PEC value by cadmium and lead.

Catchment of the Dopływ w Boguchwałowicach Stream. The catchment covers the central part of the map sheet, where Triassic ore-bearing dolomites are exposed on the surface, and continues towards the north-west. In terms of land use, it is dominated by forestry. In the lower reach of the Dopływ w Boguchwałowicach, in the area where it meets the Przeczyce-Siewierz reservoir, there are meadows, wastelands and arable fields, as well as urban areas.

Sediments of both the Dopływ w Boguchwałowicach stream and its entire catchment area are characterized by higher median contents of arsenic, cadmium, chromium, copper, mercury, lead, sulphur, titanium and vanadium than their regional geochemical background levels (Tab. 4). Relatively high concentrations of metals, arsenic and sulphur are observed mainly in the northern part of the catchment in sediments of the upper reaches of the Dopływ w Boguchwałowicach, where it drains alluvial muds, as well as in the samples taken from one of its unnamed tributaries. The levels recorded there are as follows: 1.10–4.45% aluminium, 1.87–23.00% iron, 16–83 mg/kg copper, 21–251 mg/kg vanadium, and 0.173–0.563% sulphur. Sediments of this part of the catchment are also abundant in elements associated with ore mineralization, i.e. arsenic, cadmium, lead and zinc, whose levels are in the range of 22–136 mg/kg, 3.6–24.7 mg/kg, 75–303 mg/kg and 417–2,040 mg/kg, respectively. The elevated concentrations of metals in alluvial muds and peats of the stream valleys is favoured by the composition of the sediments rich in organic matter, iron and manganese oxides and hydroxides, and clay minerals.

Exceedances of the PEC values for arsenic, cadmium, lead and zinc are observed in the catchment. The greatest number of such exceedances was recorded in the case of cadmium (55%).

Catchment of the Szeligowiec Stream. The northern part of the map sheet area is covered by the caatchment of the Szeligowiec Stream that, together with its network of tributaries, drains mainly forested areas and meadows. The stream feeds the Przeczyce-Siewierz reservoir.

The median contents of most elements in the sediments of the catchment are equal to or lower than the geochemical background values in the Silesian-Cracow region. Only in the case of cadmium, lead and sulphur, the calculated median values are higher than the background levels. The Szeligowiec Stream sediments are characterized by low contents of the elements. A slight enrichment above the geochemical background level of the region is observed for sulphur (median 0.096%) (Tab. 4).

