Szczegółowa mapa geochemiczna Górnego Śląska

Detailed geochemical map of Upper Silesia

1 : 25 000

Arkusz
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SPIS TREŚCI

Wstęp – *Anna Pasieczna, Agnieszka Konon* 5

Charakterystyka obszaru arkusza – *Anna Pasieczna, Agnieszka Konon* 5

Budowa geologiczna i złoża kopalin – *Katarzyna Strzemińska* 5

Antropopresja – *Anna Pasieczna, Agnieszka Konon* 7

Zakres i metodyka badań – *Anna Pasieczna* 7

- Prace terenowe – *Anna Pasieczna* 7
- Prace laboratoryjne – *Anna Pasieczna* 8
- Bazy danych i konstrukcja map geochemicznych – *Anna Pasieczna, Agnieszka Konon, Kamil Bala, Angelika Szczypczyk* 9

Wyniki badań – *Anna Pasieczna, Agnieszka Konon* 18

- Gleby – *Anna Pasieczna, Agnieszka Konon* 18
- Osady – *Anna Pasieczna, Agnieszka Konon* 19
- Wody powierzchniowe – *Anna Pasieczna, Agnieszka Konon* 21

Wnioski – *Anna Pasieczna, Agnieszka Konon* 21

Literatura 30

Tablice 1–63

CONTENTS

Introduction – *Anna Pasieczna, Agnieszka Konon* 22

Characteristics of the map area – *Anna Pasieczna, Agnieszka Konon* 22

Geology and mineral deposits – *Katarzyna Strzemińska* 23

Human impact – *Anna Pasieczna, Agnieszka Konon* 24

Materials and methods – *Anna Pasieczna* 24

- Field works – *Anna Pasieczna* 24
- Laboratory works – *Anna Pasieczna* 25
- Databases and geochemical maps construction – *Anna Pasieczna, Agnieszka Konon, Kamil Bala, Angelika Szczypczyk* 26

Results – *Anna Pasieczna, Agnieszka Konon* 26

- Soils – *Anna Pasieczna, Agnieszka Konon*. 26
- Sediments – *Anna Pasieczna, Agnieszka Konon* 27
- Surface water – *Anna Pasieczna, Agnieszka Konon* 28

Conclusions – *Anna Pasieczna, Agnieszka Konon* 29

References 30

Plates 1–63

LIST OF PLATES

1. Mapa geologiczna
   Geological map
2. Zabudowa terenu
   Land development
3. Użytkowanie terenu
   Land use
4. Zawartość frakcji piaskowej (1,0–0,1 mm) w glebach (0,0–0,3 m)
   Sand fraction (1.0–0.1 mm) in topsoil (0.0–0.3 m)
5. Zawartość frakcji pyłowej (0,1–0,02 mm) w glebach (0,0–0,3 m)
   Silt fraction (0.1–0.02 mm) in topsoil (0.0–0.3 m)
6. Zawartość frakcji iłowej (<0,02 mm) w glebach (0,0–0,3 m)
   Clay fraction (<0.02 mm) in topsoil (0.0–0.3 m)
7. Odczyn gleb (0,0–0,3 m) i wód powierzchniowych
   Acidity of topsoil (0.0–0.3 m) and surface water
8. Odczyn gleb (0,8–1,0 m) i przewodność elektrolityczna właściwa wód powierzchniowych
   Acidity of subsoil (0.8–1.0 m) and electrolytic conductivity of surface water
9. Srebro w glebach (0,0–0,3 m) i w osadach
   Silver in topsoil (0.0–0.3 m) and in sediments
10. Srebro w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Silver in subsoil (0.8–1.0 m) and in surface water
11. Glin w glebach (0,0–0,3 m) i w osadach
    Aluminium in topsoil (0.0–0.3 m) and in sediments
12. Glin w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Aluminium in subsoil (0.8–1.0 m) and in surface water
13. Arsen w glebach (0,0–0,3 m) i w osadach
    Arsenic in topsoil (0.0–0.3 m) and in sediments
14. Arsen w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Arsenic in subsoil (0.8–1.0 m) and in surface water
15. Bor w wodach powierzchniowych
    Boron in surface water
16. Bar w glebach (0,0–0,3 m) i w osadach
    Barium in topsoil (0.0–0.3 m) and in sediments
17. Bar w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Barium in subsoil (0.8–1.0 m) and in surface water
18. Beryl w wodach powierzchniowych
    Beryllium in surface water
19. Całkowity węgiel organiczny w glebach (0,0–0,3 m)
    Total organic carbon in topsoil (0.0–0.3 m)
20. Wapń w glebach (0,0–0,3 m) i w osadach
    Calcium in topsoil (0.0–0.3 m) and in sediments
21. Wapń w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Calcium in subsoil (0.8–1.0 m) and in surface water
22. Kadm w glebach (0,0–0,3 m) i w osadach
    Cadmium in topsoil (0.0–0.3 m) and in sediments
23. Kadm w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Cadmium in subsoil (0.8–1.0 m) and in surface water
24. Kobalt w glebach (0,0–0,3 m) i w osadach
    Cobalt in topsoil (0.0–0.3 m) and in sediments
25. Kobalt w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Cobalt in subsoil (0.8–1.0 m) and in surface water
26. Chrom w glebach (0,0–0,3 m) i w osadach
    Chromium in topsoil (0.0–0.3 m) and in sediments
27. Chrom w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Chromium in subsoil (0.8–1.0 m) and in surface water
28. Miedź w glebach (0,0–0,3 m) i w osadach
    Copper in topsoil (0.0–0.3 m) and in sediments
29. Miedź w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Copper in subsoil (0.8–1.0 m) and in surface water
30. Żelazo w glebach (0,0–0,3 m) i w osadach
    Iron in topsoil (0.0–0.3 m) and in sediments
31. Żelazo w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Iron in subsoil (0.8–1.0 m) and in surface water
32. Rtęć w glebach (0,0–0,3 m) i w osadach
    Mercury in topsoil (0.0–0.3 m) and in sediments
33. Rtęć w glebach (0,8–1,0 m)
    Mercury in subsoil (0.8–1.0 m)
34. Potas w wodach powierzchniowych
    Potassium in surface water
35. Lit w wodach powierzchniowych
    Lithium in surface water
36. Magnez w glebach (0,0–0,3 m) i w osadach
    Magnesium in topsoil (0.0–0.3 m) and in sediments
37. Magnez w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Magnesium in subsoil (0.8–1.0 m) and in surface water
38. Mangan w glebach (0,0–0,3 m) i w osadach
    Manganese in topsoil (0.0–0.3 m) and in sediments
39. Mangan w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Manganese in subsoil (0.8–1.0 m) and in surface water
40. Molibden w wodach powierzchniowych
    Molybdenum in surface water
41. Sód w wodach powierzchniowych
    Sodium in surface water
42. Nikiel w glebach (0,0–0,3 m) i w osadach
    Nickel in topsoil (0.0–0.3 m) and in sediments
43. Nikiel w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Nickel in subsoil (0.8–1.0 m) and in surface water
44. Fosfor w glebach (0,0–0,3 m) i w osadach
    Phosphorus in topsoil (0.0–0.3 m) and in sediments
45. Fosfor w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Phosphorus in subsoil (0.8–1.0 m) and in surface water
46. Ołów w glebach (0,0–0,3 m) i w osadach
    Lead in topsoil (0.0–0.3 m) and in sediments
47. Ołów w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Lead in subsoil (0.8–1.0 m) and in surface water
48. Siarka w glebach (0,0–0,3 m) i w osadach
    Sulphur in topsoil (0.0–0.3 m) and in sediments
49. Siarka w glebach (0,8–1,0 m) i siarczany w wodach powierzchniowych
    Sulphur in subsoil (0.8–1.0 m) and sulphates in surface water
50. Antymon w wodach powierzchniowych
    Antimony in surface water
51. Selen w wodach powierzchniowych
    Selenium in surface water
52. Krzemionka w wodach powierzchniowych
    Silica in surface water
53. Stront w glebach (0,0–0,3 m) i w osadach
    Strontium in topsoil (0.0–0.3 m) and in sediments
54. Stront w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Strontium in subsoil (0.8–1.0 m) and in surface water
55. Tytan w glebach (0,0–0,3 m) i w osadach
    Titanium in topsoil (0.0–0.3 m) and in sediments
56. Tytan w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Titanium in subsoil (0.8–1.0 m) and in surface water
57. Tal w wodach powierzchniowych
    Thallium in surface water
58. Uran w wodach powierzchniowych
    Uranium in surface water
59. Wanad w glebach (0,0–0,3 m) i w osadach
    Vanadium in topsoil (0.0–0.3 m) and in sediments
60. Wanad w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Vanadium in subsoil (0.8–1.0 m) and in surface water
61. Cynk w glebach (0,0–0,3 m) i w osadach
    Zinc in topsoil (0.0–0.3 m) and in sediments
62. Cynk w glebach (0,8–1,0 m) i w wodach powierzchniowych
    Zinc in subsoil (0.8–1.0 m) and in surface water
63. Klasyfikacja gleb z głębokości 0,0–0,3 m ze względu na dopuszczalną zawartość kadmu
    Topsoil (0.0–0.3 m) classification according to the permissible content of cadmium

INTRODUCTION

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

The major part of the map area covers the commune of Świerklaniec. The northern part belongs to the town of Miasteczko Śląskie, the eastern and southeastern areas are small parts of the communes of Ożarowice and Bobrowniki, the western part belongs to the town of Tarnowskie Góry, and the small areas near the southern boundary of the map sheet are included in the towns of Piekary Śląskie and Radzionków.

Historical and contemporary exploitation of mineral resources (Zn-Pb ores, limonites, dolomites, limestones and sand) resulted in the transformation of the natural environment and landscape of the study area. Shallow excavations from former extraction have been partially levelled or covered with waste and overgrown with vegetation (Prognoza, 2017; Studium…, 2019). The Zn-Pb and limonite ores were mined in the 19th century in the area currently covered with forests (between the city center of Miasteczko Śląskie and its district Bibiela, and in the northwest edge of the map sheet). Today, the Chechło-Nakło Reservoir is the largest excavation left after extraction of sand.

There are no large industrial facilities in the study area, which could be direct sources of pollution. The emissions of the Huta Cynku Miasteczko Śląskie (HCM) (zinc smelter), located just beyond the northern boundary of the map sheet, the impact of the waste landfill of the liquidated Zakłady Chemiczne (ZCH) (chemical plant) Tarnowskie Góry and the railway junction in Tarnowskie Góry (at the western edge of the map sheet) are harmful to the environment.

Part of the map sheet area is characterized by great natural and historic values. These include the Świerklaniec Park established in the 18th century on the former wetlands of the Brynica River, a park in Nakło Śląskie, a historic building (Pałac Kawalera Palace) in Świerklaniec built in 1903–1906, and the Kozłowa Góra and Chechło-Nakło reservoirs.

The results of geochemical studies within the area covered by the Świerklaniec map sheet, presented in a cartographic form with an extensive commentary text and tabular summaries, show the current quality status of soils, sediments of watercourses and reservoirs, and surface water, as well as comparison to the natural regional background and applicable legal norms.

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

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

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

The following persons participated in the implementation of the study:

- **A. Pasieczna** – research concept and project;
- **A. Konon** – supervision and coordination;
- **A. Biel, P. Kaszycki, J. Szyborska-Kaszycka** – sample collection;
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- **A. Konon, A. Pasieczna** – statistical calculations;
- **K. Bala, A. Konon, A. Pasieczna, A. Szczypczyk** – compilation of geochemical maps;
- **A. Pasieczna, A. Konon** – text preparation.

CHARACTERISTICS OF THE MAP AREA

Geographic and administrative location. According to the physical and geographical division, the area of the Świerklaniec map sheet M-34-50-D-b is located in the Silesian Upland macroregion, in the area of the Tarnowskie Góry Ridge, Katowice Upland and Upper Mała Panew Depression (Solon *et al*., 2018).

In administrative terms, the map sheet area belongs to the poviat of Tarnowskie Góry, located in the northwestern part of the Silesian Voivodeship. It covers the commune of Świerklaniec, parts of the towns of Tarnowskie Góry, Piekary Śląskie, Radzionków and Miasteczko Śląskie, and parts of the communes of Bobrowniki and Ożarowice. The western region of the map sheet area consists of parts of town districts of Tarnowskie Góry (Lasowice and Bobrowniki Śląskie–Piekary Rudne). The northern part includes the centre of Miasteczko Śląskie and its districts: Żyglin and Żyglinek. In the east, there are parts of the commune of Ożarowice, in the poviat of Tarnowskie Góry, whereas the southeastern part belongs to the commune of Bobrowniki, in the poviat of Będzin. A small area in the south belongs to the towns of Piekary Śląskie and Radzionków (Pls. 1–63).

Topography, geomorphology and hydrography. The map sheet area is characterized by a poorly varied topography. The elevations range from 280 to 349.7 m a.s.l. (in the Brynica River valley and the Piekary Rudne area, respectively).

In some parts of the map sheet area, there are topographic signs of small historical outcrops and tailings heaps that were formed as a result of extraction of metal ores, limestones and dolomites. They are clustered in the forests extending in the north, as well as in the Nakło Śląski and Świerklaniec regions, where small ponds are considered the remains of lead, silver and iron ore mining in the period from the 14th to 19th centuries (Studium..., 2019).

A distinctive geomorphological element is the hills composed of Triassic limestones in the northern part of the map sheet area (in the Żyglin and Żyglinek districts of Miasteczko Śląskie) and in its southwestern part from Piekary Rudne through Nakło Śląskie to Nowe Chechło.

The eastern part of the map sheet area is the vast valley of the Brynica River that flows into the Czarna Przemsza River (included in the Vistula drainage basin). A small area in the western part is drained by the Pniowiec Stream that is a tributary of the Stoła River (in the Odra drainage basin). The springs of the Brynica River are located in Mysłów, beyond the northeastern boundary of the study area, at an elevation of 350 m a.s.l. at the foot of the Triassic hills (Jastrząb, Mrozowski, 1997). The river originates from small streams, and flows in a flat, marshy valley, draining agricultural land. In its middle course, there is the Kozłowa Góra Reservoir. The major tributaries of the Brynica River, which flow directly into the Kozłowa Góra Reservoir, are the Potok spod Nakła Stream, and Dopływ spod Siemoni Stream. The Rów Świerklaniecki Stream flows into the Brynica River below the Góra Kozłowa Reservoir and the Dopływ spod Żyglinka Stream connects with the Brynica River beyond the northeastern boundary of the map sheet area.

The Kozłowa Góra Reservoir (Jezioro Świerklanieckie Lake) was formed in the period 1935–1939 by damming the Brynica River valley with an earth dam. Its original purpose was to use it for military and defense purposes as an element of the fortification line of the Silesia Fortified Area. Currently, it is a potable water reservoir, with a water intake and a treatment station located outside the boundary of the map sheet area (Zakład Produkcji Wody water production plant in Wymysłów). The plant supplies drinking water to the population of Miasteczko Śląskie, Świerklaniec, Piekary Śląskie, Bobrowniki and many nearby localities (Program..., 2017; Machowski, Rzętała, 2020).

In the central part of the map sheet area, there is the Chechło-Nakło Reservoir created in the 1960s as a result of an uncontrolled outflow of groundwater that flooded a sand pit. Due to the difficulties in draining the open-pit mine, a decision was made to create a reservoir for recreational functions. The reservoir is fed mainly by groundwater, by a network of drainage ditches, and by surface runoff of rainwater. In order to prevent the reservoir water from escaping (the outcrop covered the headwater course of a minor stream), a concrete weir was created to dam the stream (Solarski *et al*., 2012).

Built-up area and land use. The way of land use and built-up area differs between the individual parts of the study area – this is mostly a forest-agricultural region (Pls. 2–3). Unbuilt areas occupy about 84% of the map sheet. These are mainly forests in its central and northern parts and arable fields and wastelands scattered in the south and east. Other unbuilt areas include meadows, allotment gardens, parks, water reservoirs, and railway areas. Residential, industrial, service and trade areas occupy a small part of the map sheet. Urban development covers about 13% of the area; industrial areas cover about 1.5%.

Economy. The first mention of silver and lead ore mining dates back to 1530 from Żyglin, where one mineshaft was reported and about 315 shafts were drilled in 1530–1583 (Opracowanie...).

In the 19th century, Zn-Pb ores and limonites were mined in the area extending from Żyglin (present-day Rubinowa, Woźnicka, Cynkowa, Dworcowa and Gajowa streets) to the HCM by opencast and underground exploitation systems (Opracowanie...). In the forests between the city center Miasteczko Śląskie and its district Bibiela, Zn-Pb ores were extracted for 30 years in the Szczęście Flory mine, and limonites (containing up to 48% of iron) in the Bibiela mine (Nowak, 1927; Nowak, Pawlik, 2021). The Zn-Pb ores were transported by a narrow-gauge railway to Tarnowskie Góry.

Beyond the northern boundary of the map sheet, there is the Huta Cynku Miasteczko Śląskie zinc steelworks (HCM), which produces zinc and lead using the fire smelting method and the Imperial Smelting Process (ISP), which consists in the reduction of roasted concentrate using coke. The technological line consists of a sinter plant, a sulfuric acid plant, a cadmium department, a shaft furnace, and a lead refining furnace. A characteristic feature of the technological process is the simultaneous production of zinc and lead (Pozzi, Nowińska, 2006, 2010). The smelter was established in 1961, and as the production was growing, its negative impact on the natural environment increased due to the emission of dust and gases, and sewage discharges. Initially, the steelworks processed calamine ore from the Orzeł Biały mine in Piekary Śląskie and the material from post-mining and metallurgical dumps of the zinc smelting industry from the Piekary Śląskie, Bytom and Trzebinia regions. Additional raw materials included domestic and foreign sulfide and oxide concentrates of zinc and lead ores, from which both refined zinc (98.7% Zn content) and raw lead were obtained (Studium..., 2020).

In the 1970s and 1980s, the plant was expanded and its pressure on the environment increased. Dust emission to the atmosphere reached several tens of tonnes of zinc and lead per year. Despite the increasing zinc production (up to 80,000 t/year) in the years 1998–2004, a significant reduction in the environmental nuisance of the steelworks was made under the so-called Adjustment Program. The implemented pro-ecological measures allowed reducing dust emissions by 86%, including zinc by 95%, lead by 91%, cadmium by 95%, and gas emissions by 95%. The load of heavy metals (Zn, Pb, Cd) in the discharged sewage was also reduced by 39%. The implementation of these pro-ecological activities resulted in the partial and then complete deletion of the HCM from the list of 80 most environmentally harmful plants in Poland in 2004. The implemented remedial measures contributed to reduction of the emission of potentially toxic elements to levels not exceeding the permissible standards, but their previous long-term accumulation persists in the environment of the areas surrounding the steelworks (Studium..., 2020).

Beyond the western boundary of the map sheet area, there is a hazardous waste landfill of the Zakłady Chemiczne (ZCH) Tarnowskie Góry chemical plant that started operating in the 19th century. As a result of its production, a hazardous waste landfill, which is an ecological problem for the town, exists until the present time. At the western border of the map sheet, there is also a part of the Tarnowskie Góry railway junction, which is one of the largest marshalling yards in Europe.

GEOLOGY AND MINERAL DEPOSITS

The study area lies in the northern part of the Upper Silesian Foredeep that is part of the exposed of the Variscan Platform basement (Pożaryski *et al*., 1992), within the Upper Silesian Coal Basin (USCB, GZW in Polish) and its northern margin (Jureczka *et al*., 2005). The northern boundary of the USCB, which is the limit of Upper Carboniferous deposits, runs along the Niezdara–Świerklaniec–Nakło Śląskie line. In the northern margin of the USCB, there is a latitudinally oriented tectonic graben filled with a late Variscan Permian molasse, several hundred metres thick, included in a larger unit called the Sławków Graben (Kotas, 1985; Kiersnowski, 1991).

