CONTENTS

INTRODUCTION

The 1:25,000 geochemical mapping in the Ornontowice map sheet M-34-62-B-c is a continuation of the detailed mapping project that commenced in 1996–1999 with the pilot map sheet of Sławków M-34-63-B-b of the Detailed Geochemical Map of Upper Silesia (Lis, Pasieczna, 1999). By 2016, 17 map sheets had been developed. The work was financed by the National Fund for Environmental Protection and Water Management.

The map sheet area is located in the central part of the Silesian Voivodeship. Its north-eastern portion (within the borders of Ruda Śląska city) belongs to the Upper Silesian Industrial Region, which is the most heavily industrialized and urbanized area of Poland. The central part of the map sheet is occupied by the town of Mikołów, and its western part by the communities of Gierałtowice and Ornontowice.

In the Upper Silesian Industrial Region the main factor affecting the changes in natural environment of the map sheet area is the present-day and historical mining of hard coal. The mining activity, developing most intensely since the 1970s, is responsible for the formation of geological-anthropogenic anomalies of a number of chemical elements in soils, sediments of inland water reservoirs, and surface water (Lis, Pasieczna, 1995a, b, 1997).

The results of geochemical studies, presented on the maps with a comprehensive explanatory text and data tables, show the current quality of soils, sediments and surface water. They were compared with the values of natural regional background and related to the legal regulations. The results can be useful in assessing local land use plans, making decisions concerning environmental constraints, giving water-legal permits, assessing groundwater hazards, and discharging duties imposed upon district governors by the Environmental Protection Law, i.e. conducting regular soil and land quality tests within the framework of state monitoring system.

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

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- **W. Ogrodowczyk** – geological map compilation.
- **A**. **Pasieczna, H. Tomassi-Morawiec –** interpretation of the results.

CHARACTERISTICS OF THE MAP AREA

Geographical and administrative setting. The study area belongs to the Katowice Upland which is the central area of the Silesian Upland (Kondracki, 2009).

In administrative terms the map sheet area is located in the central part of Silesian Voivodeship. It spans Halemba which is a south-western quarter of Ruda Śląska (town with the rights of district), northern part of the town of Mikołów, and eastern areas of the municipality of Ornontowice (in the Mikołów district) and of the municipality of Gierałtowice in the Gliwice district. A small part of the map sheet near its northern boundary belongs to the town and district of Zabrze, and near the southern boundary – to the town of Łaziska Górne in the Mikołów district.

Relief and geomorphology. Land surface of the study area generally descends north-westward. The lowest situated areas (230 m a.s.l.) occur in the Kłodnica River valley near the mouth of the Promna and Jasienica streams.

Basement rocks in this area are represented mainly by Carboniferous coal-bearing deposits and glacial sediments, which is reflected in the land relief. Gentle hills, composed of Carboniferous sandstones (Pl. 1), extend near the eastern boundary of the map sheet. They attain an elevation of 300 m a.s.l. In the south-eastern part of the study area the hills are more impressive and composed of Triassic limestones and marls. They are separated from each other by tectonic depressions filled with Miocene and Quaternary deposits.

Land relief in the north of the study area is transformed by human impact due to the activity of hard coal mines, and in the south as a result of extraction of limestones and sandstones. Drainless depressions, mining excavations and piles and heaps of mine and industrial waste (ash and slag) occur over large areas. Some of the piles have already been forested.

The Ornontowice map sheet area is situated within the left-hand side of the Odra River drainage basin. It is drained by the Kłodnica River and its left tributaries: the Jasienica, Promna and Żabnica streams. The network of watercourses is complemented by a well-developed system of drainage ditches (Program..., 2013). The Kłodnica River is embanked along the entire course analysed in this study (Nocoń *et al.*, 2006; Studium..., 2013).

The Promna Stream begins outside the map sheet area. Its valley in the lower reach along a 1 km long section is 500 m wide, and the channel is deeply incised by 1.0 to 1.5 m, displaced and engineered (Studium..., 2013).

The bottom of the Jasienica Stream valley (of the Chudowski Stream) is deeply incised (up to 10 m), and the width of the valley is 250–300 m. The Jasienica Stream is recharged by many minor tributaries, and the valley is filled with wetlands over much of its length.

The Żabnica Stream, draining the eastern area of the map sheet, conveys water to the Kłodnica River from the area covered mainly by forests, and from landfills of furnace waste of the former Halemba thermal power station (Studium..., 2014).

Stagnant water reservoirs are represented by post-mining lakes that developed as a result of land subsidence above mine excavations, by settling ponds, fire pools, ponds and many other features. The first ones are filled with surface water or recharged by the water from the near-surface aquifer (Pozzi *et al.*, 2008). These represent reservoirs that formed in drainless depressions, as well as flow-through lakes that developed in valleys where they can be drained naturally (Studium..., 2014). Fishing ponds are known from the Chudów and Paniów region.

Usable groundwater occurs in the Triassic carbonate-dolomitic rocks and Quaternary sandy sediments (Program..., 2013). The Quaternary aquifer is recharged by the percolation of atmospheric precipitation. In areas located at lower elevations (in river valleys and around post-mining lakes) this aquifer occurs at small depths (about 1–2 m). Its characteristics are variable depending on seasonality and atmospheric phenomena. Groundwater table variations are particularly significant in areas of post-mining subsidence, where post-mining lakes can form during wet springtime and snow-melting periods (Studium..., 2013). In the north-eastern part of the map sheet there is the MGR No 331 Fossil Valley of the Upper Kłodnica River (Kleczkowski, ed., 1990). It is a Quaternary confined reservoir with neither maximum protection (ONO) nor high protection (OWO) areas established (Nowicki ed., 2007).

Land use. The study area is dominated by unbuilt land (75%) mostly used for agricultural purposes or covered by forests (Pl. 2). Built-up urban areas account for 12%, while rural housing areas – 9%. Industrial facilities (coal mines, settling ponds, waste piles and mine heaps) occupy 3% of the territory. Other unbuilt areas include roadside green belts, water reservoirs, wetlands and railway and road facilities.

Single-family detached housing prevails in urban areas and along transportation routes. Multi-family residential housing dominate in the Halemba quarter of Ruda Śląska city. Transport bases and service and trade facilities are also located in urbanized areas.

Industrial facilities include mining infrastructure of the Halemba coal mine and the former power station in Ruda Śląska city, and of the Budryk mine together with the Zakład Produkcji Ciepła Żory thermal power station located in the south-western part of the map sheet.

In the Mokre quarter of Mikołów town there is a reclaimed landfill of non-hazardous and neutral waste, as well as reclaimed limestone and sand pits.

Economy. The basic natural resource which is essential for the economy of the study area is hard coal. Its deposits are extracted by the Sośnica-Makoszowy, Halemba-Wirek, Bielszowice and Budryk mines.

The Sośnica-Makoszowy coal mine was established in 2005 as a result of merger of the independent Sośnica and Makoszowy mines into a single mining unit. Shaft sinking in the Makoszowy mine took place in 1900, and the first coal was extracted in 1906. The Sośnica mine started its activity in 1917 (Kompania...).

The Bielszowice mine was built in 1896–1904. Its name and mining areas have changed many times. Currently, it conducts mining operations in Ruda Śląska city.

Near the north-eastern boundary of the map sheet there are mining fields of the Halemba-Wirek mine.

The Budryk mine is one of the youngest coal mines in Upper Silesia. Mine construction and development works were performed in 1978–1994 (Historia…, 2016).

Limestone extraction and lime burning were carried out on a small scale from the 16th century until the 1960–1980s, but more intensely in the 20th century. In the 1930s, four lime kilns of the Giesche Company were active near the Mikołów-Orzesze railway track. Some of them could become monumental objects, 10 others have been devastated. Unreclaimed quarries on Góra Fiołkowa mountain (340 m a.s.l.), some of them 20 m deep, have been overgrown spontaneously by vegetation, and they arouse interest of the Silesian Botanical Garden.

Apart from the mining and thermal power industries, there are also facilities of the renovation-construction and transport sectors in the map sheet area. Commercial and service activities develop widely as well.

GEOLOGY AND MINERAL DEPOSITS

The map sheet area is located within the northern limb of the Main Trough of the Upper Silesian Coal Basin (USCB). It is part of an extensive Palaeozoic Variscan structure cut by numerous faults. Locally, it is covered by horizontal strata of Triassic, Neogene and Quaternary deposits (Wyczółkowski, 1957; Buła, Kotas, ed., 1994). The geological structure of this region is very well explored owing to numerous boreholes and mining operations.

The top of **Carboniferous** deposits occurs at various depths. In the south-eastern and north-eastern parts of the map sheet area they are exposed on the surface or occur immediately under a thin Quaternary cover. In other areas they occur under the overburden of Pleistocene glacial tills and glacial and glaciofluvial sands and gravels. In the south-eastern part of the map sheet the Carboniferous succession is overlain by Triassic limestones, marls and dolomites. The maximum depth to the top of Carboniferous rocks is some 250–270 m.

The oldest known deposits in the study area are represented by the Upper Carboniferous Paralic Series (Namurian A). No outcrops of these rocks have been found on the surface. They are overlain by continental sediments – the Upper Silesian Sandstone Series (Namurian B and C), the Mudstone Series (Westphalian A and B), and, in the extreme southeast, also by the Kraków Sandstone Series (Westphalian B). The total thickness of the Carboniferous coal-bearing deposits in the map sheet area is 3,200 m (Jureczka *et al.*, 2005).

A characteristic feature of the Paralic Series is its sedimentary cyclicity. The coal seams are usually overlain by claystones passing into mudstones, overlain in turn by coarse-clastic sediments: fine- and medium- grained sandstones, occasionally coarse-grained. The sandstone again grade into mudstones and claystones which are overlain by the next coal seam. The entire series contains numerous coal seams and sediments with marine, brackish and freshwater fauna. The thickness of the Paralic Series is estimated at approx. 800 m (*op.cit.*) in the map sheet area.

