INTRODUCTION

Geochemical mapping at the scale of 1:25 000 carried out in the Strzemieszyce Map Sheet M-34-63-B-a area is a continuation of detailed mapping works initiated in 1996-1999 by the pilot project Sławków Map Sheet M-34-63-B-d of the "Detailed geochemical map of Upper Silesia" (Lis, Pasieczna, 1999). The project was ordered by the Ministry of the Environment and it was financed by the National Fund for Environmental Protection and Water Management.

The Strzemieszyce Sheet area is located in the margin of the Upper Silesian Industrial Region, almost entirely in the Silesian-Cracow Upland. This area is situated within the geochemical anomaly of the Pb–Zn–Cd recorded in soils, aqueous sediments and surface water (Lis, Pasieczna 1995 a, b, 1997). The main source of the anthropogenic-geological anomaly are outcrops of Pb–Zn ore-bearing dolomites and associated Pb–Zn ore deposits, and their historical exploitation. Mixed (geological and anthropogenic) factors, causing both, some chemical changes in the natural environment and transformation of the landscape, include also the occurrence and extraction of other minerals (dolomites, clays, sands and hard coal) as well as intensive industrial activity (iron and steel, chemical, power supply and food industries).

North-western and western parts of the map sheet are industrial areas, which finds expression in significant changes in the topography. Central and southern areas are dominated by forests.

A number of valuable natural objects are located in this area. They include natural monuments (mainly lime, beech and oak trees) and the rising springs at Strzemieszyce Wielkie, protecting the brown trout. The Bory peat land in Sosnowiec, forest meadows in Stare Maczki and spring areas at Zakawie are valuable ecological sites. It is proposed to create a nature-landscape complex in the Sztoła Stream valley.

Information on the soils, aqueous sediments and surface water quality in the Strzemieszyce Map Sheet presented as geochemical maps can be useful in land use planning, assessing local 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 quality tests. The internet version of the atlas is available at http://www.mapgeochem.pgi.gov.pl.

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

- **A. Pasieczna** – concept and project proposal, supervision and coordination of research;
- **A. Dusza-Dobek, P. Dobek** – sample collection;
- **A. Dusza-Dobek, P. Dobek, A. Pasieczna** – databases;
- **A. Maksymowicz, P. Pasławski, E. Włodarczyk** – leadership and coordination of analytical works;
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- **A. Pasieczna, A. Dusza-Dobek** – statistical calculations;
- **A. Pasieczna, A. Dusza-Dobek, T. Gliwicz** – construction of geochemical maps;·
- **P. Dobek** – construction of geological map;
- **A. Dusza-Dobek, A. Pasieczna** – characteristics of the map area, interpretation of results;
- **S. Kurek, M. Preidl** – geology and mineral deposits;
- **S. Kurek, M. Preidl, A. Dusza-Dobek** – human impact.

CHARACTERISTICS OF THE MAP AREA

Geographical and administrative setting. Most of the map area lies in the eastern part of the Silesian Voivodeship. It covers parts of the following towns: Dąbrowa Górnicza, Sosnowiec and Jaworzno and part of the Sławków commune of the Będzin poviat. A small south-eastern part of the map area belongs to the Bukowno commune (Olkusz poviat) in the Małopolskie Voivodeship.

According to the physiogeographic division of Poland (Kondracki, 2000), the area is located within the Silesian Upland, largely within a lower-order geographical unit called the Katowice Upland. Its north-eastern part lies within the Garb Tarnogórski ridge.

Relief and geomorphology. The study area is an upland region. The Garb Tarnogórski ridge is composed of Middle Triassic dolomites and limestones, rising to the elevation of 340–380 m a.s.l. and sloping southwards towards the Katowice Upland along the tectonic-denudation escarpment. Denudation hills of gentle hill-slopes are observed in this part of the map area. The Katowice Upland is developed upon the basement of Carboniferous hard coal-bearing formations, and its landscape is highly modified by human impact.

A significant part of the map sheet is occupied by industrial areas, locally highly urbanized. Near Strzemieszyce Wielkie, there are numerous abandoned excavations of limestones and clay shales. Post-mining subsiding troughs are observed east of Maczki. Land surface deformations, caused by the activity of the Huta Katowice steelworks (currently ArcelorMittal), are very clearly expressed in the form of mining waste dumps and numerous embankments and excavations of railways of auxiliary plants of the steelworks. In the northern and western parts of the map sheet, there is the extensive road system and many flattened surfaces of anthropogenic origin to be built-up areas. Extensive sand excavation pits of the Szczakowa mine intensely extracting filling and building sands are located in the south. The excavations have been gradually forested after mining. However, many excavations of various origin are not subjected to reclamation. Some of them are filled with water, covered by wastes or overgrown.

The whole map sheet area is a part of the Vistula River drainage basin. It is situated within the catchment of the Biała Przemsza River and its tributaries (Bobrek, Kozi Bród and Sztoła streams). Some of the watercourses (Rakówka and Bobrek streams and the canal flowing across Strzemieszyce Wielkie) have engineered river channels lined with stone or concrete. The Biała Przemsza River, flowing through the southern part of the map area, has natural riverbed. From the south it is recharged by the Kanał Główny Canal, which drains the Szczakowa sand mine area (Ropka, Wyparło, 2004). The Bobrek Stream catchment is characterised by a dense network of drainage ditches, draining wetland areas. In Sosnowiec-Porąbki (Zawodzie), there is artificial Balaton Lake covering the area of 9.7 ha. This is a recreation centre, partly overgrown with vegetation.