The basement of coal-bearing deposits in the study area consists of **Carboniferous** rocks included in the Malinowice Beds (Upper Visean–Namurian A). These are terrigenous clastic deposits, which accumulated under marine conditions, containing numerous levels of marine fossils. They are composed mainly of clay-muddy rocks with sandstone interbeds. In the southern part of the map sheet area, they are covered with Paralic Series deposits, and with Permian rocks in the northern part.

The coal-bearing Carboniferous deposits occur only in the southern part of the map sheet, at a depth of approx. 200–400 m. They constitute a sandstone-mudstone-claystone complex included in the Paralic Series of the Upper Carboniferous Marginal Beds (Namurian A) (Jureczka *et al*., 2005). In most of the study area, these sediments are covered with Triassic deposits, and in the southeastern part – by Quaternary sediments.

The Paralic Series is composed of sandy and clay-muddy deposits with interbeds of thin coal seams and coal shales. They were deposited under both terrestrial and nearshore conditions, with periodic marine inundations, as evidenced by the presence of marine faunal fossils in the section, accompanied by numerous intercalations containing freshwater fossils. A characteristic feature of the deposits is their sedimentary cyclicity. The Paralic Series attains its maximum thickness of 600 m in the southern part of the map sheet area; they wedge out towards the north, marking the northern boundary of the USCB. Their outcrops are in the southern part of the map sheet area.

A tectonic graben located within the Tarnowskie Góry Trough (part of the Sławków Graben) is filled with **Permian** sandstones, conglomerates, claystones and mudstones. In the study area, the Permian deposits were encountered in two boreholes at a depth of approx. 20 m and approx. 140 m. These are mudstones with pyrite concentrations, as well as sandstones and marls, covered with alternating series of conglomerates and sandstones, 269 m in thickness. The total thickness of the Permian molasse in the map sheet area is about 400–450 m. This depositional complex, previously included in the Rotliegend (Siedlecka, 1964), is referred to as the Bolesław Formation, stratigraphically representing the Zechstein (Kiersnowski, 1991).

Lower and Middle **Triassic** deposits, approx. 200 m thick, occur in most of the map sheet area. Their thickness is constrained by both the tectonic setting and the relief of the top of Carboniferous and Permian deposits. In the southwest and north, they form small, fragmented outcrops (Pl. 1).

The Lower Triassic deposits overlie erosionally the Upper Carboniferous and Permian rocks, but are not exposed on the surface. The stratotype section of continental sands, sandstones, clays, claystones and mudstones (Świerklaniec Beds, over 40 m thick) come from the Świerklaniec area. In most of the research area, they are overlain by Middle Triassic carbonates.

The Middle Triassic section is represented in part by deposits characteristic of the epicontinental (German) facies referred to as the Muschelkalk. The total thickness of these deposits is approx. 200 m. They build numerous hills that are a distinctive topographic element in the southwestern part of the map sheet area.

The terrigenous deposits of the Świerklaniec Beds are unconformably overlain by marine deposits previously referred to as the Röt represented by marly-dolomitic facies. These are mainly dolomitic limestones, marly dolomites, dolomitic and sandy marls, and occasional cavernous limestones, ranging in thickness from 30 m to 50 m. The deposits build the hills in the southern and eastern parts of the map sheet area.

The marly-dolomitic series is overlain by limestones included in the Błotnica and Gogolin beds, about 40–60 m in thickness. The lower part of the formation (Błotnica Beds) is represented by pelitic and finely detrital limestones. The upper part of the section is composed of pelitic limestones with marl interbeds containing numerous synsedimentary deformations in the form of folds and submarine landslides.

In the lower part, the Gogolin Beds are composed of a varied series of limestones, marls, marly claystones and intraformational conglomerates. Their top part (Żyglin Beds) is a monotonous complex of platy limestones and marls, in places with interbeds of wavy limestones (Kotlicki, 1995). Their outcrops occur on the slopes of hills in the southwestern and northern parts of the map sheet area.

The Gogolin Beds are overlain by a layer of Zn-Pb ore-bearing dolomites, about 20–40 m thick. These are epigenetic rocks that formed as a result of hydrothermal alteration of limestones, mainly of the Górażdże Beds, as well as of the Terebratula and Karchowice beds. The layer is composed of dolomites. Less frequent are limestones crystallized to varying degrees, which occur as nests. They are characterized by strong fractures and the presence of irregular caverns, many of them filled with lead, zinc and iron minerals (galena, sphalerite, wurtzite, pyrite, marcasite). Within their outcrops, oxidized sulfides concentrate in calamines and limonites. They reach 40 m in thickness in the Tarnowskie Góry Trough. Limestones and marls of the Górażdże, Terebratula and Karchowice beds, which occur in the section above the ore-bearing dolomites, have totally undergone metasomatism. They are part of the Zn-Pb ore-bearing dolomites.

The **Neogene** deposits are represented by variegated loams, sands, muds and clays that form regoliths accumulated in karst sinkholes and chimneys that developed at the top of Triassic carbonates. The sinkholes range from several to tens or even hundreds of meters in diameter. These deposits are exposed on the surface in the southwest and north of the map area. They are also found in several boreholes, in which they are up to 34 m thick. Regolithic deposits (limonite ores, calamines and refractory clays) were the subject of intensive exploitation in the 19th century, e.g. in the Niezdara region.

Quaternary deposits cover more than 75% of the map sheet area. Their distribution and thickness increase towards the north (where it is approx. 40 m).

Deposits of South Polish glaciations occur in zones where the Quaternary deposits reach considerable thicknesses. These are weathering loams and glacial tills, glaciofluvial sands and gravels, as well as ice-dammed lake clays and muds.

Sediments of the Middle Polish glaciation are glaciofluvial sands and gravels, frequently overlying tills, and ice-dammed lake clays and muds found only in boreholes. Sands, gravels, boulders and tills of terminal moraines build the hills in the east of the map sheet.

Sediments of the North Polish glaciations (fluvial sands and gravels of floodplain terraces, up to 6–8 m in thickness) occur only in the southeastern part of the map sheet, in the Brynica River valley.

Undivided Quaternary deposits occupy a small part of the map sheet area. These are deluvial sands, muds and loams with clay intercalations and limestone-dolomite rubble, not exceeding a few meters in thickness. They occur at the foot of slopes and in the bottoms of dry valleys in the southwestern part of the map sheet. Fluvial-deluvial sands, gravels and muds, 2–6 m thick, are found in the bottoms of dry valleys in the southern part of the map sheet. In the central and northern part of the study area, common dunes and thin blankets of aeolian sands cover most of an extensive outwash plain. These were formed in the late Vistulian Glaciation and at the beginning of the Holocene.

Holocene sediments occur in the valleys of the Brynica River, Potok spod Nakła Stream and minor watercourses. These are fluvial sands, gravels and muds of floodplain terraces, up to 8 m in thickness, alluvial muds of valley bottoms (sandy muds containing considerable amounts of humic substance), ranging in thickness 2–4 m, and peats.

Mineral deposits. In the map sheet area, nine mineral deposits have been documented: limestones, backfilling sands, and sands and gravels. Information on the parameters of the deposits and on the quality of raw mineral materials is derived from the geological documentations of individual mineral deposits and the system of management and protection of mineral resources (MIDAS).

Within the outcrop of Middle Triassic limestones, four adjacent small **limestone** deposits have been documented. Directly on the surface or under the overburden of glacial sands with an average thickness of approx. 2 m, there are limestones (2–11 m thick) that are the raw material for the building industry and road construction. One of the fields remains undeveloped, the rest are extracted periodically.

The Chechło, Brynica and Strzybnica **sand** deposits have been documented in the central and northwestern parts of the map sheet. These raw material deposits occupy very large areas: the Chechło field is approx. 1,172 ha, and the Pole Brynica field is approx. 157 ha in size. The sand series is 17 m thick. A small part of the Chechło deposit had been exploited in the 1960s, and the resulting mining pit was flooded with water to form the artificial Chechło-Nakło Reservoir that occupies an area of over 90 ha. The reserves of this deposit are approx. 45.88 million m^3, and the reserves of the Pole Brynica sand deposit are 10.85 million m^3. The quartz sands were used as a backfilling material in nearby hard coal mines because of their parameters (approx. 95–97% is the fraction below 2 mm). The Pole Brynica deposit remains undeveloped; however, two smaller sand deposits have been documented within it and are used for the local construction industry.

The Żyglin IV deposit has been documented within aeolian sands of dunes forming a string of hills in the eastern part of the map sheet. The raw material deposit covers an area of 10.2 ha, its thickness is 1.9–11.7 m, and the thickness of the overburden is 0.2–1.5 m. The deposit provides aggregate with an increased sand content of 100% and a low content of mineral dust (2.8% on average). It was exploited at the beginning of the 1990s. The Żyglin VI deposit (exploited in 2016–2018) covers an area of 70.7 ha and its thickness ranges from 2 to 13 m. The sands are under a thin overburden (0.3 m on average).

HUMAN IMPACT

The environmental problems of the study area are a consequence of the historical mining of silver-containing Zn-Pb ores and iron ores, of the modern emission of dust and gases from the HCM, and, to a lesser extent, of the impact of urbanization and transportation. Metal ores were mined using the opencast and underground methods. As a result of this activity, post-mining waste landfills appeared, which are currently forested by a natural floral succession. They are most often poorly marked in the topography of the area.

Atmospheric air. The sources of air pollution are emissions from industrial activities, from the municipal and housing sector, and from transportation means.

According to the annual air quality assessment conducted by the Voivodeship Inspectorate for Environmental Protection (WIOŚ), the emission of gaseous pollutants (excluding carbon dioxide) in the Silesian Voivodeship is systematically decreasing. The dominant gas pollutant is carbon dioxide that accounts for 98.2% of total gas emissions. Methane, carbon monoxide and sulfur dioxide also significantly contribute to the gas pollution (Stan..., 2018).

The map sheet area is included in the Silesian zone, which belongs to class A in the assessment of air pollution in terms of health protection and pollution with sulfur dioxide, nitrogen dioxide, carbon monoxide, benzene, lead, cadmium, nickel and arsenic contained in PM10 dust. This means that the concentrations of pollutants do not exceed both the limit levels and the levels for long-term purposes respectively. Pollution by PM10, PM2.5, ozone and benzo(a)pyrene qualifies the Silesian zone to class C, which means that the concentrations of these pollutants exceed the acceptable or target levels (Roczna..., 2020).

The air quality in the study area is influenced predominantly by industrial plants located in Tarnowskie Góry, Piekary Śląskie and HCM (Studium..., 2019).

An important source of air pollution is also the low emission of pollutants from home furnaces and transportation means. Obsolete heating systems, the combustion of solid fuels, the incineration of waste in individual household furnaces, and intensive car traffic are important sources of dust pollution. Exceedances of the content of suspended dust PM10, PM2.5 and benzo(a)pyrene appear usually in winter, which is associated with the increased emission of dust generated during fuel combustion for heating purposes. Local boiler houses that operate for heating, as well as small enterprises that burn coal for heating or technological purposes, have a negative impact on the quality of atmospheric air. Significant is also the migration of pollutants from the nearby areas of the Upper Silesian Agglomeration (Program..., 2017).

Surface water and groundwater. The main sources of pollution to the aquatic environment are municipal wastewater from towns and production plants, surface runoff from urban, agricultural and forest areas, pollutants of transportation origin, produced by vehicles and washed out from the surface of roads, pollution that enters surface water from landfills, and gas and dust emissions (Program..., 2015a, 2017).

The map sheet area is located in the drainage basins of the following surface water bodies (SWBs): Kozłowa Góra Reservoir, Brynica River from its springs to the Kozłowa Góra Reservoir, Rów Świerklaniecki and Potok spod Nakła streams. On the basis of monitoring studies carried out in 2018, the condition of river waters in the study area was assessed as poor, and the classification results showed that their chemical status is below good (Stan..., 2020). The permissible average concentrations of PAHs are exceeded in the Brynica River waters. The average annual and maximum cadmium concentrations are exceeded in the Potok spod Nakła Stream waters (Prognoza, 2020).

According to the data from 2014, the Kozłowa Góra Reservoir does not meet the requirements for the protected area established due to the intended use for water supply to residents. The chemical condition of the reservoir's waters was assessed as good, while the general condition of its waters was assessed as poor. Periodically, there is a phenomenon of eutrophication in the reservoir, caused by pollution from municipal sources (Program..., 2015b; Studium…, 2019).

As part of pilot operations carried out by the Górnośląskie Przedsiębiorstwo Wodociągów water supply company in 2017 and 2018, research was conducted in the drainage basin area of the reservoir. Results of the water quality study showed that the water condition is good in terms of microbiology. The ecological and chemical status of surface water at points located on the major tributaries flowing to the reservoir has been assessed as poor. Bottom sediments in the Kozłowa Góra Reservoir are characterized by relatively low contents of nitrogen and phosphorus compounds; however, they contain high levels of some metals (Newsletter..., 2019).

In the map sheet area, the main usable aquifer is located in the Triassic carbonate formations. Near the Kozłowa Góra Reservoir, the usable aquifer occurs in Carboniferous deposits. The Triassic aquifer waters are extracted through the Bibiela multi-well groundwater intake to supply the population of this part of Upper Silesia (Studium..., 2019).

The research carried out in 2019 as part of the diagnostic monitoring of the chemical status of groundwater bodies showed that the waters (at two measurement points located in the commune of Świerklaniec) are of satisfactory quality (Wyniki... ,2019). In the Miasteczko Śląskie region, the groundwater has been degraded, as manifested, inter alia, by; (1) the reduction of water resources as a result of long-term systematic drainage of the rock mass due to historical exploitation of metal ores, common raw materials, and underground water intakes, (2) reduction in rainwater infiltration in isolated and canalized areas, (3) pollution of shallow groundwater levels (Opracowanie…).

Soils. In the map sheet area, part of the soils has been transformed as a result of anthropogenic processes, such as long-term mining of zinc and lead ores and iron ores, storage of mining waste, dust fallout, and changes in the chemistry of atmospheric precipitation, as well as due to the building industry activity and urbanization.

Research on the quality of agricultural soils showed their neutral or alkaline pH. Acidic soils on sandy bedrock occur in forest areas (Studium..., 2019). Results of the 2015 research carried out as part of the Monitoring of the Chemistry of Polish Arable Soils showed that the soils at a measuring point in Piekary Śląskie were characterized by high concentrations of cadmium, lead, zinc: 67.98 mg/kg, 491.4 mg/kg and 6,668.3 mg/kg, respectively (Wyniki…, 2015).

Soils of the so-called first influence zone around the HCM (Studium…, 2020) are characterized by high concentrations of arsenic, cadmium and thallium. Despite the use of high efficiency dedusting filters, metals and arsenic penetrate the soil as a result of dust fallout (Nowińska, Adamczyk, 2013). The source of pollution in the 1970s was slag obtained in the HCM production processes and sold as a magnesium and calcium fertilizer, used for soil deacidification.

Landfills. In the area adjoining the town of Tarnowskie Góry from the west, the main ecological problem is the landfill of hazardous waste of the former Chemical Plant (ZCH) Tarnowskie Góry, as well as dispersed numerous waste heaps left after ore mining. Metals, arsenic and sulfur from the landfill penetrate into the soil and water (Lis, Pasieczna, 1995a, b, 1997).

Initially, silver and lead ores were mined at the site of the ZCH Tarnowskie Góry plant. Later, aluminum-potassium alum and sulfuric acid were produced. The next stage was the launch of an iron and paper mill. In 1924–1925, the plant's operation started with the production of lithopone (a white pigment, being a mixture of zinc sulfide ZnS and barium sulfate $BaSO_4$). In the following years, the plant produced oil paints, varnishes, sodium dichromate, barium chloride, barium sulfide, barium nitrate, barium sulfate, boric acid, borax, aluminum sulfate, and copper sulfate. In the further stages, the production of zinc oxide, zinc nitrate, zinc sulfate, sodium perborate, borax and boric acid was launched. After World War II, lithopone, strontium reagents, and compounds of barium, zinc and boron were produced. Substances considered to be harmful (barite; nitric, phosphoric, sulfuric, saline and oxalic acids; soda lye) were used in the production (Majer, 2004). The production of barium and boron compounds continued after World War II. That activity resulted in the formation of a hazardous waste landfill that became the environmental problem to the town. For many years, the waste was deposited in dumps around the plant, without any ground protection measures. Post-production waste (about 1.2 million m^3) was stored around the plant for over 70 years, without any environmental protection measures (Zakłady...). Leakage from the landfill carries boron, barium, strontium, arsenic, copper and zinc compounds that penetrate into the soil, surface water and groundwater. On the other hand, wind erosion of waste from the landfill may contribute to the contamination of the soil of neighboring areas, especially to the east of the landfill (in Poland, winds blowing from west to east prevail).

MATERIALS AND METHODS

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

FIELD WORKS

Soil samples were collected on a regular grid 250×250 m (16 samples/km^2). In total, 1256 samples were taken from a depth of 0.0–0.3 m and 1188 samples from a depth of 0.8–1.0 m. The locations of sampling sites are marked in maps showing both the built-up areas and land use (Pls. 2, 3). In the case of a shallower depth to the bedrock, a 20-cm-thick sample was collected from just above the bedrock. Soil samples (approx. 500 g), collected with a hand auger, 60 mm in diameter, were placed in canvas bags labeled with appropriate numbers, and pre-dried on wooden pallets in a field storage facility.

Sediment and surface water samples (321 and 278 samples, respectively) were collected from rivers, streams, ditches, canals, lakes, settling tanks, and ponds. The distance between the sampling sites on watercourses was approx. 250 m. The sampling points of surface water and sediments are presented in plates showing chemical elements content in these environmental elements, starting from plates 7 and 9, respectively. Sediment samples weighing approx. 500 g (and of the finest possible fraction) were taken from the banks of water bodies using the aluminum scoop and placed in 500 ml plastic containers, marked with appropriate numbers.