The Upper Silesian Sandstone Series (Saddle Beds and Ruda Beds) is represented by grey fine- and medium-grained sandstones, locally coarse-grained sandstones and conglomerates (Wilanowski *et al.*, 2009). The interbeds of claystones and mudstones are commonly up to several metres in thickness. The characteristic feature is the relatively frequent occurrence of coal seams with a thickness of 5 m, locally more than 10 m. The Saddle Beds host the USCB's thickest coal seam 510 at their base, currently almost completely mined out. The thickness of the Upper Silesian Sandstone Series varies from about 400 m in Ruda Śląska to 600 m in Ornontowice in the south-western end of the map sheet. Deposits of this series form a belt of outcrops in the study area.

The Mudstone Series is represented by the Załęże Beds corresponding to the Westphalian A, and in the uppermost part also by the Orzesze Beds of the Lower Westphalian B. This series is very monotonous in terms of lithology with dominant mudstones and claystones. Fine- and medium-grained sandstone interbeds within this series locally attain several metres in thickness. The whole series typically shows the prevalence of aleuritic-pelitic sediments over coarse-clatic ones. It also includes a significant number of coal cyclothems, most of them containing a coal seam (Wilanowski *et al.*, 2009). Deposits of this series are exposed on the surface or occur under a cover of Quaternary sediments, up to a few metres thick in the south-eastern part of the map sheet, where they form a hill near Kolonia Huta, and in the extreme northeast in the Ruda Śląska region. The thickness of this series ranges from about 500 m in the north-eastern part of the map sheet area to around 1,800 m in the southwest.

Deposits of the Kraków Sandstone Series are represented by coarse- and variously grained sandstones and conglomerates, grading upward into medium-grained sandstones with mudstone and claystone interbeds and coal seams. In the map sheet area there is only the bottom part of this series (Łaziska Beds) attaining a thickness of approx. 15 m, which does not host thick coal seams.

The Lower and Middle **Triassic** deposits unconformably overlie Upper Carboniferous rocks in the central and eastern parts of the study area. The thickness of Triassic deposits is variable, commonly ranging between 40 and 80 m. The lithological section is represented by sands, sandstones, clays, claystones and mudstones of the Świerklaniec Beds (Lower Triassic – Buntsandstein), Röt dolomites, marls and limestones (uppermost Buntsandstein), and Middle Triassic limestones of the Gogolin Beds (Muschelkalk). The Triassic deposits are locally overlain by eluvial sands and loams, as well as by glacial tills, several metres in thickness, and, in the Kłodnica valley, also by Miocene sediments. Heavily dismembered outcrops predominantly of the Gogolin Beds compose most of the slopes and summits attaining about 310–330 m a.s.l. in elevation in the south-eastern part of the map sheet, in the Mikołów-Mokre region and near Śmiłowice. The hill slopes are locally composed of Lower Triassic sandstones, sands, clays, limestones, dolomites and marls.

Neogene. Much of the sub-Quaternary surface is covered by Miocene deposits. They occur in a NW-SE-trending belt, mainly in the Kłodnica Graben. These are Lower Miocene claystones, mudstones, marls, limestones and sandstones, and Middle Miocene clays, muds, claystones, limestones, marls, gypsum, anhydrites and local rock salts. The contact with the underlying Carboniferous and Triassic deposits is erosional. In the Kłodnica Graben the Miocene series attains a considerable thickness from about 180 m in the east to 210 m in the western area. Outside this structure the Miocene deposits fill depressions in the Triassic surface, but their thickness is small, up to several metres. The Miocene deposits do not crop out on the surface in the map sheet area.

Quaternary deposits cover about 80% of the map sheet area with a layer of highly variable thickness ranging from a few metres in upland areas to more than 100 m in the Kłodnica fossil valley. Outside the Kłodnica valley, in topographic depressions of sub-Quaternary surface, the thickness is 30–60 m. In addition to deposits of fossil valleys, the Quaternary cover is composed predominantly of glacial tills, glaciofluvial sands and gravels, and deluvial sands and loams (locally resting on Triassic and Carboniferous deposits). The Holocene is represented by fluvial and swamp deposits of modern river valleys. These are fine-grained sands grading upward into swamp muds. They attain a thickness of 3 m and fill depressions, oxbow lake basins and river channels.

Large areas are covered by anthropogenic grounds formed as a result of long-lasting hard coal mining operations. Clusters of mine heaps and settling tanks occupy considerable areas (up to 2 km^2) in the northern and north-eastern parts of the map sheet.

Mineral deposits. Nine multi-seam **hard coal** deposits have been documented throughout the map sheet area (Szuflicki *et al.*, ed., 2014) where there are parts of the Budryk, Halemba, Halemba II, Bolesław Śmiały, Makoszowy, Zabrze-Bielszowice, Łaziska, Chudów-Paniowy I and Śmiłowice coal deposits. The greatest economic resources of hard coal (835 million tonnes) have been proven in the Budryk deposit. The resources of the Bolesław Śmiały, Makoszowy, Zabrze-Bielszowice and Śmiłowice deposits are 400–520 million tonnes.

Hard coal resources of the Halemba II, Chudów-Paniowy I, Budryk and Śmiłowice have been documented to a depth of 1,250–1,300 m, and to a depth of 1,000 m in the remaining deposits. The coal-bearing series is represented by coal seams of the Orzesze Beds (group 300), Ruda Beds (group 400), Saddle Beds (group 500), in the north by the Poręba Beds (group 600), and in a small area in the southern part of the map sheet also by the Łaziska Beds (group 200). The coal types in this area include power coal (types 32–33) and coking coal (types 34–35, sporadically 37). Coking coal occurs generally in the lower portions of almost all deposits. The quality parameters of the coal are highly variable. Its calorific value varies from 17,715 to 35,000 kJ/kg, the ash content is in the range of 2–39%, and the sulphur content is from 0.08 to 3%. The best quality coal comes from the Saddle Beds. It contains the lowest amounts of ash (up to 10%) and sulphur (up to 1%), and its calorific value is 35,000 kJ/kg. Coal seams of these beds are characterised by a thickness attaining 10 m and a relatively small number of gangue intergrowths. Coal from the Ruda and Orzesze beds contains more sulphur and ash (from several to 40%).

In the study area, most of mining areas of coal mines are threatened by natural hazards by methane, dust, fire and collapse, which are of the highest risk rank and category.

Hard coal mining has a long history dating back to the 18th century in the study area. The Bolesław Śmiały mine is among the oldest mines in the USCB. It was formed by the successive merger of a number of small mines that operated using adits and shallow shafts. The beginnings of well-organized mining are dated to the year 1779. In the 19th century, several mines operated in this area. Since 1791, hard coal has been mined in the area of the present-day Zabrze-Bielszowice mine (formerly Królowa Luiza mine), combined in the 1970s with the Bielszowice mine that started coal extraction in the 19th century.

Currently, hard coal mining is carried out by the Halemba-Wirek, Bolesław Śmiały, Bielszowice, Makoszowy and Budryk mines on eight hard coal deposits. Extraction is carried out using the high-wall mining system, sporadically with the hydraulic filling. The hard coal output is variable – from 0.19 million tonnes from the Halemba II deposit to 2.89 million tonnes from the Budryk deposit.

The Śmiłowice deposit still remains undeveloped, and the Bolesław Śmiały deposit has been abandoned.

The hard coal deposits are accompanied by coal bed **methane** that occurs in a sorbed form, i.e. it is physicochemically bound to hard coal and dispersed coal particles, and its content in the coal increases with depth. Coalbed methane is considered the main or accompanying mineral deposit. As an accompanying mineral deposit, methane is documented down to a depth of 1,250–1,300 m. It is mined together with hard coal and partly used in the heating sector. The methane production is variable, ranging from 0.92 million m^3 from the Halemba II deposit to 12.75 million m^3 from the Zabrze-Bielszowice deposit, and 19.93 million m^3 from the Budryk deposit.

In the Ornontowice map sheet there are two small mineral deposits of **limestones** and **marls** in the area of Triassic carbonate outcrops. They are used for the purpose of lime industry. The limestones, marly limestones and marls occur at shallow depths (0.3–2.0 m) and attain a thickness of 20 m. They were quarried in this area already in the early 20th century, but the extraction was abandoned in the 1970s due to unsatisfied quality parameters of the limestones (too high contents of silica, and iron and magnesium oxides).

In the northern part of the map sheet there is a part of the Borowa Wieś **sand** deposit. Because of its parameters the aggregate (about 99% of the <2 mm grain-size fraction) was used for decades as a filling material in the nearby coal mines. Currently, much of the deposit area is occupied by a reclaimed and active landfill of the Zabrze-Bielszowice mine. This land use type entails the necessity of deleting the remaining resources of this deposit from the national registry of mineral deposits.

In the southern part of the map sheet a small sand and gravel deposit of Kręta has been documented in an area of 0.85 ha. Under a thin overburden the sand-gravel aggregate deposit attains a thickness of 10 m. Extraction of this mineral deposit has recently been finished.

HUMAN IMPACT

Natural environment in the study area has been undergoing transformation as a result of hard coal mining, leading to the contamination of the land surface, surface water and atmospheric air. The transformations affect predominantly the land relief due to continuous deformation in the form of sinkholes and depressions (water-logged areas). These relief changes are observed in the northern part of the map sheet, in areas of mining operations, especially in the Kłodnica River valley region. Terrain levelling and river channel restructuring were necessary in this area (using mine waste materials). In some regions, modification in the hydrographic network is observed.