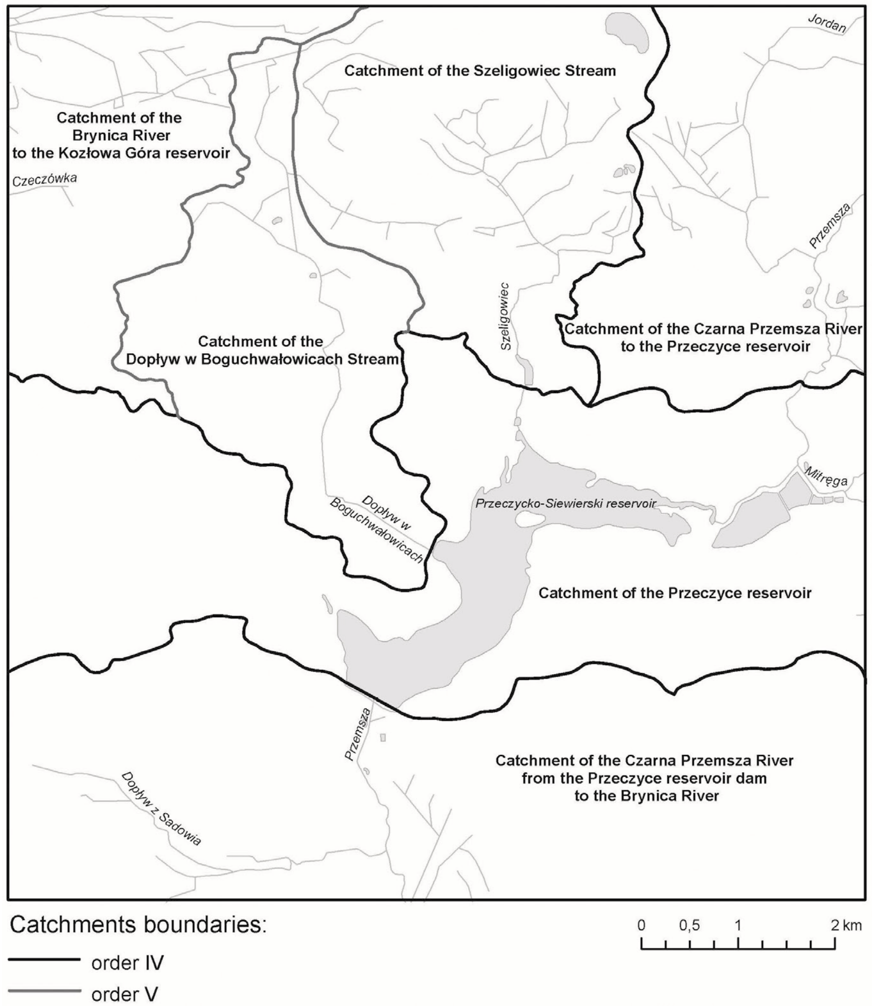

Fig. 3. Location of watercourses, standing water bodies and the catchments (https://wody.isok.gov.pl/imap_kzgw/ [access 12.09.2024])

The aluminium content in the sediments of the catchment is mostly in the range of 0.10–0.89%, exceeding 1% only in a few samples. Arsenic was found in most sediments within the natural content range (<3–10 mg/kg). In some samples from unnamed watercourses in the upper part of the catchment area, the arsenic content is 44–58 mg/kg, with a maximum of 174 mg/kg in sediments from a ditch flowing across its western part. The aquatic sediment sample with the highest arsenic concentration is also abundant in iron (8.35%) and vanadium (118 mg/kg). The concentrations of calcium and magnesium show little variability and are 0.02–1.37% and 0.01–0.23%, respectively. The mercury concentration in most of the sediments of the catchment is less than or close to the regional geochemical background level (0.06 mg/kg). In some sediments, slightly elevated concentrations of this element were recorded, falling within the range of 0.10–0.16 mg/kg.

In a forest ditch near the eastern boundary of the catchment, fine-grained organic matter-rich sediments are distinguished by significant concentrations of most of the elements analysed: 29 mg/kg arsenic, 19.4 mg/kg cadmium, 34 mg/kg chromium, 130 mg/kg copper, 8.78% iron, 127 mg/kg lead, and 2,826 mg/kg zinc. The sediments are also rich in aluminium (2.45%), barium (1,096 mg/kg) and phosphorus (4.577%).

Analysis of the results shows that several samples collected mainly from unnamed watercourses and ditches have higher contents of cadmium and zinc than the PEC values. In the case of arsenic, chromium and lead, the number of samples, in which these contents were higher than the PEC level, did not exceed nine.

Przemsza (Czarna Przemsza) River. The headwaters of the Przemsza River are located near Zawiercie in the Cracow-Częstochowa Upland (outside the map sheet area). In its upper reach, the river drains forest and farmland areas, and the water relations are close to natural. Anthropogenic changes in the river are particularly evident downstream of the Przeczyce reservoir, where it drains areas where the environment is transformed the most (Rzętała, 2003).

Within the map sheet boundaries, the median contents of the elements analysed in the Przemsza River sediments are lower than their geochemical background values for the Silesian-Cracow region (Tab. 4). Exceedances of the PEC index are observed only for lead in about 16% of samples.

Catchment of the Czarna Przemsza River to the Przeczyce reservoir. Within the catchment, there is a small fragment of the Przemsza River valley where the town of Siewierz is located. In that area, the river flows mainly across meadows in a natural, unregulated channel that forms numerous meanders (https://www.siewierz.pl/turystyka/sciezki-rowerowe-i-dydaktyczne/sciezka-dydaktyczna-w-poblizu-zamku-biskupow-krakowskich-w-siewierzu [access 9/10/2024]). It drains fluvial sands, gravels and muds of floodplain terraces. The northern part of the catchment area is drained by the Jordan Stream, one of its right-bank tributaries.