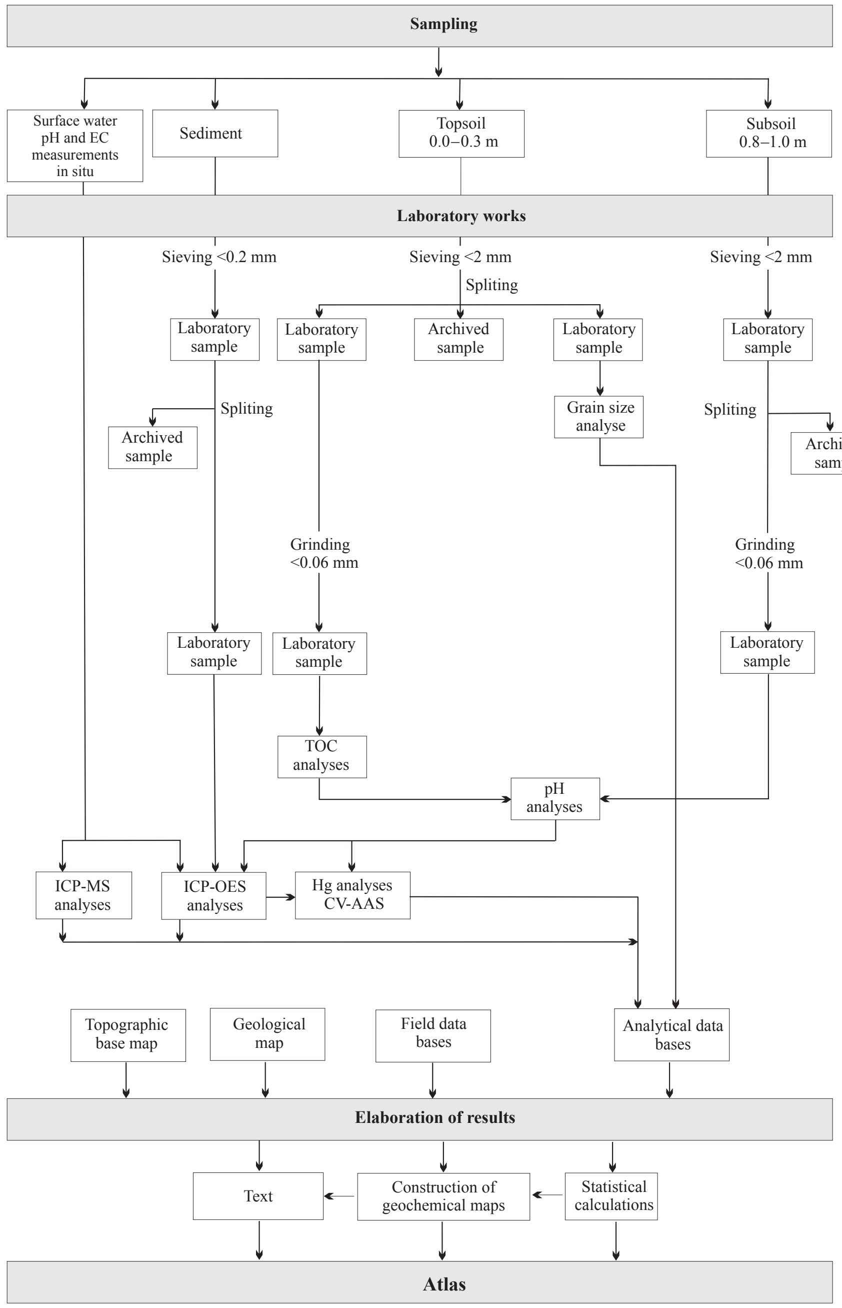


Fig. 1. Scheme of the work performed

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

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

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

LABORATORY WORKS

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

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

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

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

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

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

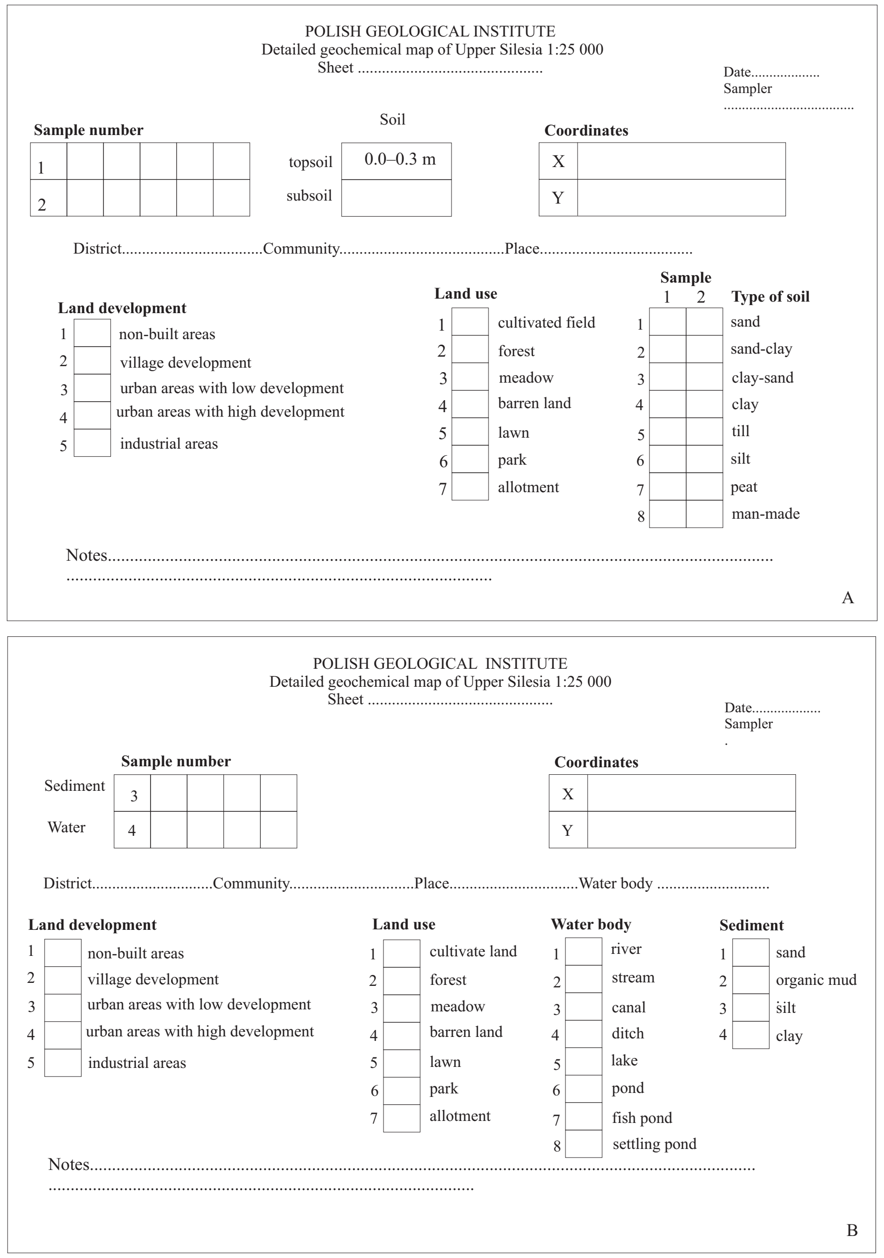
Determination of the B, Ba, Ca, Cr, Fe, K, Mg, Mn, Na, P, SiO_2, SO_4, Sr, Ti and Zn contents in surface water was carried out using the ICP-OES method, while ICP-MS Inductively Coupled Plasma-Mass Spectrometry was used to find out the contents of Ag, Al, As, Be, Cd, Co, Cu, Li, Mo, Ni, Pb, Sb, Se, Tl, U and V. The summary of analytical methods and detection limits of the elements is presented in Table 1.

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

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

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

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



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

Sample number
1 ☐☐☐☐☐
2 ☐☐☐☐☐

Soil
topsoil 0.0–0.3 m
subsoil ☐

Coordinates
X ☐
Y ☐

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

Land development
1 ☐ non-built areas
2 ☐ village development
3 ☐ urban areas with low development
4 ☐ urban areas with high development
5 ☐ industrial areas

Land use
1 ☐ cultivated field
2 ☐ forest
3 ☐ meadow
4 ☐ barren land
5 ☐ lawn
6 ☐ park
7 ☐ allotment

	Sample 1	2	**Type of soil**
1	☐	☐	sand
2	☐	☐	sand-clay
3	☐	☐	clay-sand
4	☐	☐	clay
5	☐	☐	till
6	☐	☐	silt
7	☐	☐	peat
8	☐	☐	man-made

Notes..
....

A

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

Sample number
Sediment 3 ☐☐☐☐
Water 4 ☐☐☐☐

Coordinates
X ☐
Y ☐

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

Land development
1 ☐ non-built areas
2 ☐ village development
3 ☐ urban areas with low development
4 ☐ urban areas with high development
5 ☐ industrial areas

Land use
1 ☐ cultivate land
2 ☐ forest
3 ☐ meadow
4 ☐ barren land
5 ☐ lawn
6 ☐ park
7 ☐ allotment

Water body
1 ☐ river
2 ☐ stream
3 ☐ canal
4 ☐ ditch
5 ☐ lake
6 ☐ pond
7 ☐ fish pond
8 ☐ settling pond

Sediment
1 ☐ sand
2 ☐ organic mud
3 ☐ silt
4 ☐ clay

Notes..
....

B

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

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

DATABASES AND GEOCHEMICAL MAPS CONSTRUCTION

Topographic base map. The most recent 1 : 50,000 scale topographic map in the *1992* coordinate system, map sheet Bytom M-34-50-D (VMap L2 vector data), was used for the construction of the 1 : 25,000 geochemical maps. The topographic map contains the following vector information layers:

– topography;

Tabela 1
Table

Metody analityczne i granice wykrywalności

Analytical methods and detection limits

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

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

- hydrography (subdivided into rivers, streams, ditches and stagnant water reservoirs);
- road communication network (by class);
- railway network;
- housing areas (subdivided into rural, urban and industrial housing);
- forests;
- industrial areas (industrial facilities, mine workings, heaps and settling tanks).

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

Databases. Separate databases (spreadsheets) have been created for:

- soils from the depth of 0.0–0.3 m (topsoil);
- soils from the depth of 0.8–1.0 m (subsoil);
- sediments;
- surface water.

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

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

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

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

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

Construction of maps. The following maps were developed for the Świerklaniec sheet (Pls. 2–63):

- built-up area;
- land use;
- contents of organic carbon and sand, silt and clay fractions in soils from 0.0–0.3 m depth (topsoil);
- pH in soils from 0.0–0.3 m depth (topsoil) and 0.8–1.0 m depth (subsoil);
- contents of Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, Mg, Mn, Ni, P, Pb, S, Sr, Ti, V and Zn in soils from the depths of 0.0–0.3 m and 0.8–1.0 m and in sediments;
- pH and EC and contents of Ag, Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, SO_4, Sb, Se, SiO_2, Sr, Ti, Tl, U, V and Zn in surface water;
- topsoil (0.0–0.3 m) classification according to the permissible content of cadmium.

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

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

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

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

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

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

When preparing the exemplary classification map of topsoils (Pl. 63), which indicates the proper way of their use due to pollution with cadmium, the results of geochemical investigations were compared to the values of permissible concentrations specified in the Regulation of the Minister of the Environment (Rozporządzenie..., 2016). The soil areas distinguished were classified into use groups I, II, III and IV.

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

Tabela 2
Table 2

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 mg/kg	Al %	As mg/kg	Ba mg/kg	$C_{org.}$ %	Ca %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe %	Hg mg/kg	Mg %	Mn mg/kg	Ni mg/kg	P %	Pb mg/kg	S %	Sr mg/kg	Ti mg/kg	V mg/kg	Zn mg/kg	pH
Granica wykrywalności Detection limit		1	0,01	3	1	0,02	0,01	0,5	1	1	1	0,01	0,02	0,01	2	1	0,002	2	0,003	1	5	1	1	
Gleby ogółem Soils as a whole n = 1256	a	<1	0,02	<3	12	0,05	<0,01	<0,5	<1	<1	1	0,02	<0,02	<0,01	2	<1	<0,002	3	<0,003	1	<5	<1	8	3,41
	b	14	2,25	1628	9051	49,98	18,82	266,8	24	59	540	17,76	1,77	1,99	27 238	75	0,760	8342	1,000	342	516	72	16 346	9,38
	c	<1	0,40	12	369	5,00	0,37	4,1	2	7	16	0,80	0,08	0,07	318	6	0,035	256	0,045	19	56	10	351	5,81
	d	<1	0,31	7	237	2,87	0,09	2,3	1	5	11	0,48	0,05	0,03	98	4	0,025	151	0,029	12	48	7	161	5,65
	e	<1	0,33	7	239	2,47	0,07	2,3	1	5	10	0,47	0,05	0,03	107	3	0,027	147	0,026	12	48	7	157	5,73
Tereny bez zabudowy Non-built-up areas n = 1054	a	<1	0,02	<3	12	0,05	<0,01	<0,5	<1	<1	1	0,02	<0,02	<0,01	2	<1	<0,002	3	<0,003	1	<5	<1	8	3,41
	b	6	2,25	299	9051	49,98	18,82	112,4	24	32	540	17,76	1,14	1,99	27 238	75	0,252	5158	1,000	342	418	70	15 294	9,38
	c	<1	0,37	9	377	5,41	0,25	3,5	2	6	14	0,72	0,08	0,05	273	5	0,031	221	0,045	16	50	9	259	5,52
	d	<1	0,28	6	234	2,97	0,06	2,1	1	5	10	0,43	0,05	0,02	75	3	0,022	143	0,029	10	45	7	133	5,38
	e	<1	0,29	6	231	2,50	0,05	2,2	1	4	9	0,40	0,05	0,02	68	3	0,023	143	0,025	10	46	7	130	5,34
Tereny z zabudową wiejską Village areas n = 24	a	<1	0,14	<3	26	1,25	0,03	1,5	<1	3	4	0,13	0,02	0,01	9	1	0,012	23	0,017	3	13	3	50	4,91
	b	8	0,94	220	646	14,80	3,79	30,4	10	16	125	4,59	0,25	0,61	3632	18	0,379	1249	0,143	121	223	24	2445	8,42
	c	<1	0,45	20	209	3,83	0,49	5,9	3	8	18	1,05	0,08	0,09	534	7	0,067	319	0,043	21	58	11	640	6,57
	d	<1	0,42	9	170	3,05	0,21	4,1	2	7	12	0,76	0,06	0,06	332	5	0,052	205	0,034	14	48	10	381	6,51
	e	<1	0,43	7	165	2,89	0,18	3,4	2	7	11	0,71	0,06	0,05	368	6	0,054	158	0,026	13	46	9	267	6,53
Tereny z zabudową miejską Urban areas n = 159	a	<1	0,18	<3	52	0,46	0,02	<0,5	<1	3	3	0,23	<0,02	0,01	22	1	0,018	35	0,008	3	20	3	33	5,02
	b	4	1,50	116	1241	10,34	8,30	29,7	15	59	367	7,50	0,74	1,20	4746	49	0,208	2612	0,255	265	516	72	4075	9,28
	c	<1	0,55	13	306	2,69	1,03	4,4	4	13	25	1,23	0,08	0,16	566	10	0,054	286	0,037	37	87	15	672	7,41
	d	<1	0,50	10	253	2,25	0,45	3,2	3	10	18	0,98	0,06	0,11	398	8	0,048	186	0,031	24	73	13	435	7,36
	e	<1	0,48	10	263	2,19	0,46	2,9	3	11	17	1,00	0,06	0,11	420	8	0,047	164	0,030	21	71	13	426	7,58
Tereny przemysłowe Industrial areas n = 19	a	<1	0,20	<3	140	0,74	0,03	0,6	<1	3	9	0,27	<0,02	0,02	33	2	0,008	48	0,022	16	36	4	42	5,02
	b	14	1,01	1628	2017	11,09	4,92	266,8	10	36	243	4,32	1,77	1,98	1053	38	0,760	8342	0,414	136	365	28	16 346	8,81
	c	2	0,51	126	691	3,27	1,25	35,7	3	11	65	1,29	0,31	0,28	441	11	0,071	1833	0,089	46	99	12	2410	7,16
	d	<1	0,46	21	506	2,79	0,44	6,9	3	9	42	0,92	0,12	0,13	271	8	0,031	464	0,062	39	83	10	666	7,09
	e	<1	0,46	13	482	2,91	0,63	5,0	3	9	33	0,79	0,11	0,12	340	7	0,024	287	0,046	36	72	11	667	7,31
Pola uprawne Cultivated fields n = 157	a	<1	0,18	<3	12	0,05	<0,01	<0,5	<1	2	1	0,11	<0,02	0,01	37	2	0,005	3	<0,003	2	31	3	13	4,61
	b	2	1,22	66	421	5,21	5,62	13,7	17	25	51	8,26	0,18	1,00	3343	34	0,141	1477	0,247	70	133	34	1845	8,28
	c	<1	0,62	11	195	1,59	0,44	3,1	4	11	14	1,21	0,05	0,11	590	10	0,050	179	0,022	15	68	16	352	7,01
	d	<1	0,58	9	176	1,44	0,22	2,6	4	10	13	1,01	0,04	0,09	484	8	0,047	138	0,020	13	66	14	283	6,98
	e	<1	0,60	9	180	1,44	0,16	2,7	4	10	13	1,01	0,05	0,09	505	9	0,048	143	0,019	12	68	15	278	7,07
Lasy Forests n = 725	a	<1	0,02	<3	13	0,11	<0,01	<0,5	<1	<1	1	0,02	<0,02	<0,01	2	<1	<0,002	4	<0,003	1	<5	<1	8	3,41
	b	6	2,25	299	9051	49,98	7,19	112,4	24	32	150	10,03	0,96	1,99	5674	42	0,252	5751	0,408	342	200	70	15 294	9,38
	c	<1	0,28	8	443	6,39	0,12	3,5	1	5	13	0,49	0,09	0,03	129	3	0,023	236	0,047	14	46	7	210	4,98
	d	<1	0,22	5	263	3,57	0,04	1,9	<1	3	9	0,31	0,05	0,02	39	2	0,017	144	0,030	9	41	5	96	4,89
	e	<1	0,22	5	282	3,05	0,03	1,8	<1	3	8	0,30	0,05	0,02	29	2	0,016	145	0,029	9	43	5	84	4,77
Łąki Meadows n = 81	a	<1	0,05	<3	25	1,01	0,02	0,6	<1	1	2	0,10	<0,02	<0,01	9	<1	0,007	23	0,012	2	9	2	26	4,33
	b	2	1,81	100	1737	39,95	5,63	30,4	10	28	52	8,15	0,29	0,27	7561	27	0,146	5158	0,530	134	101	47	2301	8,19
	c	<1	0,50	13	268	4,58	0,29	4,2	3	8	12	1,02	0,07	0,06	439	6	0,048	319	0,047	17	43	12	385	6,29
	d	<1	0,43	9	207	2,68	0,15	3,2	2	7	10	0,68	0,06	0,04	225	5	0,041	181	0,031	13	39	10	266	6,23
	e	<1	0,45	8	209	2,24	0,14	3,1	2	7	10	0,67	0,06	0,05	226	5	0,043	165	0,026	13	37	11	253	6,25
Nieużytki, ugory Barren lands n = 170	a	<1	0,08	<3	25	0,14	<0,01	<0,5	<1	<1	2	0,08	<0,02	<0,01	4	<1	0,003	9	<0,003	2	13	1	20	3,95
	b	14	1,46	1628	1297	37,44	18,82	266,8	19	59	540	17,76	1,77	1,98	27 238	75	0,760	8342	1,000	299	418	60	16 346	8,74
	c	<1	0,52	27	235	3,85	0,86	7,0	4	10	23	1,27	0,08	0,13	666	9	0,050	360	0,054	27	68	13	685	6,84
	d	<1	0,44	9	181	2,33	0,25	3,0	3	8	13	0,79	0,05	0,07	287	6	0,037	152	0,030	15	56	11	305	6,77
	e	<1	0,43	8	194	2,01	0,28	2,8	3	8	12	0,72	0,05	0,07	361	6	0,040	129	0,026	14	55	10	275	6,84
Ogródki działkowe Allotments n = 13	a	<1	0,36	5	165	1,45	0,18	2,4	3	7	12	0,71	0,01	0,06	301	6	0,037	118	0,019	14	36	9	270	6,73
	b	<1	1,02	25	4881	5,16	1,62	11,2	6	25	63	1,93	0,13	0,17	801	17	0,379	529	0,055	125	92	25	872	7,79
	c	<1	0,61	11	747	2,48	0,48	4,1	4	12	26	1,19	0,07	0,11	559	11	0,086	204	0,034	38	74	15	509	7,34
	d	<1	0,58	10	387	2,34	0,41	3,7	4	12	23	1,12	0,06	0,11	536	10	0,067	186	0,032	30	72	14	479	7,34
	e	<1	0,62	9	253	2,15	0,39	3,2	4	12	22	1,10	0,06	0,11	551	11	0,056	171	0,033	25	78	14	509	7,33

Tabela 2 cd.
Table 2 cont.