Atmospheric air. The quality of atmospheric air is affected in the study area by low emission from individual household sources, linear emission from transportation sources, as well as emission from neighbouring areas and industrial sources (PONE, 2011; Program..., 2013). Industrial particulate matter and gas emissions originate predominantly from the Zakład Produkcji Ciepła Żory (thermal power station) of the Budryk mine.

Data of the National Environmental Monitoring shows that the permissible concentrations of benzene, carbon monoxide, nitrogen oxide, nitrogen dioxide, sulphur dioxide, lead, arsenic, cadmium and nickel in the air have not been exceeded. More hazardous are the concentrations of particulate matter PM10 and PM2.5 as well as benzo(a)pyrene (Trzynasta roczna ocena..., 2015). Their main sources are low emission from individual household heating in the winter season, and the transport sector due to all-year heavy road traffic (PONE, 2011; Program..., 2013).

Surface water and groundwater. The poor quality of water results predominantly from both unsustainable wastewater management and discharge of mine water rich in suspended solids, sulphates and chlorides (Studium..., 2013; Ocena..., 2014).

The Kłodnica River, as well as Jasienica and Promna streams carry water whose quality is estimated as poor (Ocena..., 2014) due to the poor quality of both biological and physico-chemical elements.

Water quality assessment was also made for drainage ditches in the municipality of Gierałtowice, classifying the water as poor quality due to exceeded permissible limit values of COD, DOC and phosphate concentration. Unsustainable wastewater management is the main factor posing a negative effect on the water quality (Program..., 2013).

The groundwater, degraded in both its quantity and quality due to mining operations, occurs in sandstones of the Carboniferous Mudstone Series. The groundwater polluted by municipal sewage and leachate from landfills and from levelled and developed land is found in Triassic carbonate-dolomite rocks and Quaternary sands (*op.cit.*).

Soils. Soils of the northern and north-eastern part of the map sheet have been altered by the current and historical hard coal mining. The result of these activities is terrain subsidence giving rise to water-logged drainless depressions which consequently become barren lands. Engineering of the substantial part of the Kłodnica River channel with the use of mine waste material can be the cause of soil contamination. The land adjacent to the Kłodnica

River embankments is at risk of contaminants washed out of the embankments (Program..., 2013; Studium..., 2013).

Agricultural soils are generally not contaminated. The contents of heavy metals in these soils do not exceed the permissible limits, which allow cultivating all food and non-food plants. Locally, they are acidized and water-logged (Studium..., 2013).

Soils of some regions are too acidic for cultivation. Among the reasons for their acidity is acid rain (pH <5.6) that accounts for 46% of all rains. Through the rainwater the soils are contaminated by sulphates (17.82 kg/ha SO_4^{-2}), total nitrogen (11.75 kg/ha N), chlorides (8.54 kg/ha Cl^-), ammonia (5.23 kg/ha N), nitrates and nitrites (3.15 kg/ha N) and heavy metals, including cadmium (0.00195 kg/ha), total chromium (0.0023 kg/ha), nickel (0.0049 kg/ha), lead (0.0348 kg/ha), copper (0.0531 kg/ha) and zinc (0.442 kg/ha) (Liana *et al*., 2015). Acid-forming sulphur and nitrogen compounds, biogenic compounds and heavy metals affect negatively the functioning of aqueous and terrestrial ecosystems, changes in trophic conditions of soils and waters, and plant production.

Heaps. The gangue separated from coal by mechanical processing, as well as industrial waste and tailings are partly used in coal mines as additives to the hydraulic filling. The remaining portion is stored on heaps and piles on the land surface.

In the north of the map sheet there are three old mine heaps of the Zabrze-Bielszowice mine. A heap located in the north-western part of the map sheet is currently under reclamation, and a smaller one (on the northern bank of the Kłodnica River) has already been reclaimed. Between the Promna Stream and Kłodnica River valleys there is the largest reclaimed landfill of mine waste of the Bielszowice mine.

In the Żabnica Stream valley (southeast of the inactive Halemba thermal power station) there are four storage sites/settling ponds of its furnace waste (currently under reclamation).

In the area of Mikołów-Mokre there is a municipal waste pile located in a quarry where carbonates were mined.

MATERIALS AND METHODS

Research conducted in the years 2013–2016 included a study of published and archival materials, location of soil sampling sites on 1:10,000 topographic maps, sample collection, and measurements of geographic coordinates at sampling sites, chemical analysis of samples, development of field and laboratory databases, development of vector topographical base map, statistical calculations, compilation of geological map and construction of geochemical maps, and interpretation of study results. The sequence of workflow steps is illustrated in the attached diagram (Fig. 1).

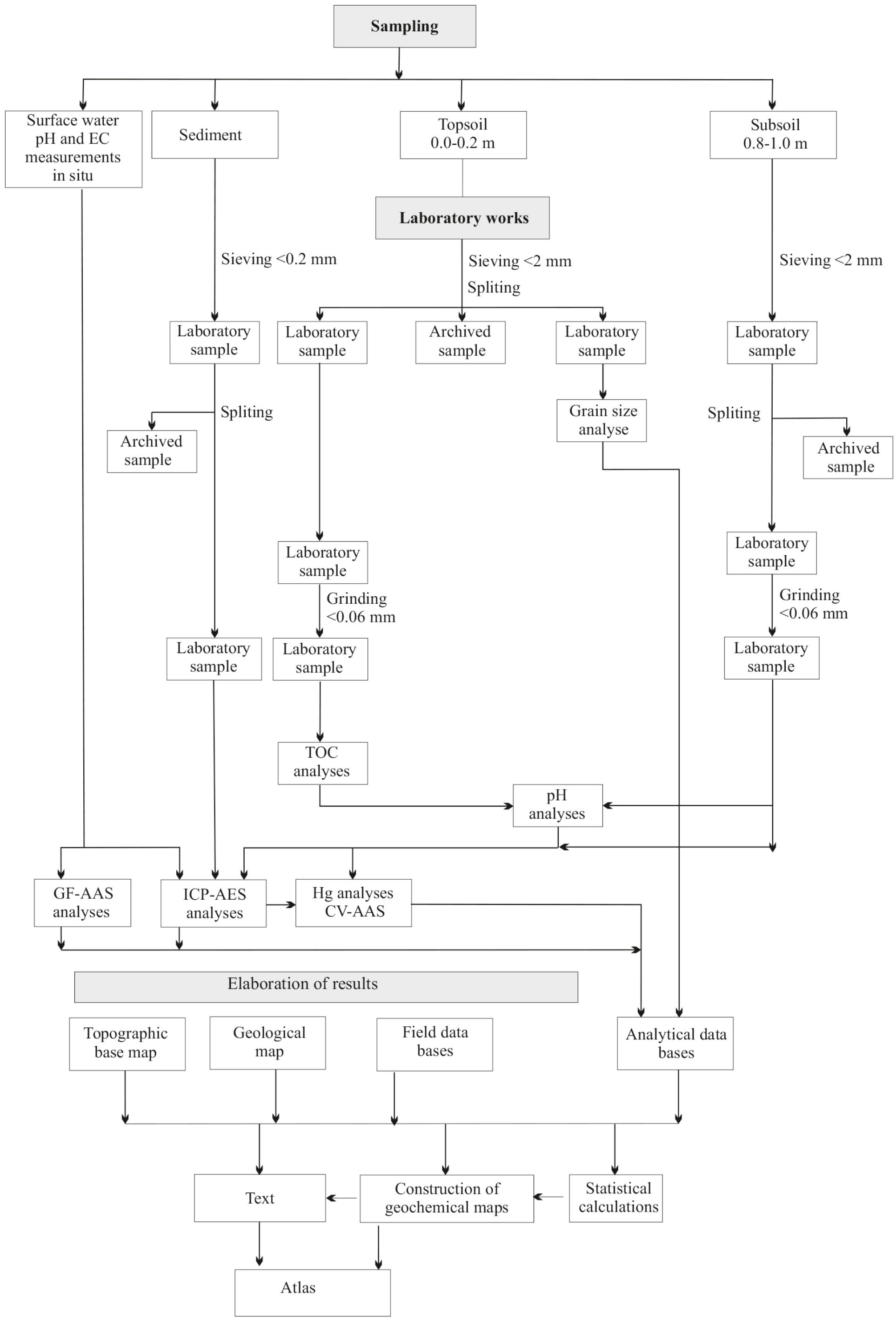

Fig. 1. The study procedure

FIELD WORKS

Soil samples were collected on a basis of a regular grid of 250x250 m (16 samples per km^2). The total number of soil sampling sites was 1,368. At every site, the samples were collected from two depths of 0.0–0.3 and 0.8–1.0 m (or from a smaller depth if the parent rock was found at a shallower depth). Soil samples (ca. 500 g) were collected using a 60-mm hand probe, put in linen bags labelled with numbers, and pre-dried on wooden pallets at a field storage site.

Samples of sediments in inland reservoirs and surface water (541 and 488 samples respectively) were collected from rivers, streams, melioration ditches, canals and ponds. The distance between sampling sites along watercourses was about 250 m. Sediment samples weighing about 500 g (as fine-grained as possible) were taken from the water reservoir shores using a scoop. They were subsequently placed in 500-ml plastic containers, each labelled with a number.

Surface water samples were collected from the same sites as sediment samples. Electrolytic conductivity (EC) and acidity (pH) of water were measured on site. Conductivity was measured using an conductivity meter with automated temperature compensation, assuming the reference temperature of 25°C. Water samples were filtered in situ using 0.45-µm Millipore filters and acidized with nitric acid in 30-ml bottles. The bottles were also labelled with numbers.

All the sampling sites were indicated in topographic maps at a scale of 1:10,000 and numbered.