The median contents of analysed chemical elements in the sediments of the Przemsza River and the whole catchment are lower than the regional background level (Tab. 4). The highest concentrations of metals are found in the central part of the catchment in the Jordan Stream and its tributary ditch draining mainly wasteland and fallow land. Locally, the concentrations are 1.8–6.4 mg/kg of cadmium, 163–722 mg/kg of lead, and 441–1,895 mg/kg of zinc. The sediments are also enriched in calcium (1.62–13.10%), magnesium (0.66–5.72%) and iron (0.36–1.87%). Exceedances of the PEC threshold value are recorded in several samples in the case of cadmium, lead and zinc.

Catchment of the Przeczyce reservoir is located in the central part of the map sheet area. The land use in the catchment is varied; there are meadows, cultivated fields, wastelands and forests.

The contents of analysed elements (expressed as their median values) in the sediments sampled in this catchment area, as well as on the Przeczyce-Siewierz reservoir shores, are in the range close to or lower than the regional geochemical background level. A slight enrichment relative to the background level is observed in the case of lead and sulphur (Tab. 4).

The Przeczyce-Siewierz reservoir is located on the Przemsza River in the central part of the catchment. The bottom of the reservoir in its eastern part is sometimes exposed during periods of low water levels. The water table lowering is accompanied by intense development of biological life, associated with the expansion of vegetation (Rzętała, 2003). Fine-grained organic sediments of the eastern part of the reservoir, close to the national road, show elevated amounts of some elements. The maximum concentrations recorded in that area are as follows: 13.2 mg/kg cadmium, 8 mg/kg cobalt, 22 mg/kg chromium, 38 mg/kg copper, 2.40% iron, 15 mg/kg nickel, 959 mg/kg lead, and 1,191 mg/kg zinc. The sediments are also enriched in calcium (up to 6.78%), magnesium (up to 2.92%) and manganese (up to 770 mg/kg).

Assessment of sediment contamination in some water bodies of the Upper Silesian region by Jaguś *et al.* (2013) showed a significant contamination especially with barium, cadmium, lead and zinc. The concentrations measured in the Przeczyce reservoir sediments were as follows: 31 mg/kg arsenic, 524.5 mg/kg barium, 13.0 mg/kg cadmium, 15.0 mg/kg cobalt, 82.5 mg/kg chromium, 36.0 mg/kg copper, 28.0 mg/kg nickel, 533.0 mg/kg lead, and 1,443.0 mg/kg zinc. Those levels for most elements are higher than these currently obtained. A small number of sediment samples (including those collected from the reservoir) demonstrated exceedances of the PEC index for cadmium, lead and zinc.

The southern part of the map sheet area is included in **the catchment of the Czarna Przemsza River from the Przeczyce dam to the Brynica River**, which covers part of the area where Triassic deposits form extensive outcrops. On the surface, ore-bearing dolomites are exposed near Podwarpie. The Przemsza River valley is lined by Quaternary deposits of flood terrace.

The medians of aluminium, barium, cobalt, chromium, copper, iron, manganese, nickel, phosphorus, sulphur, strontium, vanadium and zinc in the sediments of the catchment are lower than the geochemical background levels of the Silesian-Cracow region. Slightly higher median values are observed for calcium, magnesium and titanium, while that of lead in the catchment area is almost twice as high as the background level (Tab. 4).

Sediments of the Przemsza River flowing out of the Przeczyce-Siewierz reservoir are characterized by significantly higher concentrations of barium (22–408 mg/kg), calcium (0.17–4.35%), magnesium (0.05–0.53%), manganese (292–1,585 mg/kg) and lead (53–221 mg/kg) compared to their levels in samples taken upstream of the reservoir.

Compared to all sediments of the map sheet area, the sediments of the catchment show higher contents of lead. Its maximum concentration (1,861 mg/kg) is found near the southern boundary of the map sheet (near the village of Zarzecze) in the sediment of an unnamed watercourse that drains mainly meadows and wasteland. At this location, 27 mg/kg of cadmium and 1,365 mg/kg of zinc were also found. These elements are probably derived from surface runoff from the valley filled with peat sediments that can easily accumulate them. In this catchment area, exceedances of the PEC values are recorded for arsenic (only one sample), cadmium, lead and zinc.

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 Brynica River to the Kozłowa Góra reservoir. The specific electrolytic conductivity of the catchment waters varies between 0.06 and 0.58 mS/cm, and the pH between 3.60 and 7.30, with the majority of samples (67%) characterized by an acidic pH (<5). Acidification of the watercourses is related to the occurrence of soils showing very low pH and characterized by leaching of organic matter from forest plant litter.