Gleby Soils	Parametry Parameters	Ag mg/kg	Al %	As mg/kg	Ba mg/kg	$C_{org.}$ %	Ca %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe %	Hg mg/kg	Mg %	Mn mg/kg	Ni mg/kg	P %	Pb mg/kg	S %	Sr mg/kg	Ti mg/kg	V mg/kg	Zn mg/kg	pH
Parki Parks n = 16	a	<1	0,30	5	154	1,68	0,04	1,1	1	5	5	0,52	0,04	0,03	67	2	0,020	57	0,016	5	32	7	74	4,91
	b	<1	0,68	64	613	9,76	1,70	6,4	8	14	30	5,15	1,14	0,17	796	17	0,122	414	0,125	93	117	36	651	7,97
	c	<1	0,48	18	297	3,94	0,45	3,7	3	8	13	1,55	0,16	0,07	232	7	0,052	154	0,050	18	56	14	278	6,29
	d	<1	0,47	14	268	3,48	0,23	3,2	3	8	11	1,16	0,10	0,06	182	6	0,044	135	0,043	14	53	13	238	6,22
	e	<1	0,49	12	265	3,40	0,22	3,5	3	8	10	0,93	0,11	0,07	161	7	0,040	132	0,048	14	53	13	249	6,02
Trawniki Lawns n = 94	a	<1	0,22	<3	20	0,58	0,03	<0,5	<1	2	2	0,14	<0,02	0,02	16	1	0,009	13	0,007	3	20	3	33	5,76
	b	3	1,50	42	2778	10,34	8,09	29,7	15	57	367	7,50	0,74	1,20	4746	49	0,208	2612	0,255	265	516	72	3442	9,28
	c	<1	0,54	13	385	3,04	1,33	5,3	4	14	30	1,24	0,09	0,20	571	11	0,056	319	0,044	47	100	15	801	7,62
	d	<1	0,49	10	297	2,58	0,69	3,8	3	11	21	1,01	0,07	0,13	420	9	0,048	215	0,037	32	83	13	542	7,59
	e	<1	0,46	10	279	2,57	0,74	3,7	3	12	21	0,99	0,07	0,14	428	9	0,052	181	0,037	31	82	12	497	7,77
Gleby piaszczyste Sandy soils n = 1073	a	<1	0,02	<3	12	0,05	<0,01	<0,5	<1	<1	1	0,02	<0,02	<0,01	2	<1	<0,002	3	<0,003	1	3	<1	8	3,55
	b	6	2,25	213	4881	39,12	18,82	266,8	24	57	152	10,03	1,77	1,43	7561	43	0,760	8200	0,402	299	467	59	7239	8,81
	c	<1	0,36	9	352	3,46	0,27	3,3	2	6	13	0,71	0,07	0,06	283	5	0,031	215	0,033	15	53	9	270	5,76
	d	<1	0,28	6	223	2,44	0,07	2,0	1	5	9	0,43	0,05	0,03	89	3	0,023	134	0,025	10	47	7	137	5,61
	e	<1	0,30	6	217	2,26	0,06	2,1	1	4	9	0,42	0,05	0,02	95	3	0,023	133	0,024	10	47	7	131	5,67
Gleby gliniaste Clay soils n = 21	a	<1	0,56	8	132	1,26	0,12	2,2	4	10	14	0,84	<0,02	0,09	304	8	0,034	81	0,016	10	52	16	213	6,48
	b	1	1,38	76	1018	3,21	3,13	96,1	17	25	53	17,76	0,38	0,99	27 238	75	0,086	1658	0,041	47	154	60	6075	7,88
	c	<1	0,95	19	243	2,02	0,95	9,2	7	17	22	2,45	0,08	0,21	1946	19	0,050	310	0,027	21	85	26	822	7,46
	d	<1	0,93	16	211	1,95	0,63	4,9	6	17	21	1,79	0,06	0,18	755	17	0,049	228	0,026	19	83	25	550	7,45
	e	<1	0,91	15	191	1,89	0,46	4,0	7	17	21	1,66	0,06	0,16	626	16	0,050	198	0,025	19	82	24	497	7,67
Gleby torfiaste Peaty soils n = 97	a	<1	0,14	<3	21	0,11	<0,01	<0,5	<1	2	2	0,05	<0,02	<0,01	4	<1	<0,002	5	0,005	2	3	2	13	3,41
	b	1	1,52	80	1473	49,98	3,29	29,3	15	24	540	4,59	0,71	0,22	3632	27	0,252	1397	1,000	130	121	70	2301	7,91
	c	<1	0,49	16	488	23,74	0,42	8,5	2	8	29	0,97	0,22	0,04	184	7	0,065	505	0,174	28	44	15	430	4,68
	d	<1	0,43	12	391	18,86	0,19	6,8	1	7	20	0,68	0,18	0,03	65	5	0,051	395	0,139	21	37	12	302	4,57
	e	<1	0,42	13	415	20,92	0,14	8,4	2	8	20	0,66	0,21	0,03	46	6	0,056	471	0,153	22	38	12	305	4,28
Gleby antropogeniczne Man-made soils n = 65	a	<1	0,22	<3	73	0,49	0,04	0,7	<1	3	7	0,27	<0,02	0,03	57	2	0,010	61	0,012	8	36	4	120	5,18
	b	14	1,50	1628	9051	15,44	8,30	122,3	15	59	367	5,14	0,65	1,99	3881	49	0,180	8342	0,414	342	516	72	16 346	9,38
	c	1	0,58	52	528	3,46	1,76	9,9	4	14	43	1,43	0,10	0,28	572	13	0,049	546	0,057	61	114	16	1416	7,79
	d	<1	0,53	14	327	2,75	0,98	4,5	3	12	28	1,17	0,06	0,18	442	11	0,042	245	0,043	43	96	14	650	7,75
	e	<1	0,53	11	304	2,59	0,93	3,4	4	12	26	1,15	0,06	0,15	436	10	0,041	171	0,043	43	88	13	471	7,88
Tło geochemiczne; geochemical background																								
Gleby Europy 1) Soils of Europe n = 837	e	0,27	5,82	6	65	1,73	0,92	0,15	7	22	12	1,96	0,04	0,46	524	14	0,055	15	0,023	89	3420	33	48	7,7
Gleby Polski 2) Soils of Poland n = 10 840	e	<1		<5	32		0,18	<0,5	2	4	5	0,51	<0,05	0,06	217	4	0,034	13	0,012	8	26	7	35	6,1
Gleby regionu śląsko-krakowskiego 3) Soils of Cracow-Silesia Region n = 1564	e	<1		<5	54		0,22	1,3	3	5	7	0,63	0,08	0,07	257	5	0,030	44	0,015	10	28	9	104	6,7
Dopuszczalne zawartości pierwiastków powodujących ryzyko 4); permissible levels of elements causing the risk																								
I grupa; group I				25	400			2	50	200	200		5			150		200					500	
II grupa; group II				10–50	200–600			2–5	20–50	150–500	100–300		2–5			100–300		100–500					300–1000	
III grupa; group III				50	1000			10	100	500	300		10			300		500					1000	
IV grupa; group IV				100	1500			15	200	1000	600		30			500		600					2000	

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

1) Salminen, 2005;
2) Lis, Pasieczna, 1995a;
3) Lis, Pasieczna, 1995b;
4) Rozporządzenie Ministra Środowiska, 2016

Tabela 3
Table

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

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

Gleby Soils	Parametry Parameters	Ag mg/kg	Al %	As mg/kg	Ba mg/kg	Ca %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe %	Hg mg/kg	Mg %	Mn mg/kg	Ni mg/kg	P %	Pb mg/kg	S %	Sr mg/kg	Ti mg/kg	V mg/kg	Zn mg/kg	pH
Granica wykrywalności Detection limit		1	0,01	3	1	0,01	0,5	1	1	1	0,01	0,02	0,01	2	1	0,002	2	0,003	1	5	1	1	
Gleby ogółem Soils as a whole n = 1188	a	<1	0,03	<3	7	<0,01	<0,5	<1	<1	<1	<0,01	<0,02	<0,01	<2	<1	<0,002	<2	<0,003	<1	<5	<1	3	3,58
	b	6	3,21	461	2382	22,80	46,5	67	51	2243	24,57	0,29	5,41	25 659	184	0,150	5216	0,820	388	510	143	8404	8,92
	c	<1	0,42	6	55	0,44	1,0	2	7	8	0,73	0,02	0,07	270	6	0,013	77	0,012	10	60	9	160	6,70
	d	<1	0,31	<3	35	0,03	<0,5	1	4	3	0,27	<0,02	0,03	39	3	0,007	14	0,005	4	52	5	32	6,64
	e	<1	0,28	<3	28	0,02	<0,5	<1	3	3	0,22	<0,02	0,02	26	2	0,006	9	0,004	3	54	4	20	6,72
Tereny bez zabudowy Non-built-up areas n = 1018	a	<1	0,03	<3	7	<0,01	<0,5	<1	<1	<1	<0,01	<0,02	<0,01	<2	<1	<0,002	<2	<0,003	<1	<5	<1	3	3,58
	b	6	3,21	461	2382	22,80	42,6	67	51	421	24,57	0,29	4,64	25 659	184	0,150	5216	0,820	388	355	80	8404	8,92
	c	<1	0,41	6	51	0,40	0,8	2	6	6	0,68	0,02	0,06	248	6	0,011	67	0,012	9	58	8	131	6,58
	d	<1	0,30	<3	32	0,02	<0,5	1	4	3	0,24	<0,02	0,03	32	2	0,006	12	0,004	3	50	5	27	6,52
	e	<1	0,27	<3	26	0,01	<0,5	<1	3	2	0,20	<0,02	0,02	21	2	0,006	8	0,004	2	51	4	17	6,61
Tereny z zabudową wiejską Village areas n = 22	a	<1	0,10	<3	14	<0,01	<0,5	<1	<1	<1	0,03	<0,02	<0,01	5	<1	0,003	5	<0,003	2	17	1	15	5,20
	b	<1	2,20	22	176	5,57	5,1	22	45	152	4,23	0,14	2,52	2350	48	0,088	802	0,146	44	89	50	1805	8,43
	c	<1	0,44	4	43	0,45	0,7	3	6	12	0,73	0,03	0,16	259	6	0,020	68	0,013	9	55	9	154	7,07
	d	<1	0,34	<3	33	0,07	<0,5	1	4	4	0,30	<0,02	0,04	82	3	0,012	21	0,005	5	51	5	57	7,04
	e	<1	0,33	<3	28	0,06	<0,5	1	3	3	0,23	<0,02	0,03	67	2	0,010	16	0,006	4	60	4	43	7,07
Tereny z zabudową miejską Urban areas n = 133	a	<1	0,10	<3	13	<0,01	<0,5	<1	1	<1	0,06	<0,02	<0,01	6	<1	<0,002	<2	<0,003	1	27	1	6	5,70
	b	2	1,81	139	415	14,63	46,5	25	50	2243	10,80	0,14	5,41	6462	61	0,125	3105	0,074	180	510	143	7522	8,61
	c	<1	0,52	10	78	0,82	1,9	3	9	25	1,11	0,03	0,13	448	9	0,022	150	0,010	15	74	13	389	7,52
	d	<1	0,42	4	53	0,12	0,7	2	6	6	0,57	<0,02	0,06	141	5	0,014	38	0,006	7	66	8	99	7,50
	e	<1	0,41	3	49	0,10	<0,5	2	7	5	0,55	<0,02	0,05	177	5	0,015	35	0,005	6	68	9	83	7,66
Tereny przemysłowe Industrial areas n = 15	a	<1	0,15	<3	17	0,01	<0,5	<1	2	2	0,13	<0,02	0,02	22	2	0,003	4	<0,003	2	33	2	12	5,88
	b	<1	0,85	15	801	1,14	8,4	5	12	43	1,93	0,11	0,24	737	21	0,030	581	0,054	103	243	27	430	8,30
	c	<1	0,48	4	152	0,16	1,2	2	6	10	0,70	<0,02	0,07	147	6	0,014	93	0,012	15	82	9	114	7,23
	d	<1	0,43	3	87	0,07	0,6	2	5	7	0,50	<0,02	0,06	77	5	0,011	36	0,008	8	72	7	68	7,20
	e	<1	0,43	3	61	0,08	0,5	2	5	7	0,58	<0,02	0,06	49	5	0,012	25	0,007	6	69	7	59	7,33
Pola uprawne Cultivated fields n = 139	a	<1	0,15	<3	12	<0,01	<0,5	<1	2	1	0,10	<0,02	0,01	13	1	0,003	3	<0,003	2	27	3	7	5,32
	b	6	3,21	461	316	14,63	42,6	57	51	45	21,01	0,29	4,64	14 818	83	0,150	5216	0,101	308	211	80	7170	8,52
	c	<1	0,79	18	59	1,75	2,6	6	16	12	2,02	0,04	0,23	873	16	0,023	253	0,007	26	81	21	493	7,46
	d	<1	0,64	7	46	0,21	0,8	4	11	8	1,01	0,03	0,10	307	9	0,017	52	0,005	10	75	14	132	7,44
	e	<1	0,72	7	44	0,13	0,6	4	11	8	1,04	0,02	0,09	349	10	0,018	47	0,005	7	77	16	113	7,48
Lasy Forests n = 720	a	<1	0,03	<3	7	<0,01	<0,5	<1	<1	<1	<0,01	<0,02	<0,01	<2	<1	<0,002	<2	<0,003	<1	<5	<1	3	3,58
	b	1	2,88	127	883	22,80	17,3	35	41	172	11,61	0,25	0,46	6809	184	0,089	1245	0,451	388	310	73	1774	8,44
	c	<1	0,32	<3	41	0,11	0,4	1	4	4	0,35	<0,02	0,03	72	4	0,007	22	0,010	5	53	5	38	6,32
	d	<1	0,25	<3	28	0,01	<0,5	<1	3	2	0,17	<0,02	0,02	18	2	0,005	8	0,004	2	46	3	17	6,28
	e	<1	0,23	<3	24	<0,01	<0,5	<1	3	2	0,15	<0,02	0,02	14	2	0,005	6	0,004	2	46	3	14	6,40
Łąki Meadows n = 79	a	<1	0,08	<3	11	<0,01	<0,5	<1	<1	<1	0,03	<0,02	<0,01	3	<1	<0,002	3	<0,003	1	11	<1	5	5,20
	b	5	2,20	93	349	14,37	27,5	67	45	35	24,57	0,17	0,35	25 659	62	0,083	4336	0,367	200	137	59	8404	8,31
	c	<1	0,43	7	48	0,35	1,1	3	7	6	0,98	0,02	0,05	538	6	0,012	150	0,013	9	53	9	225	6,88
	d	<1	0,31	<3	33	0,05	<0,5	1	4	3	0,27	<0,02	0,03	40	3	0,007	15	0,004	4	47	5	34	6,85
	e	<1	0,28	<3	27	0,03	<0,5	<1	4	3	0,22	<0,02	0,02	26	2	0,006	9	0,004	3	47	4	23	7,04
Nieużytki, ugory Barren lands n = 148	a	<1	0,05	<3	10	<0,01	<0,5	<1	<1	<1	0,01	<0,02	<0,01	4	<1	<0,002	2	<0,003	1	14	<1	4	5,38
	b	4	1,79	336	610	17,06	11,7	16	38	421	10,90	0,21	5,41	6962	66	0,134	1753	0,280	249	355	72	5154	8,92
	c	<1	0,53	12	78	0,75	1,4	3	9	11	1,09	0,03	0,12	477	9	0,020	108	0,019	15	68	12	281	7,17
	d	<1	0,41	4	50	0,10	0,6	2	6	5	0,48	<0,02	0,05	105	4	0,012	31	0,007	6	60	8	81	7,13
	e	<1	0,44	<3	37	0,07	<0,5	2	6	5	0,50	<0,02	0,06	75	5	0,012	23	0,005	5	63	8	66	7,27

Tabela 3 cd.
Table 3 cont.

Gleby Soils	Parametry Parameters	Ag mg/kg	Al %	As mg/kg	Ba mg/kg	Ca %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe %	Hg mg/kg	Mg %	Mn mg/kg	Ni mg/kg	P %	Pb mg/kg	S %	Sr mg/kg	Ti mg/kg	V mg/kg	Zn mg/kg	pH
Ogródki działkowe Allotments n = 12	a	<1	0,19	<3	21	0,03	<0,5	<1	2	2	0,23	<0,02	0,02	47	2	0,014	10	<0,003	2	34	3	20	6,90
	b	<1	1,35	27	2382	10,81	4,9	11	29	106	2,54	0,06	0,40	794	31	0,047	219	0,043	140	142	31	538	8,26
	c	<1	0,69	8	310	1,28	1,1	4	12	18	1,15	0,02	0,12	400	11	0,027	75	0,012	27	83	15	184	7,69
	d	<1	0,58	5	94	0,25	0,7	3	9	9	0,88	<0,02	0,08	290	7	0,025	53	0,008	14	77	12	127	7,68
	e	<1	0,73	5	69	0,15	0,8	4	12	9	0,94	<0,02	0,11	307	9	0,025	58	0,009	12	84	15	176	7,77
Parki Parks n = 16	a	<1	0,15	<3	21	0,02	<0,5	<1	2	1	0,16	<0,02	0,02	13	2	0,003	5	<0,003	2	37	2	13	5,15
	b	<1	0,99	38	158	2,31	4,3	8	16	13	1,75	0,13	0,10	800	16	0,051	84	0,820	31	114	20	198	7,54
	c	<1	0,42	7	70	0,27	0,8	2	6	5	0,72	0,03	0,05	134	5	0,022	29	0,076	7	54	9	78	6,55
	d	<1	0,37	4	56	0,10	0,5	2	6	4	0,54	<0,02	0,05	63	4	0,014	23	0,012	5	51	8	60	6,51
	e	<1	0,37	<3	57	0,09	<0,5	2	6	5	0,52	<0,02	0,05	64	4	0,016	25	0,008	4	42	8	56	6,55
Trawniki Lawns n = 74	a	<1	0,10	<3	13	<0,01	<0,5	<1	1	1	0,06	<0,02	<0,01	6	<1	<0,002	<2	<0,003	1	27	1	6	5,97
	b	2	1,81	139	801	6,14	46,5	15	50	2243	7,65	0,12	0,87	4442	61	0,125	3105	0,074	180	510	143	7522	8,61
	c	<1	0,48	9	98	0,63	2,0	3	8	41	0,95	0,03	0,09	365	8	0,025	147	0,012	19	81	13	430	7,66
	d	<1	0,39	4	59	0,14	0,7	2	6	6	0,49	<0,02	0,05	129	4	0,016	38	0,007	8	69	7	106	7,64
	e	<1	0,39	<3	56	0,14	0,5	1	5	5	0,47	<0,02	0,05	171	4	0,017	41	0,006	8	69	7	84	7,72
Gleby piaszczyste Sandy soils n = 927	a	<1	0,03	<3	7	<0,01	<0,5	<1	<1	<1	<0,01	<0,02	<0,01	1	<1	<0,002	<2	<0,003	<1	10	<1	3	4,17
	b	6	1,42	167	2382	6,14	30,9	18	41	53	24,57	0,17	0,60	25 659	62	0,134	4287	0,262	65	206	64	5637	8,92
	c	<1	0,28	<3	41	0,05	<0,5	1	4	3	0,36	<0,02	0,03	125	3	0,008	33	0,006	4	54	5	53	6,61
	d	<1	0,24	<3	27	0,01	<0,5	<1	3	2	0,17	<0,02	0,02	22	2	0,005	8	0,003	2	47	3	19	6,56
	e	<1	0,23	<3	24	0,01	<0,5	<1	3	2	0,17	<0,02	0,02	17	2	0,005	6	0,004	2	48	3	15	6,66
Gleby gliniaste Clay soils n = 213	a	<1	0,21	<3	18	<0,01	<0,5	<1	3	2	0,05	<0,02	<0,01	5	2	0,003	7	<0,003	2	11	4	17	4,51
	b	2	3,21	461	648	22,80	46,5	67	51	56	21,01	0,29	5,41	14 818	184	0,150	5216	0,280	388	355	80	8404	8,52
	c	<1	1,00	19	91	2,03	2,7	7	19	16	2,26	0,05	0,26	852	20	0,028	241	0,014	33	83	25	563	7,12
	d	<1	0,91	9	72	0,36	1,0	5	16	13	1,60	0,03	0,15	335	15	0,022	73	0,009	15	76	21	189	7,04
	e	<1	0,93	8	67	0,21	0,9	6	17	14	1,58	0,04	0,14	376	15	0,024	58	0,008	10	77	21	154	7,28
Gleby torfiaste Peaty soils n = 23	a	<1	0,13	<3	14	<0,01	<0,5	<1	1	<1	0,04	<0,02	<0,01	4	<1	<0,002	3	<0,003	2	<5	<1	5	3,58
	b	<1	1,04	38	544	2,52	17,3	14	23	26	3,31	0,25	0,24	2350	48	0,089	802	0,820	81	69	73	1805	6,36
	c	<1	0,45	8	139	0,77	3,3	2	8	10	0,56	0,08	0,06	202	8	0,036	129	0,222	23	33	17	293	5,39
	d	<1	0,38	5	102	0,33	2,0	2	6	8	0,30	0,06	0,04	51	5	0,025	57	0,125	15	29	10	140	5,35
	e	<1	0,36	5	114	0,53	3,5	2	8	9	0,44	0,06	0,05	50	7	0,030	65	0,239	18	32	12	163	5,40
Gleby antropogeniczne Man-made soils n = 25	a	<1	0,23	<3	32	0,07	<0,5	<1	2	3	0,19	<0,02	0,03	52	2	0,008	15	<0,003	4	33	3	40	6,66
	b	4	1,33	336	801	5,25	8,2	16	26	2243	7,65	0,13	0,62	6462	34	0,088	1245	0,104	247	510	143	3203	8,30
	c	<1	0,67	28	196	1,15	2,3	5	11	136	1,59	0,04	0,18	739	13	0,032	248	0,028	40	121	22	595	7,77
	d	<1	0,60	9	142	0,57	1,6	4	9	22	1,07	0,03	0,13	330	10	0,026	122	0,018	22	97	15	306	7,76
	e	<1	0,66	6	141	0,58	1,9	4	11	16	0,93	0,04	0,14	344	10	0,024	109	0,020	22	85	15	362	7,84