Locations of the sampling sites were defined with GPS, using a device equipped with an external antenna and a computer which can record not only coordinates but also additional information (pH and EC of water samples, data on land development and land use as well as on lithologies). The geographic coordinates were taken with an accuracy of ±2 – 10 m.

The coordinates of soil sampling sites were put into the memory of the GPS equipment, before going out in the field, and the sites were subsequently found using the satellite positioning system. For safety reasons, all the field data were also recorded on special sampling cards (Fig. 2).

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

Type of soil

	Sample 1	Sample 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 as surface water (B)

LABORATORY WORKS

Sample preparation. After transferring to the laboratory, the soil samples were air-dried and sieved through a 2-mm nylon sieve. After sieving and quartering, each topsoil sample (from a depth of 0.0–0.3 m) was split into three portions: one of them was submitted for chemical analysis, the second one was analysed for grain-size, and the third one was archived. Each subsoil sample (from a depth of 0.8–1.0 m) was sieved and quartered and then split into two portions: one of them was submitted for chemical analysis, and the other one was archived (Fig. 1). The soil samples for chemical analyses were pulverized in agate planetary ball mills to a grain size <0.06 mm.

Sediment samples were air-dried and then sieved through a 2-mm nylon sieve to a grain size <0.2 mm. After quartering, the <0.2 mm fraction was divided into two portions: one of them was used for chemical analysis, and the other one was archived (Fig. 1).

All the archived samples are stored at the Polish Geological Institute – National Research Institute (PGI-NRI) in Warsaw.

Chemical analyses. Soil and sediment samples were *aqua regia*-digested (1 g of sample to final volume of 50 ml) for 1 hour at the temperature of 95°C in a thermostat aluminium block.

The contents of Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Ni, P, Pb, S, Sr, Ti, V and Zn in soils and sediments were determined by the inductively coupled plasma-atomic emission spectrometry (ICP-AES) method. Determination of Hg in soil and sediment samples was performed using the cold vapour-atomic absorption (CV-AAS) method with the FIAS-100 with flow injection system. Soil pH was measured in water extractions using a pH-meter. Organic carbon content was measured using the coulometric method (with the detection limit 0.16%), high-temperature combustion and detection with thermal conductivity TCD, and high-temperature combustion with infrared spectrometric detection (with the detection limit 0.01–0.02%).

The contents of B, Ba, Ca, Cr, Fe, K, Mg, Mn, Na, P, SiO_2, SO_4, Sr, Ti and Zn in surface waters were determined by the ICP-AES method, and the contents of Ag, Al, As, Be, Cd, Co, Cu, Li, Mo, Ni, Pb, Sb, Se, Tl, U and V were analysed using the ICP-MS method.

The applied analytical methods and the detection limits of chemical elements are shown in Table 1.

The quality control of the determinations was performed through analysis of duplicate samples (5% of all samples), analysis of reference materials with certified content of elements studied (2% of all samples), and analysis of laboratory control samples confirming correct instrument calibration (5% of all samples). Purity of reagents and vessels was controlled with "reagent blank samples" and "procedural blank samples". The expanded uncertainty of results (with the assumed probability level of 95% and coverage factor k = 2) for water, soil and sediment samples does not exceed 25%.

Grain-size analysis of topsoil samples (0.0–0.3 m) was carried out at the PGI-NRI Laboratory in Warsaw, combining the sieve analysis with the laser particle size measurement method. The grain-size analysis was conducted using unconventional methods (not in accordance with the relevant standards in soil science). Their results cannot therefore be used to classify the soils according to the soil science criteria. However, they are very helpful when interpreting the results of geochemical research.

The samples were sieved through a set of 2 mm, 1 mm and 0.5 mm sieves. Samples of some loamy soils were crumbled in a porcelain mortar before sieving. The obtained fractions of 2–1 mm, 1.0–0.5 mm and <0.5 mm were weighted. Measurements of grains from the <0.5-mm fraction were performed with use of a laser particle size analyser.

The results of grain-size analyses (recalculated to percentage ranges) are presented in the maps with respect to the following grain size classes: sand fraction 1.0–0.1 mm, silt fraction 0.1–0.02 mm, and clay fraction <0.02 mm (Pls. 4–6).

DATABASES AND GEOCHEMICAL MAPS CONSTRUCTION

Base topographic map. The 1:25,000 geochemical maps were constructed based on 1:50,000-scale topographic base map in the *1992* coordinate systems, Zabrze M-34-62-B map sheet (vector map VMap L2). The topographic map contains the following vector information layers: relief, hydrography (including categorisation into rivers, streams, ditches and stagnant water reservoirs), road communication network (with road classes indicated), railway network, land development (including subdivision into rural, urban and industrial development), forests, industrial areas (industrial facilities, mine excavations, mine heaps, and tailing ponds).

Geological map. To illustrate the geological structure of the study area, the Zabrze M-34-62-B map sheet of the 1:50,000-scale Detailed Geological Map of Poland was used (Wyczółkowski, 1957). Individual elements of the geological map were digitized to create their vector images that were subsequently combined with the topographic base, producing a geological map at the scale of 1:25,000 (Pl. 1).

Databases. Separate databases were prepared for: topsoil (0.0–0.3 m), subsoil (0.8–1.0 m), sediments and surface waters.

Soil databases contain the following information: sample number, results of measurements of geographic coordinates at sampling sites, site description (land development, land use, soil type, sampling site location – district, commune and locality), date of collection, name of sample collector, and analytical data.

Sediment and surface water databases contain the following information: sample number, results of measurements of geographic coordinates at sampling sites, site description (land development, land use, water body type, sediment type, sampling site location – district, commune and locality), date of collection, name of sample collector, and analytical data.

Statistical calculations. The results gathered in databases were used to create subsets for statistical calculations according to different environmental criteria, e.g. concentrations of elements in soils of industrial areas, forest soils and urban soils, in sediments, and in the waters of individual water bodies, as well as for geochemical map construction. Statistical calculations were made for both whole datasets and subsets created for soils, sediments and surface waters. In the case of some elements with the content lower than the detection limit value for the given analytical method, half of the detection limit value was taken. The arithmetic and geometric means, median, and minimum and maximum values were calculated. These data specified for individual elements and indices are shown in Tables 2–5 and presented in the geochemical maps.

Median values were the most commonly used parameter to interpret the results, as a measure of the average contents of each element. The median is a statistical parameter that better characterises the average contents than the arithmetic mean, because it is less affected by extreme values. Other statistical parameters (variance, standard deviation) are not suitable for the characteristics of the population with unspecified distribution.

Maps construction. The following maps were produced for the Ornontowice Sheet (Pls. 2–63): land development, land use, contents of organic carbon, and sand, silt and clay fractions in topsoil (0.0–0.3 m depth), pH of topsoil and subsoil (0.0–0.3 and 0.8–1.0 m depth), 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 topsoil and subsoil and in sediments, pH, electrolytic conductivity and contents of Ag, Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, SO_4, Sb, Se, SiO_2, Sr, Ti, Tl, U, V and Zn in surface water, classification of topsoil (0.0–0.3 m), indicating its appropriate use (including subdivision into soil use groups based on the Regulation of the Ministry of the Environment (Rozporządzenie..., 2002).

Land development, land use and classification indicating appropriate topsoil use are presented as dot maps (Pls. 2, 3 and 63).

To show the distribution of grain-size classes (Pls. 4–6) and the contents of elements in soils, contour maps were constructed because of their clarity and legibility. The geochemical contour maps were produced using the Surfer software and the *Inverse Distance to a Power* method. The classes of contents of elements were created using geometric progression.

Soil pH (Pls. 7 and 8) is presented according to the soil science classification (acidic, neutral and alkaline soils).

The geochemical maps of soils were constructed using the analytical dataset created for the Ornontowice Sheet and the adjoining 1:25,000-scale sheets to avoid any discrepancies at the sheet boundaries. The Ornontowice Sheet was then extracted from mono-element maps and combined with the topographic base map.

The geochemical maps of sediments and surface water were compiled separately for the Ornontowice Sheet. They were constructed as dot maps with the circle diameters corresponding to individual classes, most often according to geometric progression.

While constructing the map of soil classification (Pl. 63), indicating appropriate soil use, the results of geochemical analyses were referred to the permissible concentrations of metals, defined in the Regulation of the Ministry of the Environment. According to the recommendation: "soil or land is considered polluted if the concentration of at least one substance exceeds the permissible limit value" (Rozporządzenie…, 2002).

Based on the concentrations of individual elements analysed (specified in Rozporządzenie..., 2002), each soil sample was categorized into class A, B or C. In the case of equal permissible limit values for classes A and B (based on guideline values for arsenic, barium and cobalt in Rozporządzenie..., 2002), the soil was categorized into class A, which is more beneficial for the soil user and enables multifunctional land use.

For publication purposes, the geochemical maps were constructed by combining the maps into pairs: i.e. the topsoil map is presented on the same Plate together with the sediments map, and the subsoil map is shown together with the surface water map on another Plate. This method of presentation provides the possibility of direct comparison of geochemical images of various environments.

To facilitate easy use of the atlas, the maps (with a bar scale shown) have been printed out in a slightly smaller format (A3). This operation does not result in missing any important details of the maps.

RESULTS

SOILS

In the Ornontowice map sheet the parent rocks of soils differ in both lithology and age (Pl. 1). The dominant soil types are podzols and pseudopodzols (Lokalny Program..., 2010).

Grain size. Grain size composition of the soil largely determines its resistance to degradation and has an essential effect on the content of chemical elements. Soils with a high content of clay fraction (<0.02 mm) and silt fraction (0.1–0.02 mm) commonly show elevated concentration of chemical elements other that silicon, and their lower mobility in hypergenic conditions. The standards and recommendations on permissible concentrations of metals in soils usually involve the grain-size composition, allowing higher levels of concentration limits for soils with a considerable proportion of the clay fraction, and lower limits for soils with a considerable amount of the sand fraction (Kabata-Pendias *et al.*, 1995).