The catchment water samples are characterized by lower contents of silver, boron, beryllium, cobalt, chromium, copper, molybdenum, antimony, selenium, titanium, thallium and vanadium than the limits set for classes I and II of surface water quality. Arsenic also remains within these limits in most of the studied waters. There is only one sample with a higher concentration (118 µg/dm^3). Taking into account the environmental quality standards, the permissible concentrations of nickel have not been exceeded for the chemical status indicators in the studied samples (Rozporządzenie..., 2021; Tab. 5).

The waters are distinguished by high contents of aluminium. In most samples, its concentration ranges from 1,087.6 to 4,459.5 µg/dm^3, which is presumably related to the acidity of the water. Aluminium is easily sorbed by aquatic sediments. However, its significant amounts may appear in the water when the pH changes, as an increase in water acidity contributes to the release of aluminium from the bottom sediments into the aquatic environment.

Most of the waters in the catchment are classified as substandard due to their cadmium content (1.80–15.99 µg/dm^3). Some of the samples with elevated cadmium concentrations are also characterized by high contents of lead (15.29–39.11 µg/dm^3) and zinc (1.006–1.422 mg/dm^3). This is presumably related to the low pH of waters and soils in this area, which may have caused remobilization of the metals from the solid phase into solution.

Catchment of the Dopływ w Boguchwałowicach Stream. The electrolytic conductivity of the catchment waters is low, within the limits of 0.08–0.55 mS/cm (median 0.21 mS/cm). Their pH varies from 3.45 to 7.25. The acidic pH contributes to the activation of aluminium, which is clearly visible in the water composition. The waters are abundant in this element, found in most of the samples, and its concentration varies between 1,457.2 and 1,295.8 µg/dm^3.

Also of note are the high concentrations of cadmium (2.25–35.52 µg/dm^3) in the waters of the catchment of the Dopływ w Boguchwałowicach stream. Substandard waters were also found in 31% of the samples containing above 1 mg/dm^3 of zinc. Lead and nickel in the majority of the waters do not exceed the permissible concentrations indicated in Rozporządzenie... (2021). Only in a few cases, in unnamed ditches, their concentrations were higher (17.73–21.67 µg/dm^3 and 36.4–42.7 µg/dm^3, respectively). High concentrations of lithogenic elements – beryllium (up to 1.39 µg/dm^3), cobalt (up to 41.56 µg/dm^3) and iron (up to 36.01 mg/dm^3) – are also observed in the waters.

Catchment of the Szeligowiec Stream. The catchment waters are characterized by the pH values between 3.96 and 7.91, and the specific electrolytic conductivity between 0.06 and 1.23 mS/cm (Tab. 5). In an unnamed ditch draining forest and wasteland areas at the eastern boundary of the catchment, the EC values are of 0.77–1.23 mS/cm.

The contents of lithogenic elements in the waters remain at a similar level across the entire catchment and mostly do not exceed 2 µg/dm^3 of arsenic, 0.070 mg/dm^3 of barium, 50.0 mg/dm^3 of calcium, 10.0 mg/dm^3 of silica, 3.0 mg/dm^3 of potassium, and 4.0 µg/dm^3 of lithium.

A specific water composition is conspicuous in an unnamed ditch draining forest land at the western boundary of the catchment. The water contains aluminium (698.0–2,527.1 µg/dm^3), beryllium (0.13–0.83 µg/dm^3), cadmium (2.52–7.07 µg/dm^3) and iron (0.80–2.50 mg/dm^3), as well as elevated amounts of cobalt, nickel, thallium and zinc. This coincides with low pH values (3.96–4.92) in this watercourse. The low pH may have triggered remobilization of the elements from the aqueous sediments and concurrently hindered their binding by the solid phase constituents. In contrast, waters from an unnamed ditch flowing at the eastern boundary of the catchment are characterized by relatively high concentrations of antimony (4.28–6.00 µg/dm^3).

Przemsza (Czarna Przemsza) River. The value of specific electrolytic conductivity of the river waters varies between 0.53 and 0.69 mS/cm, and the pH is between 7.13 and 8.91.

Within the boundaries of the map sheet, the Przemsza River waters contain small amounts of tested components in relation to the limits defined for surface water quality classes I and II. Taking into account the environmental quality standards for chemical status indicators, the permissible concentrations of also cadmium, nickel and lead have not been exceeded in the studied samples (Rozporządzenie..., 2021; Tab. 5).