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

Tabela 4
Table

Parametry statystyczne zawartości pierwiastków chemicznych w osadach

Statistical parameters of chemical elements contents in sediments

Osady Sediments	Parametry Parameters	Ag mg/kg	Al %	As mg/kg	Ba mg/kg	Ca %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe %	Hg mg/kg	Mg %	Mn mg/kg	Ni mg/kg	P %	Pb mg/kg	S %	Sr mg/kg	Ti mg/kg	V mg/kg	Zn mg/kg
Granica wykrywalności Detection limit		1	0,01	3	1	0,01	0,5	1	1	1	0,01	0,02	0,01	2	1	0,002	2	0,003	1	5	1	1
Osady (wszystkie próbki) Sediments (all samples) n = 321	a	<1	0,05	<3	9	<0,01	<0,5	<1	<1	<1	<0,01	<0,02	<0,01	3	<1	<0,002	6	0,004	1	<5	1	20
	b	11	5,76	1072	1365	13,66	168,1	86	131	242	21,06	1,06	6,20	51 110	81	6,890	23 890	4,270	171	422	122	33 260
	c	<1	0,72	26	233	0,70	12,4	5	12	33	1,65	0,16	0,14	573	12	0,132	526	0,312	24	51	18	876
	d	<1	0,51	13	160	0,29	6,3	2	9	19	0,83	0,09	0,06	107	8	0,056	215	0,162	16	41	12	427
	e	<1	0,58	14	198	0,33	7,4	2	10	25	0,86	0,12	0,05	91	8	0,069	277	0,181	18	41	14	525
Strumienie i rowy bez nazwy Streams and ditches (without a name) n = 189	a	<1	0,05	<3	16	0,01	<0,5	<1	1	<1	0,05	<0,02	<0,01	3	<1	0,004	6	0,007	1	<5	1	33
	b	11	5,76	1072	965	13,66	168,1	86	131	195	15,10	1,06	6,20	14380	81	0,772	7417	4,270	171	422	122	33 260
	c	<1	0,89	28	283	0,66	15,7	6	13	37	1,67	0,21	0,15	436	13	0,098	581	0,310	26	47	22	1000
	d	<1	0,67	15	208	0,29	9,2	2	10	27	0,86	0,14	0,06	98	9	0,069	328	0,190	19	37	16	509
	e	<1	0,71	16	260	0,31	9,5	2	11	31	0,83	0,16	0,05	68	10	0,074	379	0,189	21	38	17	547
Sadzawki Small water pools n = 8	a	<1	0,17	<3	23	0,07	1,3	<1	4	6	0,14	<0,02	0,02	28	4	0,011	46	0,020	4	21	2	110
	b	1	1,22	151	408	8,80	100,4	11	24	99	11,81	0,26	0,28	762	54	0,437	2623	0,438	102	69	91	1744
	c	<1	0,58	36	234	1,68	21,6	4	13	41	2,65	0,14	0,12	280	17	0,119	579	0,184	31	45	23	781
	d	<1	0,49	16	169	0,60	8,9	2	11	28	1,14	0,10	0,09	146	12	0,066	282	0,128	21	41	14	576
	e	<1	0,44	25	258	0,55	7,7	3	14	37	1,42	0,18	0,10	111	14	0,086	314	0,106	26	49	17	644
Stawy Ponds n = 8	a	<1	0,08	<3	13	0,03	0,8	<1	3	2	0,16	<0,02	0,02	19	2	0,010	19	0,015	2	15	2	45
	b	8	0,60	133	269	1,39	11,1	5	23	37	10,79	0,15	0,08	2440	20	0,044	23 890	0,348	14	154	15	3037
	c	1	0,28	20	91	0,31	4,1	2	7	14	1,69	0,06	0,04	358	6	0,025	3205	0,130	7	52	6	558
	d	<1	0,22	5	57	0,17	2,7	1	5	9	0,52	0,04	0,03	83	4	0,022	162	0,075	6	41	5	200
	e	<1	0,22	4	50	0,16	2,1	<1	5	6	0,47	0,03	0,03	69	3	0,024	56	0,101	8	37	4	143
Zbiornik Chechło-Nakło Chechło-Nakło Reservoir n = 21	a	<1	0,09	<3	39	<0,01	<0,5	<1	1	<1	0,07	<0,02	0,01	9	1	<0,002	7	0,004	2	39	1	20
	b	<1	0,39	6	389	1,09	2,3	5	8	13	0,94	0,06	0,35	199	14	0,016	51	0,075	9	175	10	103
	c	<1	0,18	<3	166	0,13	1,0	<1	3	4	0,32	<0,02	0,06	38	3	0,005	24	0,028	5	76	4	53
	d	<1	0,16	<3	133	0,04	0,7	<1	3	3	0,24	<0,02	0,03	26	3	0,004	21	0,021	5	69	3	47
	e	<1	0,17	<3	156	0,03	0,6	<1	3	4	0,21	<0,02	0,02	22	2	0,005	18	0,023	5	66	3	60
Zbiornik Kozłowa Góra Kozłowa Góra Reservoir n = 20	a	<1	0,07	<3	14	0,04	<0,5	<1	1	1	0,05	<0,02	<0,01	20	<1	0,006	11	0,016	2	16	1	39
	b	<1	1,05	53	313	1,11	14,4	9	22	54	3,37	0,29	0,18	492	24	0,091	509	0,584	31	107	26	1184
	c	<1	0,44	10	90	0,39	3,6	3	8	13	0,93	0,07	0,06	138	6	0,033	107	0,180	10	39	10	294
	d	<1	0,32	6	59	0,26	1,7	2	6	6	0,52	0,04	0,04	94	4	0,024	55	0,108	7	35	8	173
	e	<1	0,39	5	59	0,38	1,9	3	8	5	0,73	0,05	0,04	94	5	0,028	64	0,131	8	33	11	153
Brynica Brynica River n = 12	a	<1	0,07	<3	18	0,04	0,6	1	1	<1	0,25	<0,02	0,01	50	1	0,010	13	0,010	2	14	2	46
	b	<1	1,46	27	284	0,94	22,5	9	22	42	1,86	0,19	0,33	434	25	0,157	403	0,619	74	39	32	2454
	c	<1	0,44	12	126	0,40	5,8	6	7	12	0,98	0,06	0,10	184	8	0,074	107	0,183	15	31	10	609
	d	<1	0,34	9	99	0,29	3,6	5	6	8	0,82	0,04	0,07	147	6	0,056	73	0,109	10	29	8	379
	e	<1	0,37	11	131	0,38	4,7	7	6	9	1,08	0,05	0,09	142	7	0,075	77	0,140	10	34	9	517
Dopływ spod Żyglinka Dopływ spod Żyglinka Stream n = 14	a	<1	0,11	<3	9	0,01	<0,5	<1	<1	1	0,05	<0,02	<0,01	4	<1	0,004	23	0,009	1	17	1	20
	b	4	1,71	204	473	1,10	99,6	8	27	131	2,30	0,49	0,48	1067	22	0,378	3066	0,566	71	103	37	4268
	c	<1	0,77	54	159	0,30	18,1	2	10	33	0,84	0,17	0,08	141	7	0,073	588	0,211	18	39	14	895
	d	<1	0,55	26	93	0,17	9,2	<1	6	17	0,56	0,11	0,03	36	4	0,041	318	0,129	10	34	10	473
	e	<1	0,91	39	114	0,23	12,1	<1	8	20	0,66	0,12	0,04	28	5	0,057	448	0,218	12	33	14	633
Zlewnia Brynicy Brynica River catchment n = 112	a	<1	0,05	<3	9	0,01	<0,5	<1	<1	<1	0,05	<0,02	<0,01	4	<1	0,004	6	0,007	1	12	1	20
	b	11	3,16	1072	610	13,66	168,1	31	47	131	11,81	1,06	6,20	4125	54	0,437	7417	4,270	171	107	91	33 260
	c	<1	0,60	29	180	0,60	15,2	4	10	27	1,11	0,18	0,16	249	9	0,070	534	0,258	17	39	15	936
	d	<1	0,44	11	119	0,24	6,7	2	7	15	0,63	0,09	0,05	85	6	0,046	216	0,139	11	35	10	404
	e	<1	0,52	11	150	0,24	7,7	2	8	18	0,64	0,11	0,04	83	6	0,056	275	0,163	13	35	12	469
Potok spod Nakła Potok spod Nakła Stream n = 21	a	<1	0,29	4	98	0,11	2,1	2	3	4	0,47	<0,02	0,02	45	3	0,041	88	0,078	10	20	5	183
	b	3	1,66	95	525	2,36	18,9	12	34	89	2,64	0,29	0,55	744	24	0,310	792	0,972	71	195	31	2909
	c	<1	0,73	23	201	0,79	7,1	6	16	36	1,48	0,11	0,18	248	14	0,129	357	0,465	38	77	18	907
	d	<1	0,66	18	179	0,56	6,2	5	14	28	1,36	0,09	0,12	185	13	0,103	303	0,362	33	63	16	712
	e	<1	0,66	20	168	0,48	5,7	5	15	40	1,50	0,08	0,13	239	15	0,072	314	0,367	33	64	16	788

Tabela 4 cd.
Table 4 cont.

Osady Sediments	Parametry Parameters	Ag mg/kg	Al %	As mg/kg	Ba mg/kg	Ca %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe %	Hg mg/kg	Mg %	Mn mg/kg	Ni mg/kg	P %	Pb mg/kg	S %	Sr mg/kg	Ti mg/kg	V mg/kg	Zn mg/kg
Zlewnia Potoku spod Nakła Potok spod Nakła Stream catchment n = 110	a	<1	0,09	<3	13	<0,01	<0,5	<1	1	<1	0,07	<0,02	<0,01	3	1	<0,002	7	0,004	2	<5	1	20
	b	8	3,85	143	833	2,82	149,1	44	131	195	11,68	0,71	1,13	3860	49	0,772	23 890	2,517	118	195	122	8022
	c	<1	0,80	22	269	0,47	11,2	4	13	32	1,50	0,15	0,10	279	12	0,105	686	0,267	27	56	20	783
	d	<1	0,57	11	199	0,22	5,1	2	9	19	0,77	0,09	0,06	80	8	0,049	221	0,143	18	45	13	339
	e	<1	0,65	13	245	0,31	5,9	2	10	29	0,80	0,14	0,05	64	10	0,070	325	0,166	24	49	15	375
Rów Świerklaniecki Rów Świerklaniecki Stream n = 21	a	<1	0,06	4	30	0,18	1,8	<1	2	3	0,28	<0,02	0,02	69	2	0,033	20	0,035	5	21	2	164
	b	3	1,08	143	488	6,52	18,4	8	38	101	21,06	0,20	0,67	7626	27	6,890	770	2,507	61	141	30	3113
	c	1	0,45	38	159	1,87	8,2	4	16	40	3,44	0,08	0,29	1303	13	0,780	258	0,631	30	71	14	1203
	d	<1	0,35	25	123	1,47	7,2	3	12	28	1,90	0,06	0,21	518	11	0,201	173	0,351	24	64	12	975
	e	1	0,40	29	143	1,64	7,6	4	14	32	1,72	0,07	0,26	508	12	0,152	231	0,294	28	76	15	958
Zlewnia Rowu Świerklanieckiego Rów Świerklaniecki Stream catchment n = 45	a	<1	0,06	<3	16	0,06	<0,5	<1	2	2	0,16	<0,02	<0,01	24	1	0,010	8	0,011	2	20	2	45
	b	3	5,76	143	488	8,80	27,9	30	47	125	21,06	0,27	0,88	7626	33	6,890	774	2,507	102	189	43	3113
	c	<1	0,61	28	149	1,71	9,3	6	15	34	2,42	0,09	0,25	968	14	0,399	247	0,502	26	70	16	1032
	d	<1	0,40	17	112	0,98	6,3	4	12	23	1,44	0,06	0,16	380	11	0,098	155	0,211	19	61	13	677
	e	<1	0,42	21	134	1,34	7,0	4	13	28	1,69	0,07	0,20	326	12	0,071	171	0,253	19	67	15	768
Zlewnia Pniowca Pniowiec Stream catchment n = 49	a	<1	0,12	<3	15	0,01	0,8	<1	1	3	0,05	<0,02	<0,01	6	1	0,008	19	0,035	4	6	2	33
	b	11	4,67	218	1365	1,62	32,7	68	30	148	15,10	0,53	0,55	51 110	81	0,655	1551	2,883	88	422	65	3122
	c	<1	0,91	28	336	0,42	10,9	7	10	35	2,25	0,18	0,06	1332	12	0,090	368	0,352	25	42	21	705
	d	<1	0,69	16	249	0,25	7,9	2	8	24	0,98	0,12	0,04	89	8	0,065	234	0,226	21	31	15	464
	e	<1	0,79	18	303	0,31	8,4	1	10	24	0,93	0,14	0,04	53	9	0,073	238	0,216	23	31	17	469
Tło geochemiczne; geochemical background																						
Osady strumieniowe Europy[1)] Stream sediments of Europe n = 794	e		10,4	6	87,5	2,44	0,29	8	22	15	1,97	0,04	0,72	453	17	0,056	14	0,050	124	3800	29	60
Osady Polski[2)] Sediments of Poland n = 12 778	e	<1		<5	54	0,86	<0,5	3	5	7	0,80	0,05	0,11	274	6	0,059	13	0,040	20	30	7	62
Osady regionu śląsko-krakowskiego[3)] Sediments of Cracow-Silesia Region n = 1459	e	1		6	98	0,71	2,5	4	9	15	1,07	0,06	0,13	292	11	0,066	59	0,052	24	42	12	259

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

[1)] Salminen, 2005;
[2)] Lis, Pasieczna, 1995a;
[3)] Lis, Pasieczna, 1995b;