For the purpose of this report, the classification of particles into grain-size groups follows the standard BN-78/9180-11, which has been valid since 2008, because this is a continuation of a serial publication performed over a long period in accordance with the instruction to the 1:25,000-scale geochemical map. The results of grain-size analysis are presented for the following grain-size groups: 1.0–0.1 mm sand fraction, 0.1–0.02 mm silt fraction, <0.02 mm clay fraction (Pls. 4–6). The change in the grain-size ranges in accordance with the guidelines of the Polish Society of Soil Science (PTG) (Klasyfikacja..., 2008) would make it impossible to compare the grain-size composition with data from previously compiled map sheets.

The study results show that soil's particle size is related predominantly to the bedrock lithology. On the maps of distributions of the contents of individual grain size fractions (Pls. 4–6) a subdivision into two main areas is visible, which differ in the grain size characteristics. In the north-eastern part of the map sheet there are soils enriched in the sand fraction (>40%), which are developed on Quaternary glaciofluvial sands. Most of these soils are overgrown with forests. In the remaining area, where soils are developed on glacial tills and on outcrops of older basement (sand-clay and carbonate rocks), the silt fraction is dominant (Pl. 5). These are predominantly agricultural soils, wasteland areas, or urban soils. The clay fraction in these soils accounts for the smallest percentage. In most of the soils the proportion of this grain size fraction is below 20% (Pl. 6).

Acidity. Soil pH is dependent on the bedrock lithology, land use, and on anthropogenic factors.

Acidic topsoils (pH <6.3) are found in forest areas. Soils of arable land show neutral pH. Small areas with alkaline topsoils occur in the outcrops of Triassic carbonates in the south-eastern part of the map sheet or in urban and industrial areas (Ruda Śląska, Halemba and Budryk mines).

At a depth of 0.8–1.0 m acidic soils are observed locally in small forest areas. Neutral and slightly alkaline soils are predominant in the study area. In the south-eastern part of the map sheet, soil alkalinisation is the result of the occurrence of Triassic carbonates in the basement, whereas in the remaining areas – the result of anthropogenic factors. Soil alkalinisation in urban-industrial areas is caused mainly by the fallout of particulate matter emitted by power stations and other industrial plants, while in the rest area – probably by the fallout of calcareous dust from home furnaces. The much greater extent of alkaline subsoils l as compared to the topsoils is a result of migration of calcium and magnesium compounds down into the soil profiles. The compounds are constituents of industrial dusts and local waste piles of mines and power stations.

At both depth intervals the most alkaline soils (pH 9.6 in the topsoil and 10.1 in the subsoil) are found in the village of Stara Kuźnica near settling ponds of the Halemba power station.

Geochemistry. The spatial distribution of the chemical elements in soils of the map sheet area results from the bedrock chemical composition and anthropogenic factors.

Soils of the Ornontowice map sheet show a low contamination level by the analysed elements. This confirms the conclusion that human impact in the study area is low due to prevalent non-built and rural areas. Industrial and urban areas are located only in the margin of the map sheet: in the northeast – outskirts of Ruda Śląska city, in the southeast – outskirts of Mikołów town, and in the southwest – in Ornontowice community. The median values of silver, mercury, magnesium, nickel and strontium at both depth intervals are equal to the values of the geochemical background for Poland (Lis, Pasieczna, 1995a), which are usually lower than the corresponding regional background values (Lis, Pasieczna, 1995b). In the topsoil, the median of calcium content (0.12%) equals the median value of this element in soils of non-built areas (Pasieczna, 2003). In the subsoil the median values of barium, cadmium, copper, cobalt and iron are close to the geochemical background value for Poland, while the median values of calcium, manganese, lead, phosphorus, sulphur and zinc are lower. The median values of chromium, titanium and vanadium in soils of the map sheet area from both depth intervals are greater than both the regional and whole-country geochemical background values. The several-fold enrichments in the topsoil relative to the subsoil (due to human impact) are observed in the case of the following elements: barium (two times greater concentration), calcium (two times), copper (two times), manganese (four times), lead (five times), phosphorus (three times), sulphur (four times) and zinc (three times).

Distribution of most elements in soils shows two major areas where the bedrock chemistry clearly affects the contents of them. Soils of the southern part of the map sheet, developed on Carboniferous sandy-clayey sediments, Triassic carbonates and Quaternary tills, are characterised by high content of aluminium, calcium, cobalt, chromium, copper, iron, magnesium, manganese, nickel, strontium and vanadium in relation to the soils from the northern area of the map sheet, which developed mainly on Pleistocene glaciofluvial sandy sediments, and in relation to peaty soils. Anthropogenic factors have a crucial effect on the distribution of barium, cadmium, copper, mercury, lead, phosphorus, sulphur, titanium and zinc in the soils, but they are also often responsible for anomalies of the above-mentioned lithogenic elements (appearing against the background of their natural contents).

The lowest contents of the analysed elements are found in sandy or peaty soils of non-built and rural areas, which are usually overgrown by forests. The most enriched in these components are soils of urban and industrial areas (usually parks and lawns), often anthropogenic in nature.

Among anomalies of natural origin are those of calcium, magnesium and strontium, occurring in the south-eastern part of the map sheet in soils developed on Triassic carbonates. This area belongs to the Mikołów-Mokre quarter. The calcium content attains 14.02% in the topsoil and 18.40% in the subsoil (at a maximum), and the magnesium contents are 5.75% and 4.20% (at a maximum), respectively. The strontium content in the area of quarries is up to 69 mg/kg in the topsoil and 250 mg/kg in the subsoil.

Of natural origin are probably the enrichments in iron and manganese found in meadow soils of the Promna Stream and Jasienica Stream valleys. The iron content in the topsoil in the Promna Stream valley is up to 4.88%, and the manganese content – up to 1,261 mg/kg near the confluence of the Promna Stream to Kłodnica River, and up to 1,246 mg/kg in the Jasienica Stream valley at Chudów.

The enrichment in titanium at a depth of 0.8–1.0 m in Mikołów-Mokre is probably of lithogenic origin due to the occurrence of sandstones and claystones of the Łaziska Beds in the bedrock.

Elevated organic carbon contents, although of natural origin, are typical in soils of forest and meadow areas, which often occur in wetlands where peat is frequently found. In a forest area between Stara Kuźnica and Mikołów, peaty soils contain up to 44.4% of organic carbon.

The major anthropogenic anomalies of the analysed elements occur in areas of active hard coal mines (Halemba Mine in Ruda Śląska and Budryk mine in Ornontowice), in areas of mine heaps (mostly reclaimed), around settling ponds of the inactive Halemba thermal power plant, near transportation routes and in urban areas. The contamination is related mainly to the fallout of particulate matter from coal combustion, and to the material stored on old mine heaps and in settling ponds. The mine heaps typically show increased contents of aluminium, barium, organic carbon, calcium, chromium, cobalt, copper, mercury, iron, nickel, sulphur, strontium and vanadium. The topsoils covering mine heap of the Zabrze-Bielszowice mine, located in the area of former Lach pond (northern part of the map sheet), shows the greatest aluminium (2.99%) and sulphur (1.595%) contents. In the reclaimed heap in a forest area of Borowa Wieś, the highest concentration of mercury (0.90 mg/kg) was found at a depth of 0.8–1.0 m. Mine areas are polluted by aluminium, barium, organic carbon, cobalt, chromium, copper, iron, manganese, nickel, lead, sulphur, titanium, vanadium and zinc. In the immediate neighbourhood of the Halemba Mine, anthropogenic soil reveals the maximum chromium concentrations of 139 mg/kg in the topsoil and 260 mg/kg in the subsoil. At the same site, the subsoil shows the maximum iron content (10.3%) and elevated concentrations of nickel (87 mg/kg), lead (392 mg/kg), zinc (1,163 mg/kg), cadmium (6.5 mg/kg) and manganese (8,763 mg/kg). In areas of railway sidings the greatest zinc concentration (1,451 mg/kg) was found in the topsoil. A high percentage of organic carbon (38.1–44.6%) is observed near a waste heap and a settling pond. The lead concentration in the Halemba Mine is up to 3,764 mg/kg in the topsoil and 636 mg/kg at a depth of 0.8–1.0 m. Probably of anthropogenic origin is the strong enrichment in strontium of the topsoil at Paniówki, however no closer determination of its provenance is available.

Furnace waste of the Halemba thermal power station, deposited in four settling ponds in a forest area at Stara Kuźnica, is rich in aluminium, barium, calcium, cobalt, chromium, copper, iron, mercury, nickel, strontium, titanium, vanadium and organic carbon. The waste is characterised by the maximum titanium concentration: 604 mg/kg in the topsoil and 617 mg/kg at a depth of 0.8–1.0 m. The topsoil also shows the highest phosphorus content (0.461%), while the maximum vanadium concentration (97 mg/kg) is recorded in the subsoil.

Soils of urban areas in Ruda Śląska, Mikołów, Bujaków and Ornontowice and those located along transportation routes are locally polluted by copper, lead, zinc, manganese, barium and cobalt. The pollutants come from dust emitted by industrial plants, power stations and transport systems. The maximum lead concentration (4,638 mg/kg) was recorded in the topsoil of anthropogenic origin at Bujaków near the Mikołów – Ornontowice road. Soils heavily polluted by manganese are found in Paniowy near a road crossing: 9,010 mg/kg in the topsoil and 107,800 mg/kg in the subsoil. This soil, being a made ground by nature, has probably been brought from a highly polluted industrial area. At a depth of 0.8–1.0 m there are the maximum concentrations of silver (5 mg/kg), barium (2,156 mg/kg) and cobalt (51 mg/kg) and elevated contents of calcium (6.53%) and strontium (172 mg/kg). The greatest concentration of cobalt (49 mg/kg) was recorded in loamy topsoil in Ornontowice, and the greatest barium concentration (1,215 mg/kg) in anthropogenic soil in the Mikołów-Mokre quarter.