Catchment of the Czarna Przemsza River to the Przeczyce reservoir. The electrolytic conductivity values in the catchment waters are in the range of 0.20–0.72 mS/cm and the pH is 5.86–9.25. They contain low concentrations of tested elements, including metals potentially toxic to living organisms. At one site, near the eastern boundary of the map sheet, an unnamed ditch contains high concentrations of aluminium (1,781.7 µg/dm^3).

Catchment of the Przeczyce reservoir. The waters are characterized by an EC of 0.41–0.62 mS/cm and a pH of 7.54–9.27. The contents of silver, aluminium, arsenic, boron, beryllium, cobalt, chromium, molybdenum, antimony, selenium, titanium, thallium, vanadium and zinc are below the limits defined for surface water quality classes I and II. In the case of barium, higher levels are observed at one point in the eastern part of the catchment (0.771 mg/m^3). The concentrations of cadmium, nickel and lead in the Przeczyce-Siewierz reservoir do not exceed permissible levels specified in Rozporządzenie (2021; Tab. 5).

Waters from an unnamed ditch flowing in the forest area near road DK 78 draw our attention. They are characterized by low pH values of 4.47–4.82 and high concentrations of aluminium (up to 2,445.7 µg/dm^3), beryllium (up to 2.50 µg/dm^3), cadmium (up to 49.42 µg/dm3), nickel (up to 34.2 µg/dm^3), lead (up to 130.69 µg/dm^3) and zinc (up to 2.715 mg/dm^3), as well as by cobalt and lithium concentrations higher than elsewhere in the catchment area.

Catchment of the Czarna Przemsza River from the Przeczyce reservoir dam to the Brynica River. The results obtained are the pH of the waters ranging from 7.13 to 8.16, and the electrolytic conductivity between 0.38 and 0.84 mS/cm. EC above 0.8 mS/cm was found in the Dopływ z Sadowia waters. The catchment waters are characterized by low contents of analysed elements, including metals. Cadmium and chromium are present in most samples in amounts below their limits of quantification. The contents of copper do not exceed 4.18 µg/dm^3 (median 0.55 µg/dm^3), of nickel 2.7 µg/dm^3(median 1.3 µg/dm^3), of lead 8.71 µg/dm^3 (median 0.26 µg/dm^3), and of thallium 0.20 µg/dm^3 (median 0.06 µg/dm^3).

SUMMARY AND CONCLUSIONS

1. The type of subsoil bedrock is clearly manifested in the chemical composition of the soils. Those developed mainly on Quaternary glaciofluvial sands and gravels, rich in the sand fraction, generally contain the lowest amounts of analysed elements. In contrast, soils that developed on the outcrops of Triassic carbonates, abundant in the silt and clay fractions, are distinguished by increased concentrations of calcium, magnesium and manganese and are enriched in most of the studied elements in relation to the regional geochemical background level.

2. The pH of the soils is related to the bedrock lithology and the way they are used. Very acidic and acidic soils are found in the north-western part of the map sheet, mostly covered by forests. The remaining area is dominated by neutral and alkaline soils. The greater proportion of alkaline soils in the 0.8–1.0 m depth layer indicates the effect of carbonate bedrock on the soil profiles.

3. The median contents of most elements (silver, arsenic, barium, calcium, cobalt, chromium, copper, iron, mercury, magnesium, manganese, nickel, phosphorus, sulphur, strontium and vanadium) in the soils are lower or close to the geochemical background values in the Silesian-Cracow region. The cadmium and zinc contents are slightly higher. Contents approximately twice as high as the regional background level are found in the case of lead and titanium.

4. Soils that are clearly enriched in cadmium, lead and zinc are observed in the areas of Triassic carbonates. Presumably, the main sources of the apparent geochemical anomalies are the outcrops of ore-bearing and Diplopora dolomites and historical mining and processing of Zn-Pb ores.

5. All the catchments in the map sheet area are covered by sediments that show exceedances of the PEC thresholds for cadmium, lead and zinc.

6. Sediments and waters of the watercourses flowing across the north-western part of the map sheet are characterized by high aluminium contents. They are also enriched in cadmium, iron, lead and zinc.

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