Tabela 5
Table

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

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

Wody powierzchniowe Surface water	Parametry Parameters	EC mS/cm	pH	Ag µg/dm^3	Al µg/dm^3	As µg/dm^3	B mg/dm^3	Ba mg/dm^3	Be µg/dm^3	Ca mg/dm^3	Cd µg/dm^3	Co µg/dm^3	Cr mg/dm^3	Cu µg/dm^3	Fe mg/dm^3	K mg/dm^3	Li µg/dm^3	Mg mg/dm^3	Mn mg/dm^3	Mo µg/dm^3	Na mg/dm^3	Ni µg/dm^3	P mg/dm^3	Pb µg/dm^3	SO$_4$ mg/dm^3	Sb µg/dm^3	Se µg/dm^3	SiO$_2$ mg/dm^3	Sr mg/dm^3	Ti mg/dm^3	Tl µg/dm^3	U µg/dm^3	V µg/dm^3	Zn mg/dm^3
Granica wykrywalności Detection limit				0,05	0,5	2	0,01	0,001	0,05	0,1	0,05	0,05	0,003	0,05	0,01	0,5	0,3	0,1	0,001	0,05	0,5	0,5	0,05	0,05	1	0,05	2	0,1	0,003	0,002	0,05	0,05	1	0,003
Wody powierzchniowe (wszystkie próbki) Surface water (all samples) n = 278	a	0,02	4,4	<0,05	1,0	<2	0,01	0,035	<0,05	5,9	<0,05	<0,05	<0,003	0,37	0,01	<0,5	<0,3	1,0	0,001	<0,05	0,9	<0,5	<0,05	0,06	2	<0,05	<2	0,1	0,026	<0,002	<0,05	<0,05	<1	<0,003
	b	1,39	8,3	0,16	10 023,2	32	0,38	0,782	2,97	214,2	53,35	26,47	0,004	13,65	67,63	20,6	26,0	41,1	7,650	4,80	140,9	33,3	5,09	395,49	419	9,11	3	32,1	0,460	0,020	10,97	6,98	17	6,910
	c	0,37	6,6	<0,05	593,3	3	0,08	0,149	0,17	50,6	4,11	2,15	<0,003	2,21	1,22	4,1	4,4	10,0	0,247	0,41	14,5	4,0	0,16	11,29	74	0,64	<2	12,6	0,142	<0,002	0,32	0,52	2	0,477
	d	0,30	6,5	<0,05	104,5	<2	0,07	0,120	0,07	37,3	0,56	0,57	<0,003	1,69	0,25	3,2	2,9	7,4	0,104	0,20	9,1	2,3	0,05	1,49	63	0,46	<2	8,6	0,129	<0,002	0,11	0,13	1	0,100
	e	0,29	6,8	<0,05	69,1	<2	0,07	0,102	<0,05	35,7	0,51	0,58	<0,003	1,65	0,27	2,9	3,8	6,7	0,140	0,23	9,0	2,5	<0,05	0,95	63	0,44	<2	12,6	0,131	<0,002	0,08	0,07	1	0,100
Strumienie i rowy (bez nazwy) Streams and ditches (without a name) n = 145	a	0,02	4,4	<0,05	1,5	<2	0,02	0,035	<0,05	5,9	<0,05	<0,05	<0,003	0,41	0,01	0,6	<0,3	1,0	0,001	<0,05	0,9	<0,5	<0,05	0,07	11	<0,05	<2	2,2	0,026	<0,002	<0,05	<0,05	<1	<0,003
	b	1,39	7,7	0,16	10 023,2	32	0,38	0,438	2,97	214,2	53,35	26,47	0,004	13,65	25,42	20,6	26,0	41,1	3,702	4,80	140,9	33,3	5,09	395,49	419	9,11	3	32,1	0,460	0,020	10,97	6,98	17	6,910
	c	0,33	6,2	<0,05	984,8	3	0,09	0,113	0,28	43,8	6,58	3,39	<0,003	2,86	1,26	3,9	5,5	8,5	0,273	0,37	13,46	5,8	0,08	18,46	77	0,73	<2	15,7	0,137	0,003	0,42	0,46	3	0,746
	d	0,26	6,1	<0,05	269,7	<2	0,07	0,105	0,13	31,9	1,98	1,22	<0,003	2,25	0,38	3,0	4,2	6,0	0,137	0,12	6,91	4,0	<0,05	2,86	64	0,51	<2	14,5	0,120	<0,002	0,17	0,09	2	0,306
	e	0,24	6,4	<0,05	495,0	<2	0,07	0,104	0,14	33,2	3,13	2,00	<0,003	2,28	0,45	2,6	4,7	5,7	0,168	0,09	5,0	4,4	<0,05	2,84	66	0,54	<2	15,4	0,123	<0,002	0,17	<0,05	2	0,418
Sadzawki Small water pools n = 8	a	0,14	6,0	<0,05	4,5	<2	0,03	0,067	<0,05	19,7	<0,05	<0,05	<0,003	0,41	0,01	1,6	0,6	3,5	0,008	<0,05	2,6	<0,5	<0,05	0,06	28	0,12	<2	1,7	0,062	<0,002	<0,05	<0,05	<1	0,007
	b	0,81	7,6	0,05	1103,0	3	0,27	0,191	0,45	159,7	1,95	6,20	<0,003	2,66	6,10	14,4	10,4	20,1	0,430	1,15	66,8	6,0	0,39	5,65	109	2,55	<2	24,0	0,296	0,006	0,49	3,50	2	0,124
	c	0,49	6,9	<0,05	230,6	<2	0,08	0,131	0,11	65,5	0,50	0,96	<0,003	1,69	1,02	6,2	4,0	9,4	0,148	0,40	20,7	2,0	0,08	2,14	55	0,67	<2	9,4	0,160	<0,002	0,11	1,00	1	0,049
	d	0,40	6,9	<0,05	33,4	<2	0,06	0,124	0,06	53,1	0,23	0,13	<0,003	1,40	0,14	5,1	2,7	7,8	0,062	0,24	9,7	1,2	<0,05	0,98	50	0,44	<2	6,4	0,141	<0,002	0,06	0,30	1	0,034
	e	0,54	6,9	<0,05	14,9	<2	0,06	0,135	<0,05	62,8	0,19	<0,05	<0,003	1,82	0,10	5,4	3,4	6,4	0,092	0,35	6,7	1,3	<0,05	1,31	45	0,40	<2	7,4	0,140	<0,002	<0,05	0,60	1	0,029
Stawy Ponds n = 9	a	0,17	6,1	<0,05	1,0	<2	0,04	0,059	<0,05	28,9	<0,05	<0,05	<0,003	0,87	0,01	1,8	<0,3	3,4	0,001	0,08	3,5	0,7	<0,05	0,09	58	0,18	<2	0,1	0,092	<0,002	<0,05	<0,05	<1	0,007
	b	0,69	7,8	<0,05	135,9	<2	0,14	0,204	<0,05	113,0	1,21	0,25	<0,003	2,54	0,45	6,3	4,5	21,9	0,270	0,69	28,0	1,8	0,09	6,59	229	0,45	<2	16,7	0,266	<0,002	1,06	1,40	2	0,121
	c	0,50	7,0	<0,05	29,3	<2	0,08	0,111	<0,05	79,5	0,21	0,07	<0,003	1,33	0,07	4,1	2,5	15,1	0,073	0,38	15,9	1,3	<0,05	1,14	124	0,30	<2	7,4	0,170	<0,002	0,27	0,69	1	0,039
	d	0,43	7,0	<0,05	11,2	<2	0,07	0,105	<0,05	69,0	0,09	0,05	<0,003	1,25	0,02	3,7	1,4	11,9	0,037	0,29	12,4	1,2	<0,05	0,30	110	0,28	<2	2,5	0,160	<0,002	0,09	0,30	<1	0,023
	e	0,66	7,0	<0,05	15,7	<2	0,06	0,099	<0,05	88,9	0,07	<0,05	<0,003	1,06	0,02	4,4	3,6	18,3	0,053	0,46	18,6	1,2	<0,05	0,12	120	0,30	<2	11,8	0,171	<0,002	<0,05	0,39	<1	0,020
Zbiornik Chechło-Nakło Chechło-Nakło Reservoir n = 21	a	0,16	6,9	<0,05	3,0	<2	0,08	0,546	<0,05	12,5	<0,05	<0,05	<0,003	0,47	0,01	2,1	<0,3	4,1	0,004	0,21	8,6	<0,5	<0,05	<0,05	31	0,70	<2	0,1	0,124	<0,002	0,06	<0,05	<1	<0,003
	b	0,19	8,3	<0,05	59,1	<2	0,08	0,782	<0,05	13,7	<0,05	0,32	<0,003	0,86	0,11	2,3	<0,3	4,3	0,257	0,34	9,5	1,0	<0,05	0,65	35	1,19	<2	1,0	0,134	<0,002	0,35	<0,05	<1	0,003
	c	0,17	7,3	<0,05	25,3	<2	0,08	0,594	<0,05	13,0	<0,05	0,06	<0,003	0,71	0,03	2,2	<0,3	4,2	0,027	0,29	8,9	<0,5	<0,05	<0,05	33	0,04	<2	0,3	0,129	<0,002	0,10	<0,05	<1	<0,003
	d	0,17	7,3	<0,05	21,1	<2	0,08	0,592	<0,05	13,0	<0,05	<0,05	<0,003	0,71	0,02	2,2	<0,3	4,2	0,012	0,29	8,9	<0,5	<0,05	<0,05	33	0,03	<2	0,2	0,129	<0,002	0,09	<0,05	<1	<0,003
	e	0,17	7,3	<0,05	23,0	<2	0,08	0,575	<0,05	13,0	<0,05	0,05	<0,003	0,73	0,02	2,2	<0,3	4,2	0,011	0,29	8,9	<0,5	<0,05	<0,05	33	1,05	<2	0,2	0,129	<0,002	0,09	<0,05	<1	<0,003
Zbiornik Kozłowa Góra Kozłowa Góra Reservoir n = 21	a	0,21	6,2	<0,05	9,8	<2	0,01	0,090	<0,05	24,6	<0,05	<0,05	<0,003	0,37	0,03	<0,5	0,7	3,3	0,002	<0,05	3,8	<0,5	<0,05	0,11	21	<0,05	<2	1,4	0,049	<0,002	<0,05	<0,05	<1	<0,003
	b	0,59	7,8	<0,05	111,1	2	0,07	0,246	0,05	84,4	0,36	10,60	<0,003	1,97	67,63	4,5	3,0	15,8	7,650	0,52	12,5	2,0	0,12	3,15	122	0,37	<2	11,2	0,165	<0,002	<0,05	0,94	2	0,065
	c	0,35	6,9	<0,05	37,0	<2	0,03	0,125	<0,05	52,5	0,06	1,09	<0,003	0,84	4,62	2,9	2,2	10,7	0,644	0,30	10,2	1,0	<0,05	0,66	55	0,21	<2	6,0	0,120	<0,002	<0,05	0,46	1	0,115
	d	0,34	6,9	<0,05	29,2	<2	0,03	0,120	<0,05	50,3	<0,05	0,24	<0,003	0,79	0,39	2,4	2,1	10,1	0,074	0,21	9,9	0,8	<0,05	0,38	51	0,18	<2	5,2	0,115	<0,002	<0,05	0,34	<1	0,009
	e	0,36	6,8	<0,05	25,0	<2	0,03	0,102	<0,05	54,7	<0,05	0,15	<0,003	0,84	0,19	3,7	2,3	11,8	0,040	0,42	11,1	1,0	<0,05	0,28	53	0,23	<2	5,0	0,127	<0,002	<0,05	0,53	1	0,007
Brynica Brynica River n = 12	a	0,36	6,7	<0,05	24,8	<2	0,03	0,096	<0,05	61,3	<0,05	0,37	<0,003	0,47	0,20	3,6	3,1	13,0	0,081	0,51	8,6	1,5	<0,05	0,18	31	0,16	<2	7,4	0,137	<0,002	<0,05	0,70	<1	0,023
	b	0,48	7,6	<0,05	59,6	<2	0,03	0,111	<0,05	69,0	0,20	2,62	<0,003	1,30	0,72	5,1	3,9	14,9	0,575	0,73	15,0	1,9	<0,05	0,37	68	0,28	<2	10,1	0,179	<0,002	0,08	0,91	2	0,051
	c	0,42	7,2	<0,05	43,3	<2	0,03	0,101	<0,05	66,9	0,14	0,65	<0,003	1,10	0,33	4,1	3,4	14,4	0,140	0,65	11,5	1,7	<0,05	0,29	63	0,25	<2	9,4	0,146	<0,002	0,06	0,79	1	0,037
	d	0,42	7,2	<0,05	40,8	<2	0,03	0,101	<0,05	66,9	0,12	0,54	<0,003	1,07	0,30	4,1	3,4	14,4	0,115	0,64	11,4	1,6	<0,05	0,29	62	0,25	<2	9,4	0,146	<0,002	0,06	0,79	<1	0,034
	e	0,42	7,2	<0,05	43,5	<2	0,03	0,100	<0,05	67,6	0,14	0,49	<0,003	1,17	0,33	4,0	3,4	14,6	0,094	0,64	11,5	1,7	<0,05	0,31	65	0,25	<2	9,6	0,143	<0,002	0,07	0,80	1	0,036
Dopływ spod Żyglinka Dopływ spod Żyglinka Stream n = 10	a	0,15	5,0	<0,05	162,1	3	0,04	0,066	0,03	10,2	9,02	0,23	<0,003	1,18	0,10	1,9	2,8	2,5	0,013	0,03	2,0	2,2	<0,05	6,84	45	0,44	<2	7,2	0,073	<0,002	0,72	<0,05	1	1,178
	b	0,46	6,8	0,06	2006,6	12	0,08	0,118	0,38	60,3	17,77	4,16	<0,003	7,52	2,26	6,0	7,5	10,1	0,175	1,30	22,5	4,7	<0,05	38,87	91	2,54	<2	20,2	0,171	0,004	3,43	<0,05	4	1,992
	c	0,24	5,9	<0,05	1342,3	6	0,05	0,095	0,23	26,8	14,96	2,34	<0,003	3,53	0,84	3,1	6,0	5,4	0,132	0,41	8,4	3,6	<0,05	28,20	62	1,17	<2	16,2	0,097	0,003	1,91	0,08	3	1,694
	d	0,22	5,9	<0,05	1043,9	5	0,05	0,094	0,17	22,9	14,72	1,74	<0,003	3,14	0,62	2,8	5,7	5,0	0,107	0,24	6,3	3,5	<0,05	25,86	60	1,05	<2	15,3	0,091	0,003	1,77	<0,05	3	1,674
	e	0,18	5,8	<0,05	1648,5	5	0,05	0,095	0,28	18,6	16,04	2,72	<0,003	2,85	0,83	2,3	7,0	4,5	0,156	0,21	4,9	3,9	<0,05	27,80	57	0,98	<2	18,4	0,076	0,004	1,77	<0,05	3	1,772
Zlewnia Brynicy Brynica River catchment n = 91	a	0,02	4,4	<0,05	1,5	<2	0,01	0,035	<0,05	5,9	<0,05	<0,05	<0,003	0,37	0,01	<0,5	0,5	1,0	0,001	<0,05	0,9	<0,5	<0,05	0,06	11	<0,05	<2	1,4	0,026	<0,002	<0,05	<0,05	<1	<0,003
	b	0,87	7,7	0,16	10 023,2	32	0,15	0,438	1,58	142,5	53,35	19,48	0,004	13,65	67,63	20,6	12,8	30,9	7,650	3,99	55,7	19,8	5,09	395,49	216	3,53	<2	27,0	0,241	0,020	10,97	2,79	17	6,910
	c	0,31	6,5	<0,05	712,6	4	0,05	0,112	0,15	43,3	6,69	1,92	<0,003	2,39	1,60	3,7	4,0	8,8	0,272	0,33	9,3	3,5	0,10	22,91	57	0,57	<2	11,7	0,113	0,002	0,65	0,35	2	0,730
	d	0,27	6,4	<0,05	139,2	2	0,04	0,104	0,07	34,9	0,66	0,58	<0,003	1,61	0,33	3,0	3,3	6,8	0,086	0,17	6,7	2,1	<0,05	1,82	51	0,37	<2	10,3	0,104	<0,002	0,14	0,13	1	0,114
	e	0,31	6,7	<0,05	85,8	<2	0,04	1,101	<0,05	46,2	0,30	0,54	<0,003	1,30	0,32	3,2	3,2	8,1	0,118	0,20	7,5	1,9	<0,05	0,77	55	0,30	<2	10,0	0,111	<0,002	0,07	0,10	1	0,049
Potok spod Nakła Potok spod Nakła Stream n = 22	a	0,16	5,8	<0,05	47,7	<2	0,04	0,080	<0,05	23,6	0,34	0,31	<0,003	0,72	0,10	1,7	3,1	4,7	0,071	0,06	4,2	1,7	<0,05	0,61	36	0,21	<2	6,4	0,114	<0,002	<0,05	<0,05	<1	0,096
	b	0,97	7,8	0,06	1024,5	11	0,11	0,178	0,46	63,6	7,54	8,75	<0,003	4,62	1,63	20,5	8,0	15,6	0,292	0,69	64,6	7,0	4,53	12,41	110	0,78	<2	24,2	0,293	0,004	0,42	0,39	13	1,654
	c	0,38	6,8	<0,05	195,6	2	0,08	0,103	0,09	33,3	1,17	1,49	<0,003	1,98	0,50	5,9	4,1	6,9	0,159	0,31	19,4	3,0	1,16	5,17	60	0,49	<2	13,8	0,143	<0,002	0,07	0,10	1	0,229
	d	0,33	6,8	<0,05	124,1	<2	0,07	0,102	0,06	32,7	0,86	0,95	<0,003	1,68	0,38	4,2	4,0	6,7	0,149	0,21	13,6	2,8	0,20	3,33	58	0,46	<2	12,5	0,139	<0,002	0,05	0,06	<1	0,168
	e	0,27	6,8	<0,05	110,3	<2	0,07	0,100	0,07	32,4	0,84	0,62	<0,003	1,57	0,42	2,7	3,6	6,4	0,135	0,16	9,7	2,6	<0,05	2,38	61	0,48	<2	16,0	0,131	<0,002	<0,05	<0,05	1	0,139

Tabela 5 cd.
Table 5 cont.

Wody powierzchniowe Surface water	Parametry Parameters	EC mS/cm	pH	Ag µg/dm^3	Al µg/dm^3	As µg/dm^3	B mg/dm^3	Ba mg/dm^3	Be µg/dm^3	Ca mg/dm^3	Cd µg/dm^3	Co µg/dm^3	Cr mg/dm^3	Cu µg/dm^3	Fe mg/dm^3	K mg/dm^3	Li µg/dm^3	Mg mg/dm^3	Mn mg/dm^3	Mo µg/dm^3	Na mg/dm^3	Ni µg/dm^3	P mg/dm^3	Pb µg/dm^3	SO$_4$ mg/dm^3	Sb µg/dm^3	Se µg/dm^3	SiO$_2$ mg/dm^3	Sr mg/dm^3	Ti mg/dm^3	Tl µg/dm^3	U µg/dm^3	V µg/dm^3	Zn mg/dm^3
Zlewnia Potoku spod Nakła Potok spod Nakła Stream catchment n = 93	a	0,06	4,5	<0,05	3,0	<2	0,02	0,040	<0,05	7,1	<0,05	<0,05	<0,003	0,41	0,01	1,3	<0,3	1,5	0,001	<0,05	1,0	<0,5	<0,05	0,09	19	0,12	<2	0,1	0,030	<0,002	<0,05	<0,05	<1	<0,003
	b	0,97	8,3	0,10	6852,0	11	0,30	0,782	2,97	159,7	19,26	26,47	0,003	13,10	25,42	20,5	19,2	28,2	3,702	1,22	66,8	33,3	4,53	47,33	267	1,92	<2	31,4	0,308	0,009	1,47	4,99	13	2,389
	c	0,28	6,5	<0,05	625,4	2	0,08	0,217	0,24	29,6	3,15	2,82	<0,003	2,05	1,01	3,7	3,6	6,0	0,273	0,25	11,9	4,2	0,29	6,76	66	0,69	<2	12,0	0,138	0,002	0,19	0,16	2	0,397
	d	0,24	6,5	<0,05	172,1	<2	0,08	0,152	0,10	24,5	0,69	0,73	<0,003	1,62	0,24	2,9	1,7	5,2	0,099	0,16	8,0	2,0	0,05	2,51	56	0,61	<2	4,8	0,130	<0,002	0,12	0,05	1	0,087
	e	0,20	6,6	<0,05	145,5	<2	0,08	0,109	0,08	27,8	0,84	0,83	<0,003	1,69	0,37	2,3	3,6	4,7	0,134	0,17	8,7	2,8	<0,05	2,09	60	0,63	<2	13,4	0,129	<0,002	0,10	<0,05	1	0,151
Rów Świerklaniecki Rów Świerklaniecki Stream n = 23	a	0,63	6,4	<0,05	4,8	<2	0,05	0,087	<0,05	100,5	<0,05	<0,05	<0,003	1,05	0,02	4,3	1,9	18,4	0,051	0,32	18,5	0,8	<0,05	0,09	112	0,17	<2	8,0	0,120	<0,002	<0,05	1,37	1	0,019
	b	0,86	7,8	0,05	69,5	4	0,10	0,126	<0,05	140,4	0,39	0,63	<0,003	2,33	0,56	12,2	5,8	29,3	0,357	1,60	48,0	3,1	0,22	1,85	148	0,68	<2	14,0	0,245	<0,002	0,06	2,19	3	0,045
	c	0,75	7,2	<0,05	13,7	<2	0,07	0,097	<0,05	123,0	0,08	0,23	<0,003	1,62	0,12	5,7	3,8	23,8	0,145	0,70	25,6	1,6	0,09	0,37	125	0,33	<2	11,2	0,183	<0,002	<0,05	1,60	2	0,031
	d	0,75	7,2	<0,05	10,9	<2	0,07	0,096	<0,05	122,3	0,06	0,18	<0,003	1,58	0,08	5,3	3,6	23,5	0,132	0,65	24,8	1,5	0,07	0,27	125	0,31	<2	11,1	0,180	<0,002	<0,05	1,60	2	0,030
	e	0,75	7,1	<0,05	13,0	<2	0,07	0,094	<0,05	125,6	0,05	0,24	<0,003	1,61	0,07	5,5	4,0	24,7	0,142	0,73	24,4	1,3	0,07	0,27	120	0,33	<2	10,9	0,188	<0,002	<0,05	1,56	2	0,032
Zlewnia Rowu Świerklanieckiego Rów Świerklaniecki Stream catchment n = 49	a	0,24	6,4	<0,05	1,0	<2	0,04	0,050	<0,05	37,2	<0,05	<0,05	<0,003	0,85	0,01	0,6	<0,3	4,3	0,004	<0,05	4,1	<0,5	<0,05	0,07	59	0,07	<2	1,7	0,115	<0,002	<0,05	<0,05	<1	<0,003
	b	1,39	7,8	0,05	286,3	4	0,27	0,208	0,11	214,2	12,21	2,90	<0,003	4,86	1,33	15,6	10,4	41,1	0,411	3,18	140,9	11,2	0,22	6,47	419	0,88	3	16,4	0,460	0,002	0,40	6,98	5	0,990
	c	0,67	7,2	<0,05	20,4	<2	0,09	0,110	<0,05	112,4	0,88	0,30	<0,003	1,90	0,15	6,1	3,9	21,0	0,124	0,75	30,1	2,6	0,06	0,49	126	0,36	<2	11,2	0,196	<0,002	0,05	1,73	2	0,105
	d	0,73	7,2	<0,05	10,7	<2	0,08	0,107	<0,05	107,4	0,14	0,14	<0,003	1,73	0,06	5,2	3,3	19,5	0,087	0,48	25,6	1,9	0,05	0,27	119	0,30	<2	10,7	0,188	<0,002	<0,05	1,08	2	0,044
	e	0,70	7,1	<0,05	9,80	<2	0,07	0,099	<0,05	113,0	0,08	0,15	<0,003	1,68	0,06	5,4	4,1	21,2	0,103	0,55	25,2	2,0	<0,05	0,27	120	0,33	<2	11,0	0,185	<0,002	<0,05	1,52	2	0,034
Zlewnia Pniowca Pniowiec Stream catchment n = 40	a	0,08	4,4	<0,05	14,8	<2	0,02	0,060	<0,05	7,1	<0,05	<0,05	<0,003	0,48	0,04	<0,5	1,2	1,0	0,013	<0,05	1,1	<0,5	<0,05	0,09	2	0,10	<2	4,0	0,044	<0,002	<0,05	<0,05	<1	0,006
	b	1,09	7,3	0,11	8853,2	22	0,38	0,387	1,88	140,4	31,51	18,15	0,004	7,62	21,38	14,8	26,0	36,3	1,012	4,80	106,0	18,8	0,31	103,90	234	9,11	2	32,1	0,456	0,011	1,13	2,43	6	3,234
	c	0,29	6,1	<0,05	1016,8	4	0,12	0,127	0,26	37,8	4,91	3,56	<0,003	2,46	2,24	3,0	7,7	8,0	0,252	0,43	10,9	5,7	<0,05	9,63	67	1,01	<2	17,6	0,139	0,002	0,27	0,25	2	0,596
	d	0,24	6,0	<0,05	317,2	2	0,09	0,116	0,13	29,4	1,72	1,74	<0,003	1,93	0,71	2,3	6,6	5,9	0,185	0,12	5,9	4,3	<0,05	2,34	55	0,63	<2	16,9	0,123	<0,002	0,16	0,07	2	0,299
	e	0,25	6,4	<0,05	543,2	<2	0,09	0,111	0,15	29,6	2,57	2,51	<0,003	1,98	0,71	2,3	7,3	5,5	0,236	0,08	4,4	5,3	<0,05	3,27	57	0,64	<2	17,6	0,120	<0,002	0,20	<0,05	2	0,436
Wartości wskaźników jakości wód powierzchniowych i pitnych; surface water and drinking water quality guidelines																																		
I klasa 1) Class I		≤0,36	7,5–8,2	≤5	≤400	≤50	≤2	≤0,5	≤0,8	≤68,3	0,5	≤50	≤0,05	≤50	0,1			≤5,0		≤40		10	≤0,18	10	≤31,6	≤2	≤20			≤0,05	≤2		≤50	≤1
II klasa 1) Class II		≤0,45	7,3–8,2							≤76,2	1				0,3			≤7,8				20	≤0,22	10	≤37,7									
Naturalne wody mineralne 2) Natural Mineral Water						10		1			3		0,05						500			20		10		5	10							
Wody pitne 3) Drinking Water		2,5	≥6,5–9,5≤		200	10	1				5		0,05						50		200	20		10	250	5	10							

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

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

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

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

RESULTS

SOILS

Diversity of the granulometric and chemical compositions of soils from the study area is mainly due to the influence of the different lithological and chemical characteristics of their parent rocks (Carboniferous, Triassic, Neogene and Quaternary deposits) (Pl. 1). Pseudo-podzolic and podzolic soils occur over most of the map sheet area. Brown soils are developed mainly in the lower parts of the hills composed of Triassic rocks (in the southwestern part of the map sheet and near Miasteczko Śląskie). In the top parts of the Triassic hills (near Żyglin, Świerklaniec, Nakło and Orzech), rendzinas have developed on carbonate bedrock. Black earths, mud-peaty soils, and alluvial soils occur locally (Program..., 2017; Studium..., 2019, 2020).