In soils of the Ornontowice map sheet the silver concentration does not exceed the detection limit for the analytical method (1 mg/kg).

In most of the soils (at both depth intervals) the arsenic content does not exceed 10 mg/kg. In the topsoil the highest arsenic concentration is typically found in soils of parks (median value 6 mg/kg). The maximum concentrations of this element are recorded in agricultural soils: in the topsoil in Śmiłowice upon Żabnica (60 mg/kg), and in the subsoil in Chudów (86 mg/kg).

The phosphorus content in the soils is dependent on both the chemical composition of parent rocks and the mode of soil use. Soils of arable land and meadows contain the greatest amount of phosphorus (median values 0.044% and 0.043%, respectively); the lowest contents are found in forest soils (median 0.020%). In the topsoil the greatest amounts of phosphorus were recorded in anthropogenic soils of industrial areas. At a depth of 0.8–1.0 m the maximum phosphorus content (0.400%) is found in meadow soils near the Promna Stream at Borowa Wieś. The topsoil layer from this site contains 0.073% of this element.

Topsoil classification indicating appropriate soil use. The proportion of soils contaminated to various degrees by cadmium, lead and zinc is presented in Table 6. Over much of the map sheet area (98.55%) the topsoil contains <4 mg/kg of cadmium. At a depth of 0.8–1.0 m, 94.84% of the soils contain less than 1 mg/kg of this element. The lead concentration <100 mg/kg in the topsoil was found in 91.52% of soils, and the zinc concentration <500 mg/kg in 97.59%.

The topsoil was analysed for the degree of pollution by metals, classifying it into the soil use groups A, B and C, based on permissible limit values (Rozporządzenie…., 2002). While using the summary classification, we used the principle that the soil is categorised into a given group if the concentration of at least one element exceeds the permissible lower limit value. With respect to the concentration of metals the topsoils look relatively favourably. 40.57% of the soils are included into group A, 45.1% into group B, and 14.33% into group C (Tab. 7). The criteria required for soil's multifunctional use are met by the soils assigned to groups A and B (total 85.67%) and, in the study area, they are mostly used in accordance with the recommendations (Rozporządzenie…, 2002). Soils classified into group C (mainly due to the content of lead, zinc and barium) occur predominantly in urban and industrial areas, in areas of old mine heaps and settling ponds of furnace waste, as well as in the Kłodnica River valley (within the borders of Ruda Śląska city), where anthropogenic material was used for river channel engineering (Pl. 63). Locally, the current land use is inappropriate. The concentrations of metals in some soils of arable land, meadows, forests and parks are so high that these areas should be reclaimed or used only for industrial purposes.

SEDIMENTS

The chemical composition of sediments in inland water reservoirs is constrained by many natural and anthropogenic factors. It depends primarily on the geological structure of the drainage basin, geomorphology, and climatic conditions, which determine the processes of weathering of rocks, and the mobilization, migration and accumulation of elements (Bojakowska, Gliwicz, 2003).

In the study area, anthropogenic contamination that originates from the discharge of industrial and household sewage affects the composition of sediments more strongly than natural factors do. A special feature of most of sediments of watercourses and water reservoirs in the map sheet area is the high content of very fine coal particles. They are characterised by sorption capacities leading to binding of metals and their easy precipitation (Nocoń, Kostecki, 2005).

The feature in common for these sediments is the high content of elements from the iron group: Co, Cr, Fe, Mn and Ni, which are used for steel processing of and for plating, but are poorly represented in the bedrock, suggesting contamination by unidentified electroplating plants and/or scrap metal collection points. It should be emphasized that the sorption properties of colloidal suspensions of Fe, Mn and peat cause the capture of cations from the solution.

Kłodnica River. The river's headwaters originate in the Brynów quarter of Katowice, beyond the eastern boundary of the map sheet. In its upper reach the river flows through both forests and industrial areas of Katowice and Ruda Śląska. Along nearly the entire course within the map sheet area the river channel is engineered (Nocoń *et al.*, 2006). Through sewage discharges and the tributaries the Kłodnica River carries contaminants from the western part of the Upper Silesian Industrial Region (Czaja, 1999).

In the east of the Ornontowice map sheet the Kłodnica River receives sewage from the Halemba coal mine and from a sewage treatment plant, as well as leachate from power station's ash storage sites.

Sediments in this section of the Kłodnica River are only slightly contaminated. The medians values of both major elements (aluminium, calcium, iron, magnesium, manganese and phosphorus) and trace elements (arsenic, barium, cadmium, cobalt, copper, mercury, chromium, lead, strontium, vanadium and zinc) are lower than the regional geochemical background values (Tab. 4).

The silver content in sediments of the Kłodnica River in the map sheet area is lower than the detection limit of the analytical method (1 mg/kg).

In most of sediments the arsenic content is lower than the regional geochemical background value (6 mg/kg), and in many cases also lower than the detection limit: 3 mg/kg. It is the value below which no negative effects of this element on aquatic organisms are observed. Negative effects of arsenic on aquatic organisms may occur at the concentration above 33 mg/kg (MacDonald *et al.*, 2000).

The arsenic content of >33 mg/kg was detected in sediments of no-name watercourses flowing near waste storage sites of the Halemba thermal power station (including the surrounding ditch), in sediments of watercourses recharging the Kłodnica River along the section downstream of the sewage treatment plant, and in sediments of a ditch draining the area of former mine heap at Paniówki.

The barium concentration is 18–252 mg/kg in sediments of the Kłodnica, whereas the sediments of its minor tributary streams contain 500–650 mg/kg of this element. The greatest barium concentrations typically occur in sediments of surrounding ditches around furnace waste storage sites of the Halemba thermal power station near Stara Kuźnica, and in a settling pond of the Halemba Mine.

Most of sediments of the Kłodnica River contain below 5 mg/kg of cadmium. The concentration of 53 mg/kg was recorded in sediments of an unnamed watercourse in a wetland terrain of the Halemba residential area. These sediments also contain 660 mg/kg of barium, 90 mg/kg cobalt, 35 mg/kg copper, 8.50% iron, 2,900 mg/kg manganese, 34 mg/kg nickel, 0.545% phosphorus, 125 mg/kg lead, and 4,040 mg/kg zinc. Contamination by cadmium (42 mg/kg) was observed also in sediments of a stagnant water reservoir near Miła Street in Ruda Śląska and near settling ponds of the Halemba thermal power station. The contents of other metals in these water bodies are also significant. The concentration of copper is 112 mg/kg, iron 1.78%, mercury 0.46 mg/kg, lead 363 mg/kg, zinc 1,630 mg/kg. The sediments also contain above 2% of sulphur.

Contamination by metals is observed in sediments of a ditch draining the area adjoining allotments in Ruda Śląska (near a former sewage treatment plant located west of Energetyków Street). They contain up to 53 mg/kg of arsenic, 73 mg/kg chromium, 875 mg/kg copper, 0.26 mg/kg mercury, 570 mg/kg lead, and 2,440 mg/kg zinc. The metals can originate from leachate of a waste heap located south of this area, from contaminants left by the former sewage treatment plant, and from sewage of the allotment gardens.

In the Kłodnica River drainage basin the most contaminated sediments are found in the upper reach of a left tributary of the river. They contain 2.50–3.27% of aluminium, and some samples reveal contamination by cadmium (up to 79.6 mg/kg), cobalt (up to 136 mg/kg), lead (up to 152 mg/kg) and zinc (up to 4,673 mg/kg). The same sediments abound in manganese (12,020 mg/kg) and iron (2–5%).

Worth noting is the elemental composition of sediments in the watercourses around the waste heap near the Halemba thermal power station. Most of the samples abound in aluminium (0.80–2.20%). Moreover, some sediments contain 19–49 mg/kg of arsenic, 500–670 mg/kg barium, 100–200 mg/kg strontium, 50–80 mg/kg copper, and up to a few percent of iron and 300–740 mg/kg of vanadium. This contamination is likely related to leachate from the waste storage site.

Jasienica Stream and its catchment. The Jasienica Stream valley hosts a dense network of streams which are surrounded by belts of near-water vegetation. In its lower reach the Jasienica Stream drains areas of agricultural areas of the Gierałtowice community, crosscut by a dense network of small creeks. The streams are accompanied by wetland meadows and rushes. The main sources of contaminants in the surface water and sediments are municipal and household sewage from residential areas, water washed out from arable fields, and runoff from atmospheric precipitation.

The median values of the major and trace elements in sediments of the Jasienica Stream and in sediments of the watercourses and reservoirs in its catchment are lower than their geochemical background values in the Silesian-Cracow region (Tab. 4). The exception is an elevated content of titanium. Sediments in the upper reach of the stream are contaminated by zinc (1,100–1,200 mg/kg), cadmium (13–28 mg/kg), nickel (30–59 mg/kg), cobalt (20–35 mg/kg) and manganese (1,200–2,800 mg/kg).

The zinc concentration of 700–2,383 mg/kg was also recorded in sediments of the Ornontowicki Potok stream in the southwest of the study area.