Most of the soils in the study area are exposed to deposition of dusts and gases from industrial plants. In the northern part, these are metal-bearing dusts. In the past, their huge amounts were emitted from the HCM in Miasteczko Śląskie. In the west, these were emissions from the ZCH Tarnowskie Góry and from waste dumps of this plant, while in the south – dusts and gases from power plants and steelworks in Bytom and Piekary Śląskie (Studium..., 2019).

Agriculture has also significantly affected the changes in the soil environment by the use of chemical pesticides and artificial fertilizers. Important sources of anthropogenic pollution are also emissions from vehicles and municipal wastewater discharged into the soils of river valleys (Program..., 2017; Studium..., 2019). The metal ores mining and metallurgy cause especially significant changes in the soil chemistry, and the greatest threats include the impact of waste from this activity (Navarro *et al*., 2006; Acosta *et al*., 2011).

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

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

Grain-size composition of the studied soils is clearly related to the lithology of their parent rocks. The whole area is dominated by soils rich in the sand fraction (>60%), which developed mainly from Quaternary glaciofluvial sands and gravels. The most sandy soils and the least abundant in the clay and silt fractions (often <10%) are covered mostly with forests.

The soils that developed from Triassic carbonate deposits and alluvial muds of river valley are characterized by the clay fraction content >20%. This fraction, consisting mainly of clay minerals and secondary oxide minerals, highly enables the retention of both plant nutrients and toxic elements, and reduces their mobility under hypergenic conditions, as compared to sandy soils.

Acidity. The pH of soils depends on the chemical composition of bedrock, land use, and anthropogenic factors.

In the topsoil (0.0–0.3 m), a very acidic (pH <5) or acidic (pH <6.3) pH was recorded mainly in the soils of forests, which are rich in organic substances. The soils of arable fields are neutral. Small areas of alkaline soils are found on Triassic carbonate outcrops and in urbanized areas.

At a depth of 0.8–1.0 m (subsoil), neutral and alkaline soils prevail. Their greater spread indicates that the pH depends primarily on the bedrock chemistry (Triassic carbonates). Soil alkalization in urban and industrial areas is partly related to the fallout of dust emitted from industrial plants and home furnaces as well as weathering of construction and road materials made of cement.

Geochemistry. The distribution of contents of main and trace chemical elements in the studied soils is dependent on both the chemical composition of bedrock and anthropogenic factors.

The contents of silver, cobalt, chromium, iron, magnesium, manganese, nickel, phosphorus and vanadium in the topsoil (expressed by the values of their medians) are lower or close to the geochemical background level of these elements in the Silesian-Cracow region (Tab. 2). The contents of arsenic, copper, zinc and strontium are slightly higher. The contents of cadmium, sulfur and titanium are twice as high as the regional background level; in the case of lead, it is more than three times, and in the case of barium – more than four times. In contrast, the depletion in calcium is threefold, which is associated with the predominance of sandy soils that contain small amounts of its compounds.

Both the topsoil and subsoil, which developed on the Triassic deposits, are distinguished by an increased content of aluminum (>0.40%), compared to the soils that formed on glaciofluvial sands and gravels. The acidic pH of soils facilitates its leaching and accumulation in waters (Migaszewski, Gałuszka, 2016), which is especially well marked in the watercourses of the northern part of the map sheet area (Pl. 12).

The content of organic carbon (<3%) is characteristic of topsoil developed on carbonate rocks. Its naturally elevated contents (6–24%) are found in soils of river valley wetlands, filled with alluvial muds and peats. The content of this component in soils is clearly influenced by their use. The median content of organic carbon in forest soils is 3.05%. In arable field soils, it is only 1.44%.

In most of the studied soils, the sulfur content in both depth intervals ranges usually from <0.003 to 0.080%. The sulfur-rich soils (0.160%) are also rich in organic carbon, which indicates that organic matter is a natural, common source of these components.

The phosphorus content in the soils depends on both the chemical composition of parent rocks and the land use. The basic, natural source of phosphorus is bedrock and its phosphorus minerals (Sapek, 2014). In the map sheet area, the phosphorus content is higher in topsoil than in subsoil (median values are 0.027% and 0.006%, respectively). The soils from both depth intervals, which developed from carbonate rocks, are richer in phosphorus than those developed on sandy deposits (>0.030% and <0.030%, respectively). In the topsoil, the highest phosphorus content (>0.120%) is found in some arable fields and allotment gardens, and in the Brynica River valley. The probable sources of phosphorus in these areas are fertilizers and wastewater discharges.

In the western part of the map sheet area, the topsoil is heavily polluted with barium (>480 mg/kg) (Pl. 16). Its maximum concentration (9,051 mg/kg) was recorded in a forest area east of Lasowice. The pollution by barium is probably related to the dispersion of waste from the ZCH Tarnowskie Góry, where its compounds were produced for several decades (Zakłady…). In the subsoil, anomalous barium contents are found locally over much smaller areas at the western boundary of the map sheet, where they commonly do not exceed 120 mg/kg (Pl. 17).

Soils from both depth intervals, which formed on Triassic carbonates, show increased levels of calcium (>1.00%), magnesium (>0.50%), strontium (>40 mg/kg), manganese (>400 mg/kg) and iron (>1.00%). In areas with high contents of iron and manganese, there are also higher levels of cobalt, nickel, chromium and vanadium. These are the areas of historical mining of limestones and dolomites. In urban areas, the enrichment of soils in calcium may also be due to the emissions of dust from coal combustion. The strongest strontium anomalies (>320 mg/kg) in topsoil in the Lasowice area, mainly near the ZCH Tarnowskie Góry waste landfill, are associated with the dispersion into the environment its compounds, which were used as reagents in production processes.

Anomalous contents of arsenic (>160 mg/kg), cadmium (>8.0 mg/kg), lead (>250 mg/kg) and zinc (>1,000 mg/kg) were recorded in both the topsoil and subsoil at the northern boundary of the map sheet area, adjacent to the HCM in Miasteczko Śląskie, as well as in the topsoil in the valley of the Dopływ spod Żyglinka Stream. They are related to both the historical mining of Zn-Pb ores and the modern emissions from the HCM. The topsoil's highest concentrations (lead 8,342 mg/kg, zinc 16,346 mg/kg, cadmium 266.8 mg/kg, and arsenic 1,628 mg/kg) were recorded near the zinc smelter. Local anomalies of these elements in the southwestern and eastern parts of the map sheet area are probably related to the mining of Zn-Pb ores (Piekary Rudne, Radzionków, Orzech, Nakło Śląskie, Świerklaniec, Niezdara).

In the topsoil the mercury content is commonly <0.20 mg/kg, while in the subsoil, the concentration is close to the geochemical background level in the Silesian-Cracow region (<0.10 mg/kg). Some soils of wetlands and peat soils of the valleys of the Brynica River and other watercourses show slightly increased concentrations in the topsoil layer (0.20–0.40 mg/kg). The highest mercury concentration (1.77 mg/kg) was recorded near the HCM in Miasteczko Śląskie. Despite its high volatility, mercury is easily absorbed by organic matter and clay minerals, which leads to its accumulation in topsoil, but its migration from soils is significantly limited. Mercury sorption increases in acidic soils, and it is most easily bonded at pH 3–5 (Kabata-Pendias, Pendias, 1999; Wikarek-Paluch, Rosik-Dulewska, 2020). The increased mercury content may be due to the precipitation of atmospheric dust from fuel combustion (Bojakowska, Sokołowska, 2001; Hławiczka, 2008).

The widespread occurrence of arsenic, cadmium, lead and zinc compounds in soils from which they can penetrate into waters is the cause of many human diseases in various countries across the world (Kabata-Pendias, Mukherjee, 2007; Kabata-Pendias, Szteke, 2015; Migaszewski, Gałuszka, 2016). Due to their ease of accumulation and the harmful effects of their excess on plants and soil microorganisms, and consequently on human health, the percentage of the sheet area polluted with these metals to different extents has been estimated (Tab. 6). There are few soils polluted with arsenic in the study area. Its harmful concentration (>100 mg/kg) refers to 0.87% of topsoil and 0.75% of subsoil. Soils polluted by cadmium, lead and zinc occur only locally. In the topsoil 1.75% of soils contain >15 mg/kg of cadmium, 8.12% of soils contain >600 mg/kg of lead, and 1.91% of soils contain >2,000 mg/kg of zinc. At a depth of 0.8–1.0, the percentage of soils polluted with these metals decreases to 0.84% for cadmium, 2.44% for lead, and 1.43% for zinc.

For topsoil, the assessment of the degree of toxic elements was carried out by classifying them into use groups I–III and IV based on permissible contents (Rozporządzenie.., 2016). Considering the contents of arsenic, barium, chromium, zinc, cadmium, cobalt, copper, nickel, lead and mercury, from 90.05% to 100% of the analyzed soils have been classified into groups I–III (meeting the conditions of multifunctional use –residential buildings, arable lands and forests). Group IV (soils that can be used only for industrial purposes) accounts for 0.08% to 5.81% of soils, while 0.08% to 8.12% represent soils with oversized elements content (Tab. 7). In many cases, the current land use is inappropriate and requires monitoring and reclamation. An example of soil classification (in a cartographic form) indicating their proper use (in accordance with Rozporządzenie.., 2016) is presented on the map of the distribution of cadmium content (Pl. 63). About 1.75% of the map sheet area is covered with soils containing >15 mg/kg of cadmium, which can be considered toxic.

SEDIMENTS

Bottom sediments of inland watercourses and stagnant water bodies are an important element of aquatic ecosystems, actively participating in the geochemical cycle of elements and organic matter (Jabłońska-Czapla, Grygoyć, 2020). They are formed as a result of sedimentation of mineral and organic suspensions that come from surface runoff and components precipitating from water. The chemical composition of the sediments is constrained by many natural and anthropogenic factors. It depends predominantly on the bedrock lithology, geomorphology, and climatic conditions, as well as on the way of management and land use of the catchment area (Bojakowska, Gliwicz, 2003; Smal *et al*., 2015; Tytła, Kostecki, 2019).

In industrial, urbanized and agricultural areas, elements and their compounds are transported to surface waters and sediments by discharges of municipal and industrial wastewater, surface runoff from farmlands, transportation routes, and urban areas, and in dust from fuel combustion and transportation means (Siebielec *et al*., 2015). In the areas of mining and processing of metal ores, a large part of their loads, released into the environment as a result of industrial processes and due to infiltration and leaching from old mining and metallurgical waste dumps, is retained in alluvial sediments (Bojakowska, Sokołowska, 1998).

In the map sheet area, the investigations focused on sediments of watercourses and reservoirs in the drainage basins of the Brynica River and Potok spod Nakła, Rów Świerklaniecki and Pniowiec Streams; the areas of the catchments are schematically shown in Fig. 3. The ranges and statistical parameters of the contents of the analyzed elements in the individual drainage basins are summarized in Table 4.

Tabela 6
Table

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

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

Pierwiastek Element	Zawartość Content mg/kg	Powierzchniowa warstwa gleb Topsoil 0,0–0,3 m		Podglebie Subsoil 0,8–1,0 m	
		Obszar/Area		Obszar/Area	
		km²	%	km²	%
As	<10	57,87	70,14	72,71	88,13
	10–25	19,64	23,80	6,04	7,32
	25–50	2,95	3,58	2,36	2,86
	50–100	1,31	1,59	0,76	0,93
	>100	0,72	0,87	0,62	0,75
Cd	<2	33,89	41,08	74,30	90,06
	2–5	33,17	40,21	5,28	6,39
	5–10	9,98	12,10	1,80	2,19
	10–15	4,01	4,85	0,42	0,50
	>15	1,44	1,75	0,69	0,84
Pb	<100	25,09	30,41	72,78	88,21
	100–200	29,49	35,75	3,89	4,71
	200–500	19,70	23,88	3,54	4,29
	500–600	1,51	1,83	0,28	0,33
	>600	6,70	8,12	2,01	2,44
Zn	<300	58,52	70,94	74,65	90,49
	300–500	10,57	12,82	2,22	2,69
	500–1000	8,27	10,03	2,57	3,11
	1000–2000	3,55	4,30	1,87	2,27
	>2000	1,58	1,91	1,18	1,43

Brynica River and its catchment. The drainage basin area is covered with glaciofluvial sands and gravels, underlain by Triassic carbonates. In its northern part (located outside the map sheet area), the water relations are close to natural (Czaja, 1988; Jastrząb, Mrozowski, 1997). The quality status of the river sediments is influenced mainly by components of artificial fertilizers and pesticides, as well as by leachate from roads and sewage from small settlements and villages (Studium..., 2019). The sediments of its tributaries are affected by the historical mining of Zn-Pb and limonite ores and by industrial dust emissions from the HCM in Miasteczko Śląskie.

Outside the map area (and in a small sector within it - from the eastern boundary to the Kozłowa Góra Reservoir), the Brynica River flows across a marshy valley in a natural riverbed. In this river course, the content of the analyzed elements in sediments is similar or slightly higher than the geochemical background level in the sediments of the Silesian-Cracow region (Tab. 4). In this area of the catchment, significant pollution of organic sediments was found in a small water body at Niezdara and in a minor watercourse near the village of Ossy, where Zn-Pb ores were mined. The remains from this economic activity are a source of arsenic (151 mg/kg), cadmium (100.4 mg/kg), copper (99 mg/kg), iron (11.81%), nickel (54 mg/kg), phosphorus (0.437%), lead (224 mg/kg) and zinc (1,470 mg/kg) in the Niezdara area. In the analyzed sediments of the watercourse near the village of Ossy, the concentrations are as follows: silver 11 mg/kg, arsenic 1,072 mg/kg, cadmium 168.1 mg/kg, lead 7,417 mg/kg, and zinc 33,260 mg/kg. They are also rich in calcium (13.06%), iron (7.63%) and sulfur (4.270%)

Because of both the significant metal pollution of sediments in the area of historical mining of Zn-Pb and iron ores, and the impact of the HCM due to the discharge of its wastewater and metal-bearing dust emissions, a catchment of the Dopływ spod Żyglinka Stream has been separated in the northern part of the Brynica River drainage basin. This stream, along with the system of mid-forest ditches, drains this area. Alluvial sediments of the stream and its tributaries are polluted with silver (up to 4 mg/kg), arsenic (up to 204 mg/kg), cadmium (up to 122.9 mg/kg), copper (up to 131 mg/kg), lead (up to 3,066 mg/kg) and zinc (up to 4,268 mg/kg). The sources of metals and arsenic are the surface runoff from the sites of historical mining of Zn-Pb ores and limonites extracted in the watercourse catchment area, as well as emissions from the HCM. In the forests between Miasteczko Śląskie and the Bibiela, the ores were mined to a depth of 60 m in the Szczęście Flory and Bibiela mines in 1889–1917 (Bibiela; Nowak, 1927). The mines were flooded as a result of a sudden inflow of water to the workings and have not been relaunched, despite the attempts to drain it. Since 1961 to the present day, the area of the Dopływ spod Żyglinka Stream drainage basin is also polluted by dust and slags emitted from the HCM technological processes. Apart from basic metals (zinc, lead), they contain a number of accompanying elements, including cadmium, arsenic and thallium (Nowińska, Adamczyk, 2013), which is reflected in the composition of the analyzed sediments and waters. Sediments of the stream's upper course contain phosphorus (up to 0.378%) that is probably associated with the discharge of municipal sewage from the village of Imielów. Most of the sediments of its drainage basin area show an increased mercury concentration (0.40–1.06 mg/kg). It is difficult to define clearly its origin, but it is presumably related to the fall of dust generated during the combustion of fossil fuels (Bojakowska, Sokołowska, 2001; Hławiczka, 2008)

The Kozłowa Góra Reservoir, located in the middle course of the Brynica River, is the boundary between drainage basin close to natural in nature and transformed. It is closed by a concrete dam from the south, whereas from the west and partly from the northwest, it is surrounded by an earth-concrete embankment that is connected with the front dam. Along the embankment, there is a ditch collecting leaks from the reservoir and the water of short watercourses flowing from the west. In the northern part, there is the Brynica River estuary with extensive reedbeds. From the east, the shore of the reservoir is natural, flat, and covered with reeds and wet meadows (Rzętała, 2008; Studium..., 2019; Machowski, Rzętała, 2020).