Sediments of the Paniówka Sream, connecting the Promna Stream valley with the Jasienica Stream valley, are characterised by clearly increased contents of many elements compared to the remaining sediments in the drainage basin. They contain up to 2.69% of aluminium, up to 299 mg/kg barium, up to 2.96% calcium, up to 26 mg/kg cadmium, up to 34 mg/kg chromium, up to 52 mg/kg copper, up to 5.73% iron, up to 42 mg/kg nickel, up to 0.707% phosphorus, up to 173 mg/kg lead, up to 2.83% sulphur, up to 95 mg/kg strontium, and up to 1,090 mg/kg zinc. This stream probably receives municipal sewage from the village of Paniówki.

Sediments severely polluted by mercury (up to 22.23 mg/kg) have been found in a minor stream flowing north of Bujaków. The mercury may origin from plant protection products, once used in excess.

Promna Stream and its catchment. The valley of the stream runs in northern Mikołów. In the upper part of its drainage basin, Carboniferous sandstones and claystones and Triassic clastics and carbonates crop out on the surface. In the lower reach of the stream the valley bottom is composed of Quaternary glaciofluvial sands and gravels.

The catchment area comprises mainly arable land, meadows and forests. In the Mikołów-Mokre region there are old lime kilns and an inactive landfill of municipal waste.

The median values of major and trace elements in sediments of the Promna Stream and in sediments of watercourses in its drainage basin are lower than the regional geochemical background values in the Silesian-Cracow region, except for sulphur and titanium (Tab. 4).

The distribution of elements in sediments remarkably varies between the upper, middle and lower parts of the drainage basin, indicating their origin from erosion of rocks of different chemical compositions. Low contents of aluminium, barium, cobalt, iron, manganese, nickel, phosphorus and vanadium are characteristic of sediments in the upper reach of the stream, which is associated with their lower contents in carbonates than in alluvial muds of the lower part of the drainage basin. In turn, the contents of calcium, sulphur and strontium are highest in sediments of the upper reach of the stream, because limestones and evaporates are the carriers of these elements.

Contamination of sediments by elements harmful to living organisms is observed in the lower reach of the stream. Concern is raised especially with respect to the zinc concentration which exceeds the level of 1,000 mg/kg, and the maximum value is 2,263 mg/kg. The sediments in which zinc is accumulated also contain elevated amounts of barium (250–350 mg/kg), cadmium (4–9 mg/kg), cobalt (20–30 mg/kg), iron (5–8%), copper (20–40 mg/kg), nickel (do 179 mg/kg), phosphorus (0.200–0.630%), lead (150–200 mg/kg) and sulphur (0.500–1.130%). The accumulation of these elements is associated with the environment favourable for their sorption in sediments resembling alluvial muds, which contain abundant organic matter, clay minerals, and iron and aluminium oxides and hydroxides. They are sourced from both weathered Triassic rocks occurring in the upstream area, and anthropogenic pollution outbreaks distributed throughout the drainage basin. A specific source is probably leachate from a waste heap located to the east of the lower section of the Promna Stream valley. Worth noting are the very high manganese concentrations (6,510–25,542 mg/kg) in sediments of the ditch surrounding the Borowa I heap, on its western side.

Żabnica Stream and its catchment. Along its entire course the stream drains the area covered with glaciofluvial sands, used as farmland and forests, but also waste storage sites of the former Halemba thermal power station.

The median values of lithogenic and anthropogenic elements (excluding titanium and vanadium) in sediments of the Żabnica Stream are lower than the regional geochemical background values (Tab. 4), and show a slight variation along the entire course of the stream. Contaminated sediments are found in the surrounding ditch of the former Halemba thermal power station. They are distinguishable by high concentrations of aluminium (up to 1.81%), arsenic (up to 49 mg/kg), barium (up to 672 mg/kg), cobalt (up to 68 mg/kg), iron (up to 4%), manganese (up to 2,846 mg/kg), strontium (up to 136 mg/kg), titanium (up to 240 mg/kg), vanadium (up to 740 mg/kg) and zinc (up to 1,321 mg/kg).

SURFACE WATER

Kłodnica River. The surface water quality in the Kłodnica drainage basin is strongly affected by mine water discharged from coal mines, both active and closed down due to restructuring (Lach *et al.*, 2004). In the study area the river also receives municipal and industrial wastewater from Katowice, Ruda Śląska and Mikołów.

As the main index characterising the chemical composition of the water in the Kłodnica River, worth noting is the electrolytic conductivity value (6.30–11.40 mS/cm), due to high salinity of mine water discharged into the river. EC values above 1 mS/cm are indicative of strong water pollution (Witczak, Adamczyk, 1994). Low mineralization is observed only in the water of some stagnant water bodies (EC 0.20–0.40 mS/cm), which likely come from atmospheric precipitation.

The measured pH values are poorly variable along the entire river course, ranging from 9.0 to 9.6. High alkalinity of the water is probably due to a significant load of calcium and magnesium bicarbonates. The median values of calcium and magnesium in the water of the Kłodnica River (the highest among all rivers) are 149.2 and 105.2 mg/dm^3, respectively, and are uniform along the entire river course. The source of the elements is mine water, sewage and surface runoff.

Drainage of the rock mass and removal of mine water have caused strong pollution of the water by elements coming from mine water: boron, potassium, lithium, magnesium, sodium, sulphates and strontium. The concentrations of these elements in the water of the Kłodnica River are uniform, and lower values are observed only in some stagnant water bodies in the river valley. The average concentration of boron is 0.93 mg/dm^3, potassium 38.6 mg/dm^3, and lithium 229.2 µg/dm^3.

The concentrations of sodium (942.7–1670.8 mg/dm^3), strontium (2–3 mg/dm^3) and sulphates (3,700–6,500 mg/dm^3) remain at a very high level along the entire river course in the map sheet area.

The concentrations of metals do not exceed the boundary limits for surface water quality class I. In the upper reach of the river the barium concentration is almost twice as high (0.120 mg/dm^3) as downstream in the river (0.070 mg/dm^3).

The positive fact is the occurrence of low amounts of metals toxic to organism in the water. The chromium concentration does not exceed 0.003 mg/dm^3. The concentration of copper is 1–6.76 µg/dm^3, of cadmium <0.05–0.34 µg/dm^3. The average concentration of lead is 0.10 µg/dm^3, and of zinc 0.037 mg/dm^3, which allows classifying the water into quality class I with respect to the content of the elements.

In the water of the Kłodnica River the iron concentration varies from 0.02 to 0.11 mg/dm^3, attaining a level of 2–3 mg/dm^3 in stagnant water bodies near the river channel. The distribution of manganese concentration is poorly variable. The water of the upper reach of the river contain more manganese (0.500–0.700 mg/dm^3) than those of the lower reach (about 0.300–400 mg/dm^3).

The average concentrations of antimony (1.44 µg/dm^3), selenium (5 µg/dm^3), molybdenum (2.58 µg/dm^3) and thallium (0.05 µg/dm^3) are typical of water quality class I. The probable source of antimony is mine water of the Halemba Mine. Upstream of the site of mine water discharge to the Kłodnica River the antimony concentration is 0.30–0.80 µg/dm^3, but downstream of this site the values are 1.4–2.66 µg/dm^3. The thallium concentration shows a different distribution, being 0.10–0.12 µg/dm^3 in the upper reach of the river and about 0.05 µg/dm^3 downstream of the mine facilities. Such a thallium concentration distribution (like that of selenium) indicates that the source of these elements is located in the upper part of the drainage basin.

The Kłodnica River water contain an average of 4.9 µg/dm^3 of nickel, and the contamination by this element (up to 15.3 µg/dm^3) and by cadmium (2.0 µg/dm^3) is recorded only in stagnant water bodies near industrial facilities of the Halemba Mine.

As regards the phosphorus concentration (median 0.10 mg/dm^3) the water in the Kłodnica can be classified into quality class I.

The silica concentration is 8.6–11.3 mg/dm^3.

Jasienica Stream and its catchment. The water in the Jasienica Stream and its drainage basin within the map sheet area is not strongly contaminated. It is evidenced by relatively low electrolytic conductivity values that are commonly below 1.5 mS/cm. The greatest salinity is observed in the water of unnamed watercourses. The highest conductivity values (EC 4.11 and 2.89 mS/cm), and drainage basin's highest concentrations of sodium, lithium, magnesium, selenium and strontium have been recorded in the water of a ditch in Ornontowice.

The water of the Jasienica Stream and its catchment are slightly alkaline (pH 7.0–9.0). Alkaline water (pH >9.0) are also found in fish ponds at Kąty and Sośnia Góra.

As regards the magnesium concentration, the water can be classified into quality class I, but with respect to the concentrations of silver, arsenic, boron, barium, cobalt, chromium, copper, molybdenum, lead, antimony, selenium, titanium, thallium, vanadium and zinc – into quality class I/II. 44% of the water meet the calcium content criteria for water quality class I, and 56% – for water quality class II. Elevated concentrations of calcium (>100 mg/dm^3) and uranium (>0.8 µg/dm^3) are typical of watercourses draining the areas of glacial tills.

Clearly increased concentrations of a number of elements are observed in the Paniówka Stream, especially in the water of its forest course, which is characterised by low pH values (pH 4.4–5.0). The concentration of aluminium is up to 6,863 μg/dm^3, cadmium up to 5.1 μg/dm^3, beryllium up to 1.43 μg/dm^3, cobalt up to 16.84 μg/dm^3, iron up to 8.6 mg/dm^3, manganese up to 1.095 mg/dm^3, nickel up to 17.4 μg/dm^3, and zinc up to 0.974 mg/dm^3. The water of the Paniówka Stream and its minor left tributary in the village of Paniówki is characterised by high sodium (up to 164 mg/dm^3) and sulphate (up to 3,000 mg/dm^3) concentrations, too. Along nearly the entire length of the stream there are also anomalous silica concentrations (16.4–57.4 mg/dm^3).