The levels of the analyzed elements in most of the sediments collected from the banks of the reservoir are close to or lower than the regional geochemical background level (Tab. 4). Pollution with metals and sulfur was found only downstream of the mouth of the Potok spod Nakła Stream that flows here through a wide, marshy valley filled with peat. The highest concentration of lead (509 mg/kg), cadmium (14.4 mg/kg), copper (54 mg/kg), zinc (823 mg/kg) and sulfur (0.584%) were found

Tabela 7
Table

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

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

Pierwiastek mg/kg	Wartości dopuszczalne stężeń w glebie (Rozporządzenie Ministra Środowiska z dnia 1 września 2016 r.) Permissible limit values in soil (Decree of the Polish Ministry of the Environment of 1th September 2016)			Liczba próbek /udział procentowy próbek w zależności od stopnia zanieczyszczenia Number of samples/percentage of samples according to the pollution degree		
	Grupa I–III Group I–III	Grupa IV Group IV	A	Grupa I–III Group I–III	Grupa IV Group IV	A
As	<50	50–100	>100	1225 97,53%	20 1,59%	11 0,88%
Ba	<1000	1000–1500	>1500	1159 92,28%	73 5,81%	24 1,91%
Cr	<500	500–1000	>1000	1256 100%	–	–
Zn	<1000	1000–2000	>2000	1178 93,79%	54 4,30%	24 1,91%
Cd	<10	10–15	>15	1173 93,39%	61 4,86%	22 1,75%
Co	<100	100–200	>200	1256 100%	–	–
Cu	<300	300–600	>600	1254 99,84%	1 0,08%	1 0,08%
Ni	<300	300–500	>500	1256 100%	–	–
Pb	<500	500–600	>600	1131 90,05%	23 1,83%	102 8,12%
Hg	<10	10–30	>30	1256 100%	–	–

Grupy I–III – obszary zabudowy mieszkaniowej, użytków rolnych i lasów
Group I–III agricultural, forest and residential areas
Grupa IV – obszary przemysłowe
Group IV industrial areas
A – obszary o zawartości ponadnormatywnej
areas with oversized content

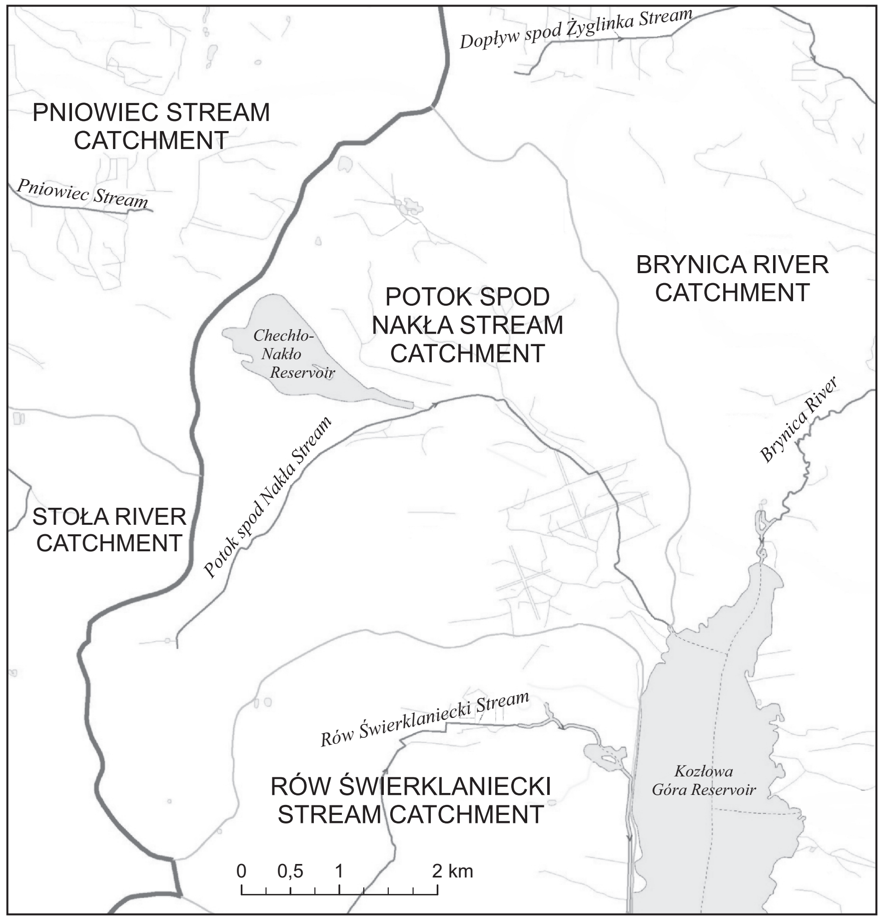


Fig. 3. Location of watercourses and stagnat water reservoirs and catchment areas (according to Mapa...)

in organic sludge. Heavy metals in the sediments of this part of the reservoir, derived from zinc-lead ore-bearing areas, may adversely affect the water quality.

Potok spod Nakła Stream and its catchment. The stream draining the central part of the map sheet area feeds the Kozłowa Góra Reservoir. In its upper reach, it is a drainage ditch, while in its lower reach, it flows through a wide valley and is fed by a dense network of tributaries draining forest and built-up areas (Studium..., 2019).

In alluvial sediments of the stream's drainage basin, the values of the medians of arsenic, cadmium and mercury are twice as high as the values of the regional geochemical background (Tab. 4). The enrichment is threefold in the case of barium and sulfur, and fivefold in the case of lead. As in the entire region, the content of zinc in the sediments of the stream and its catchment is high. The contents of calcium and magnesium are lower than the geochemical background values by half. The lower contents of these elements in the drainage basin sediments are due to the predominance of quartz in its glacial sand and gravel cover.

The high values of statistical parameters of metals, arsenic and sulfur in the drainage basin sediments are related mainly to their accumulation in the sediments of one of the unnamed tributaries of the Potok spod Nakła Stream, which rises in the marshy area in the vicinity of Gałczyński Street in Miasteczko Śląskie. Alluvial sediments of this watercourse and the nearby stagnant water bodies show the following maximum concentrations: silver 8 mg/kg, arsenic 133 mg/kg, cadmium 149.1 mg/kg, chromium 131 mg/kg, copper 195 mg/kg, lead 23,890 mg/kg, and zinc 6,059 mg/kg. Moreover, these sediments are rich in iron (frequent 8–10%) and manganese (2,400–3,800 mg/kg). The anomalies can be associated with the Zn-Pb and iron mining that was probably carried out in the stream valley, like near Żyglin (Degenhardt, 1870).

Sediments of some minor watercourses in the catchment, which drain alluvial muds in the valley, are characterized by the abundance of aluminum (frequent 1–2%), barium (300–500 mg/kg), and locally iron (2–5%) and vanadium (30–122 mg/kg). The drainage basin sediments of the Potok spod Nakła Stream (except in the Chechło-Nakło Reservoir) are polluted with mercury (0.15–0.40 mg/kg). Local accumulations of phosphorus (0.721%) were recorded in alluvial sediments of the unnamed watercourse flowing across the forest area, and in sediments of the Potok spod Nakła Stream (0.772%) near Nowe Chechło.

The Chechło-Nakło Reservoir is located on a complex of sandy glacial deposits in the catchment of the Potok spod Nakła Stream. It is recharged by ground water and atmospheric precipitation (Rzętała, 2008; Solarski *et al*., 2012). There are summerhouses, camping sites, hotels, restaurants, etc. around the reservoir. No impurities were found in sediments of the reservoir.

Rów Świerklaniecki Stream and its catchment. The stream flows around a hill composed of Triassic carbonates. It flows through the Świerklaniecki Park and the western edge of the Kozłowa Góra Reservoir, and then flows into the Brynica River. It drains the Świerklaniec area and the surrounding arable lands.

The contents of most elements in the drainage basin sediments are similar to their geochemical background levels. Clearly increased contents are recorded for sulfur and zinc (Tab. 4).

Increased contents of metals were recorded in sediments of stagnant water bodies near the sewage treatment plant at Wiosenna Street and in a large park in Świerklaniec. The maximum levels in these areas are as follows: silver 2 mg/kg, cadmium 24.5 mg/kg, chromium 47 mg/kg, copper 125 mg/kg, lead 774 mg/kg, and zinc 2,783 mg/kg.

In the stream passing by the Kozłowa Góra Reservoir, sludge-like sediments, rich in organic matter, contain arsenic (up to 143 mg/kg), iron (up to 21.06%), manganese (up to 7,626 mg/kg), phosphorus (up to 6.890%) and sulfur (up to 2.507%) supplied to the stream by local wastewater discharges. The organic matter of the sediments is a geochemical barrier for the components transported by small watercourses as well as surface and subsurface runoff.

Pniowiec Stream catchment. The northwestern part of the map sheet is located in the forested upper part of the Pniowiec Stream catchment area. The drainage basin area is covered with glaciofluvial sands and gravels underlain by Triassic deposits (including ore-bearing dolomites). The Zn-Pb ores were mined using the opencast method from the deposits in this area since the 16th century (Nowak, 1927; Filak, 2019) as evidenced by post-mining dumps in the Jasiowa Góra region in Miasteczko Śląskie. The erosion of the area of former shallow mining of Zn-Pb ores is the main source of sediment pollution in the drainage basin. The Zn-Pb ore mining resulted in local pollution of sediments of the Pniowiec Stream and its tributaries by silver (up to 11 mg/kg), arsenic (up to 218 mg/kg), cadmium (up to 32.7 mg/kg), lead (up to 1,551 mg/kg)) and zinc (up to 3,122 mg/kg).

An important usable element creating potential pollution hazard to the area is also wide railroad embankments of the Tarnowskie Góry-Miasteczko Śląskie railway junction. It is one of the largest marshalling yards in Europe, 8.5 km long. Increased concentrations of cobalt (54–68 mg/kg), copper (144–148 mg/kg) and mercury (0.24–0.53 mg/kg) are recorded in sediments of the watercourses draining railway areas, which can be associated with surface runoff from railway tracks (Wiłkomirski *et al*., 2011; Stojič *et al*., 2017).

Some sediments in the drainage basin are rich in elements of geogenic origin: aluminum (1.50–4.67%), barium (300–1,365 mg/kg), iron (9–15%), manganese (3,660–51,110 mg/kg) and vanadium (40–65 mg/kg).

Stoła River catchment. An unnamed watercourse in the Stoła River catchment drains the Lasowice residential area in Tarnowskie Góry. Metal pollution of sediments of this stream is probably related to the discharge of sewage from the nearby vehicle dismantling station at Cmentarna Street. Alluvial sediments of the watercourse contain up to 4 mg/kg of silver, up to 39.1 mg/kg of cadmium, up to 86 mg/kg of cobalt, up to 242 mg/kg of copper, up to 12.46% of iron, up to 68 mg/kg of nickel, up to 544 mg/kg lead, and up to 3,033 mg/kg zinc. In Lasowice, shallow mining of Zn-Pb ores was carried out as well; therefore, some of the pollutants may also be related to this source. The name of the Płuczki estate, where an iron smelter (Lasowice) also operated for a certain period, proves that ores were extracted and enriched in this area.

SURFACE WATER

The anthropogenic impact on water resources is of quantitative (change in water relations), qualitative (water pollution, changes in chemistry), and topographic (transformation of the shape of watercourse channels or water body basins) nature. As a consequence, adverse changes cause ecological effects, such as disturbance of habitat conditions, disappearance of certain species, and reduction in biodiversity (Bańkowska, Sikora, 2010). In the last century, significant changes in water quality were caused mainly by the increased surface runoff of chemical pollutants and nutrients from industrial, agricultural and horticultural areas, by leachate from landfills, and by wastewater discharges (Hajdukiewicz *et al*., 2013; Gromiec, 2014).

The study of surface water were performed to assess the content of selected chemical components and the values of electrolytic conductivity and pH. Table 5 presents the content ranges of individual elements and constituents, and of pH and EC of water in the study area, along with the results of their calculated statistical parameters. For the purpose of comparison, it also includes the values of surface water quality indicators used in Poland, assuming the values determined for small and medium-sized rivers on carbonate bedrock (Rozporządzenie..., 2019). Additionally, the values of indicators for mineral waters and drinking waters in accordance with the EU recommendations (EU Directive 1998/83/EC; EU Directive 2009/54/EC) are provided.

The pH value of water in the watercourses and water bodies in the map sheet area is unsatisfactory. The pH value of 90% of the waters was <7.5 (including part the Kozłowa Góra Reservoir water), which allows classifying them as substandard waters. However, mineralization of 60% of the waters, which is expressed by EC values, does not exceed 0.36 mS/cm. This value is assumed as the limit for class I waters (Rozporządzenie..., 2019). Substandard waters (EC≤0.45) cover 31% of all tested samples. They were found in the Rów Świerklaniecki Stream drainage basin and in the upper course of the Potok spod Nakła Stream (from the springs to Nowe Chechło).

Brynica River and its catchment. The Brynica waters contain excessive concentrations of barium (0.096–0.111 mg/dm^3), iron (0.20–0.72 mg/dm^3), magnesium (13.0–14.9 mg/dm^3) and sulfates (63–68 mg/dm^3).

In the lower part of the drainage basin area (southeastern margin of the map sheet), the waters of the watercourses in the valleys filled with Quaternary alluvial deposits contain aluminum concentrations that qualify them into substandard waters (600–2,160 µg/dm^3). They also contain beryllium (up to 0.63 µg/dm^3), cadmium (up to 25.84 µg/dm^3), cobalt (up to 19.48 µg/dm^3), iron (up to 0.61 mg/dm^3), sulfates (up to 89 mg/dm3), and locally also lead (up to 22.74 µg/dm^3) and zinc (up to 1.499 mg/dm^3).

In the waters of the Brynica tributary draining the Niezdara area, a very high phosphorus concentration (5.09 mg/dm^3) was found, presumably due to discharges of domestic sewage.

As in the case of alluvial sediments, it is necessary to separate a minor Dopływ spod Żyglinka Stream catchment within the Brynica River catchment due to the specific composition of the waters. They are polluted with arsenic (up to 21 µg/dm^3), cadmium (up to 29.87 µg/dm^3), lead (up to 242.77 µg/dm^3), thallium (up to 10.97 µg/dm^3) and zinc (up to 6.910 µg/dm^3). The water pollution is presumably related to the runoff from the areas of historical Zn-Pb mining and HCM emissions. The waters of the Dopływ spod Żyglinka Stream drainage basin are also rich in elements of lithogenic origin: aluminum (frequently in the range of 1,500–2,000; a maximum of 10,023 µg/dm^3), beryllium (up to 1.58 µg/dm^3), cobalt (up to 10.28 µg/dm^3) and iron (up to 3.98 mg/dm^3).

Kozłowa Góra Reservoir. The pH of the reservoir water is 6.2–7.8, and the EC is 0.21–0.59 mS/cm (Tab. 5). The contents of most of the analyzed elements do not exceed the guideline values, except for the concentration of sulfates (median >37.7 mg/dm^3), which qualifies the waters as substandard. In the southeastern part of the reservoir, increased concentrations of cobalt (up to 10.6 µg/dm^3), iron (up to 67.63 mg/dm^3) and manganese (up to 7.65 mg/dm^3) were recorded.

Potok spod Nakła Stream and its catchment. The electrolytic conductivity in the waters of the drainage basin of the stream is in the range of 0.06–0.97 mS/cm, and the pH is 4.5–8.3. Due to the concentration of sulfates (median 60 mg/dm^3), the waters are classified as substandard (Tab. 5).

The water composition differs between different parts of the drainage basin area. Enrichments with elements found in the chemical composition of bedrock are observed in the watercourse flowing from the outskirts of Miasteczko Śląskie and in the network of minor ditches in the lower part of the catchment. These waters are rich in aluminum (1,000–4,900 µg/dm^3), beryllium (0.30–1.70 µg/dm^3), cadmium (10–19 µg/dm^3), cobalt (5–12 µg/dm^3) and iron (0.40–3.00 mg/dm^3). They are locally enriched in lead (20–40 µg/dm^3), silica (20–30 mg/dm^3) and zinc (1–2 mg/dm^3).

In the upper course of the Potok spod Nakła Stream, there are increased concentrations of copper (2.20–4.62 µg/dm^3), phosphorus (2.29–4.53 mg/dm^3), sodium (31–67 mg/dm^3) and lead (6.41–11.91 µg/dm^3). The probable source of these elements is sewage discharges in the area of Główna Street in Nakło Śląskie (Hydroportal).

Chechło-Nakło Reservoir. The electrolytic conductivity of the reservoir waters varies within the range of 0.16–0.19 mS/cm, indicating a slight mineralization, while the pH ranges from 6.9 to 8.3. The concentration of analyzed constituents allows classifying the waters as meeting the standard for quality class I/II. The only element showing increased concentration is barium (0.546–0.782 mg/dm^3).

Rów Świerklaniecki Stream and its catchment. The pH values of the waters of the Rów Świerklaniecki and its drainage basin area range from 6.4 to 7.8, and their electrolytic conductivity varies between 0.24 and 1.39 mS/cm.

In the water of the watercourse flowing along Damrota Street in the Borki estate in Świerklaniec and in the samples from the moat surrounding the castle ruins in the Świerklaniec Park, an EC value of >1 mS/cm was recorded, associated with an increased content of sulphates (140–264 mg/dm^3), strontium (0.423–0.460 mg/dm^3), copper (3.47–4.37 µg/dm^3) and thallium (0.23–0.40 µg/dm^3). The probable source of these components are the sewage discharged from residential, service and industrial areas of Orzech and Świerklaniec.

As in the whole area, the waters of the catchment area are enriched in bar (0.060–0.208 mg/dm^3). They are rich in calcium (100.5–214.2 mg/dm^3) and magnesium (20.1–41.1 mg/dm^3), and locally they are contaminated by cadmium (up to 12.21 µgm^3), copper (up to 4.86 µg/dm^3), uranium (up to 6.98 µg/dm^3) and zinc (up to 0.990 mg/dm^3).

Pniowiec Stream catchment. The EC of the waters of the catchment area ranges from 0.08–1.09 mS/cm, and the pH varies from 4.4–7.3. Due to the concentration of sulphates (median 57 mg/dm^3) and aluminum (median 543.2 µg/dm^3), most of the waters of the catchment are outside the class.

The aluminum-rich waters show increased concentrations of constituents of lithogenic origin: beryllium (up to 1.88 µg/dm^3), cobalt (up to 18.15 µg/dm^3), iron (up to 21.38 mg/dm^3) and silica (up to 32.1 mg/dm^3).

Water pollution by cadmium (up to 31.51 µg/dm^3), lead (up to 103.90 µg/dm^3), thallium (up to 1.13 µg/dm^3) and zinc (up to 3.234 mg/dm^3) is probably associated with the erosion of historical waste heaps of Zn-Pb ore mining in this area.

Stoła River catchment. Increased concentrations of copper (up to 6.13 µg/dm^3), manganese (up to 0.887 mg/dm^3) and strontium (up to 0.296 mg/dm^3) were found in the waters of the unnamed watercourse flowing at the western boundary of the map sheet.

CONCLUSIONS

1. The geochemistry and grain-size distribution of the soils is determined by the chemical composition of their parent rocks. Soils that developed on Pleistocene sandy deposits rich in the sand fraction and poor in all studied elements are predominant throughout map sheet area. Soils rich in the silt and clay fractions and in aluminum, calcium, cobalt, chromium, iron, manganese, nickel, strontium and vanadium developed on the Triassic carbonates and Holocene alluvial muds of river valleys.

2. The distribution of most elements (cobalt, chromium, copper, iron, magnesium, manganese, nickel, phosphorus, strontium, titanium and vanadium) in the soils, which are sourced from the parent rocks, does not differ from the geochemical background level for the Silesian-Cracow region. There is about a twofold enrichment in cadmium, sulfur and titanium, more than threefold enrichment in lead, and over fourfold enrichment in barium. Threefold depletion in calcium is associated with the predominance of sandy soils, containing small amounts of its compounds.

3. The pH of the soils is related to both the lithology of the parent rocks and the land use. The topsoil is dominated by very acidic and acidic soils that developed from sandy deposits in the central and northern part of the map sheet area. The soils of urban and industrial areas are usually alkaline. The subsoil is dominated by neutral and alkaline soils grouped in the south.

4. Arsenic, cadmium, lead and zinc anomalies that occur in both the topsoil and subsoil in the north of the map sheet area are related to the historical mining of Zn-Pb and limonite ores and emissions from the zinc smelter in Miasteczko Śląskie.

5. The sources of silver, arsenic, cadmium, lead and zinc in the sediments of the watercourses in the northern part of the map sheet are the drainage of zinc-lead ore waste heaps and dispersed silver smelting sites, and surface runoff from soils polluted with these elements in the area of the Miasteczko Śląskie zinc smelter. The enrichment in iron and manganese is related mainly to their leaching from places of historical limonite extraction.

6. The barium and copper pollution of soils, sediments and waters is related to the impact of the waste landfill of the Zakłady Chemiczne (ZCH) (chemical plant) Tarnowskie Góry, which contains compounds of these elements.

7. The surface waters are characterized by high variability of pH and electrolytic conductivity. In the watercourses of the northern part of the map sheet area, there is local pollution by a group of elements that originate from surface runoff from the areas of metal ore mining and zinc smelting (arsenic, cadmium, manganese, lead, thallium and zinc). The water of the watercourses draining the landfill area of the Zakłady Chemiczne (ZCH) (chemical plant) Tarnowskie Góry is polluted by barium and copper, and the water of the watercourses in the south of the map sheet, receiving sewage from the treatment plant, are polluted by phosphorus and sulfates.

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