Elevated concentrations of sodium (up to 162.8 mg/dm^3), lithium (up to 19.1 μg/dm^3), potassium (up to 22.7 mg/dm^3) and boron (up to 0.15 μg/dm^3) are found in the water of the Ornontowicki Stream, while increased contents of sodium and lithium are also observed in the lower reach of the Jasienica Stream, downstream of the site where the Ornontowicki Stream joins the Jasienica Stream. This contamination may be associated with the discharge of mine water from the Budryk Mine, discharge of sewage from the Ornontowice sewage treatment plant, and surface runoff.

Anomalous concentrations of potassium (up to 416.5 mg/dm^3) and manganese (up to 1.018 mg/dm^3) and elevated amounts of sodium, lithium, iron and cobalt have been recorded in the water of a stream flowing across the Kąty residential area. The enrichment in manganese, iron and cobalt may be related to the drainage of basement rocks.

Anomalous concentrations of cadmium (6.79 μg/dm^3), cobalt (11.73 μg/dm^3), manganese (3.124 mg/dm^3), nickel (24.1 μg/dm^3) and zinc (0.700 mg/dm^3) have been recorded in the water of the upper reach of the Jasienica Stream. Contamination by these elements is also observed in its sediments.

With respect to the phosphorus content the water of the Jasienica Stream can be classified into quality classes I or II (≤0.4 mg/dm^3). The greatest concentrations of this element are found in its tributaries flowing through Ornontowice, Paniówki, Chudów and the Kąty residential area. The maximum phosphorus concentration (10.10 mg/dm^3) is recorded in the water of a ditch in Chudów.

Promna Stream and its catchment. The water of the Promna Stream, its tributaries and water bodies in its drainage basin are characterised by relatively low electrolytic conductivity values. In terms of EC, most of them (84%) meet the criteria required for water quality class I. 14% of the water is included into water quality class II. Markedly elevated EC values are observed in the southern course of the Promna Stream, which drains the area composed of glacial tills and older basement rocks (Carboniferous sandstones and claystones and Triassic clastics and carbonates). The increased conductivity is also related likely to the influx of contaminants from the area of Mikołów (surface runoff and sewage), as evidenced by elevated concentrations of sodium (up to 128.5 mg/dm^3), lithium (up to 16.7 µg/dm^3), manganese (up to 1.332 mg/dm^3) and phosphorus (up to 7.42 mg/dm^3).

The water of the Promna Stream is predominantly poorly alkline. The middle and lower reach of the stream is made distinctive by higher pH values. Highly alkaline water (pH 9.0–9.8) occur in Bocianie Gniazdo pond and in a ditch that drains this pond and surrounds the Borowa I heap.

As regards the contents of elements such as silver, aluminium, arsenic, boron, cobalt, chromium, copper, molybdenum, lead, antimony, selenium, thallium, titanium, vanadium and zinc, all of the water in the drainage basin can be classified into quality class I (Rozporządzenie…, 2014).

In terms of calcium and magnesium concentrations, most of the water meet the criteria required for quality class I, and only few of samples are included into class II. Elevated concentrations of both these elements are found in the water of Promna Stream near the old lime kilns. Distinctly anomalous magnesium concentrations (56–89 mg/dm^3) are found in Piaski pond and in a ditch draining the area adjoining the Borowa I heap to the north. The water show increased EC values and the maximum concentrations of manganese (2.100 mg/dm^3) and sulphates (3,900–6,100 mg/dm^3).

The water of watercourses and reservoirs in the village of Borowa Wieś are locally contaminated by barium (0.12–0.13 mg/dm^3), sodium (89.1–99.8 mg/dm^3), potassium (22.3 mg/dm3), antimony (1.75 µg/dm^3), molybdenum (2.51 µg/dm^3), cobalt (2.62–4.08 µg/dm^3), iron (0.55–0.60 mg/dm^3), manganese (0.415 mg/dm^3), zinc (0.419 µg/dm^3) and cadmium (0.89 µg/dm^3). These contaminants can originate from leachate from the Borowa I heap. A similar origin is suggested for iron (up to 0.80 mg/dm^3), manganese (up to 0.758 mg/dm^3) and cobalt (up to 1.55 µg/dm^3) in the water of the lower reach of the Promna Stream, but they also possibly come partly from the drainage of meadow soils naturally enriched in these elements.

Clearly elevated concentrations of a number of elements are found in the water of unnamed watercourses in Stracona Wioska, where the maximum concentrations of zinc (0.442 mg/dm^3), beryllium (0.92 µg/dm^3), cobalt (39.86 µg/dm^3), and cadmium (2.67 µg/dm^3) and nickel (66.8 µg/dm^3), and elevated amounts of iron (0.84 mg/dm^3), manganese (1.466 mg/dm^3), antimony (1.51 µg/dm^3) and sodium (82.7 mg/dm^3) have been recorded. Illegal discharges of sewage are probably responsible for the increased contamination.

The boron, uranium and vanadium enrichment of the water in the southern course of the Promna Stream is likely of lithogenic origin.

Along the entire length of the Promna Stream the concentrations of strontium and silica are relatively uniform.

Żabnica Stream and its catchment. The Żabnica flows predominantly through non-urbanized areas. The quality of its water is affected largely by the drainage of furnace waste piles of the former Halemba thermal power station by the plant-powering watercourses.

In the stream course adjoining the waste piles and downstream, its water is enriched in boron, cobalt, iron, lithium, molybdenum, sodium and strontium. However, the most contaminated water is found in the surrounding ditches and small ponds in their immediate neighbourhood. They show very high concentrations of aluminium (6,310.9 μg/dm^3), boron (up to 1.83 mg/dm^3), beryllium (2.47 μg/dm^3), cadmium (14.70 μg/dm^3), cobalt (up to 33.54 μg/dm^3), iron (16.9 mg/dm^3), lithium (663 μg/dm^3), manganese (2.039 mg/dm^3), molybdenum (181.75 μg/dm^3), sodium (149.4 mg/dm^3), nickel (54.6 μg/dm^3), lead (44.78 μg/dm^3) and strontium (up to 1.742 mg/dm^3), and elevated concentrations of selenium (6 μg/dm^3), thallium (1.02 μg/dm^3), titanium (0.003 mg/dm^3) and zinc (2.086 mg/dm^3).

Elevated concentrations of a number of elements are found in the water of a minor left tributary of the Żabnica, flowing from Stracona Wioska, e.g. 3.89 μg/dm^3 of cadmium, 1.204 mg/dm^3 of manganese, and 0.86 mg/dm^3 of iron.

In the upper reach of the Żabnica (upstream of the piles) the water is categorised into quality class I with respect to most elements. Locally, it shows elevated concentrations of phosphorus (0.863 mg/dm^3), antimony (1.44 μg/dm^3), uranium (2.03 μg/dm^3) and vanadium (3 μg/dm^3). The water is also characterised by low EC and is less alkaline compared with the water of the lower reach.

The concentrations of potassium and sulphates are relatively uniform in the analysed water. Higher concentrations are observed in the lower reach of the Żabnica, downstream of the piles: sulphates 1,000–8,000 mg/dm^3, potassium 33–160 mg/dm^3.

CONCLUSIONS

1. Grain size and chemical composition of the soils are strictly dependent on the lithology of basement rocks. Soils of the northern part of the map sheet have developed on glacial and glaciofluvial sandy deposits and are characterised by a considerable proportion of the sand fraction and low contents of most of chemical elements. Soils of the southern area, developed on glacial tills or older basement rocks (sandy-clay and carbonate deposits), are enriched in the silt fraction and the following elements: aluminium, calcium, cobalt, chromium, copper, iron, magnesium, manganese, nickel, strontium and vanadium.

2. Acidity of the soils is dependent on the lithology, land use and anthropogenic factors. Acidic topsoils are observed in areas of forests and peaty meadows, whereas soils of arable land are neutral. Alkaline topsoils occur in areas of outcrops of Triassic carbonates in the south-eastern part of the map sheet, as well as in urban and industrial areas. Subsoils are predominantly neutral or slightly alkaline.

3. The contamination of the soils is low, because the map sheet area hosts not as many industrial plants, which are the main source of anthropogenic pollution, as the adjacent areas of the Upper Silesian Industrial Region. The main anomalies of aluminium, barium, cobalt, chromium, copper, iron, manganese, nickel, lead, sulphur, titanium, vanadium and zinc are found in mining areas and former mine waste and furnace waste piles.

4. Natural anomalies include those of calcium, magnesium and strontium, occur in soils developed on Triassic carbonates in the south-eastern part of the map sheet. Of natural origin are also the enrichments in iron and manganese of meadow soils in the Promna Stream and Jasienica Stream valleys.

5. The main sources contamination of sediments and surface water are discharges of mine water and industrial and municipal sewage, drainage of mine waste and furnace waste heaps, as well as surface runoff.

6. Sediments of inland water reservoirs are moderately contaminated. Strong pollution by metals is found only locally in sediments of minor watercourses. Clearly elevated concentrations of some elements (aluminium, arsenic, barium, cobalt, copper, iron, manganese, sulphur, strontium, titanium, vanadium and zinc) are found in sediments of ditches surrounding mine waste heaps and storage sites of power plant waste.

7. Most of surface water show a low contamination level. The water is slightly alkaline or alkaline. The water of the Kłodnica River is characterised by high electrolytic conductivity and elevated concentrations of boron, potassium, lithium, magnesium, sodium, sulphates and strontium due to influx of mine water. The water of surrounding ditches around furnace waste storage sites of the former Halemba thermal power station is contaminated by aluminium, boron, beryllium, cadmium, cobalt, iron, lithium, manganese, molybdenum, nickel, lead and strontium.

8. The water and sediments of the Paniówka Stream are contaminated by, among others, aluminium, cadmium, iron, nickel and zinc.

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