Underground extraction of hard coal deposits has large impact on the surface water reservoirs condition. It causes both the drying-up of some lakes (e.g. in the Ostrowy Górnicze district of Sosnowiec) and the formation of new ones, resulting in ground surface subsidence (Sosnowiec Maczki district).

The effects of intense industrial activity are disturbances in the water system and a small number of springs. Spring area in Strzemieszyce Wielkie and Zakawie are among the largest ones.

Land use. Non-built-up areas cover 76%, urban areas account for 11%, whereas industrial areas occupy 13% of the map sheet (Plate 2). Urban and industrial areas of Dąbrowa Górnicza and Sosnowiec cover the northern and western parts of the map sheet.

Barren lands (mainly industrial areas) and forests occupy 46% of the map sheet each. The remaining areas include arable land (<1%), urban lawns and allotment gardens (Plate 3).

Economy. Iron and steel industry is the most important economy sector in this region. The strongly developing businesses include glass, construction, chemical, textile and food processing industries.

The largest companies operating in this region are: ArcelorMittal steelworks (formerly Huta Katowice steelworks) and car glass factory (Saint-Gobain Glass and Saint-Gobain Sekurit HanGlas) in Dąbrowa Górnicza, Szczakowa Sand Mine in Jaworzno and the terminals of the Broad Gauge Metallurgy Line in Sławków (in use by various operators).

In addition to industrial production, other well growing businesses include service activities conducted by companies involved in trade (wholesale and retail) and services for the population: waste management, utilities, consultancy and banking services, telecommunication, transport and education (Program…, 2003).

GEOLOGY AND MINERAL DEPOSITS

The study area is composed of lithologically and genetically diversified Carboniferous, Permian (Rotliegend), Lower and Middle Triassic, and Quaternary deposits (Plate 1).

Carboniferous rocks are known from exposures, mine workings and numerous boreholes. The oldest rocks, outcropping at the surface, are claystones, siltstones and sandstones of the Malinowice Beds discovered in the excavation of the broad gauge railway. They are included in the paralic series of the undivided Lower and Upper Carboniferous (Kurek *et al.*, 1994, 1999).

Upper Carboniferous deposits are represented by coal-bearing series of the eastern part of the Upper Silesian Coal Basin (USCB). These are the Grodziec Beds, Saddle Beds, Ruda Beds and Orzesze Beds. The beds are outcropped at the surface in small patches (south of Cieśle, north of Burki and in the Ostrowy Górnicze district of Sosnowiec). The Grodziec Beds, up to 200 m in thickness, are included in the Namurian. They are represented by sandstones, siltstones, claystones and conglomerates containing thick coal seams (groups 600 and 700). The Saddle Beds, also included in the Namurian, are composed of sandstones, conglomerates, siltstones and claystones with thick coal seams (group 500). The thickness of the Saddle Beds is below 30 m. The Ruda Beds, approximately 300 m thick, are of Namurian–Westphalian age. They are represented by sandstones, siltstones, claystones and conglomerates containing coal seams (group 400). The youngest Carboniferous deposits, outcropping at the surface, are siltstones, claystones and sandstones of the Orzesze Beds included in the Westphalian. These beds contain hard coal seams (group 300). Their thicknesses do not exceed 100 m.

The central-eastern part of the map area is composed of Lower **Permian** (Rotliegend) deposits. These are calcareous conglomerates, more than 100 m thick, several-metres thick porphyry-calcareous conglomerates (Myślachowice conglomerates) and varicoloured claystones and siltstons (Sławków clays) reaching a few tens of metres in thickness. The largest exposures of the Myślachowice conglomerates are observed along the excavation of the broad gauge railway near the Niwa village (Plate 1).

The **Triassic** succession rocks, forming extensive outcrops in the north-east are reduced. The Lower Triassic (Buntsandstein) is 30 m thick and represented by terrestrial deposits: gravels, conglomerates, sandstones and claystones. The upper, undivided unit of the Lower and Middle Triassic (Rhoetian) is composed of marine deposits: dolomites, marls and limestones reaching a thickness of 30 m. The Middle Triassic (Muschelkalk) is also represented by marine deposits. Its lower part is composed of limestones and marls of the Gogolin Beds, attaining a thickness of 30 m. They are overlain by epigenetic Zn–Pb ore-bearing dolomites (including the Górażdże, Terebratula and Karchowice beds in this region) reaching the thickness of 40 to 70 m.

The **Quaternary** cover attains its greatest thickness (up to 70 m) in the ancient valley of the Biała Przemsza River. The sediments are characterised by a great lithological and genetic diversity. The oldest formations are Pleistocene tills deposited during the South Polish Glaciations, exposed at the surface near Strzemieszyce. The largest areas are occupied by Pleistocene glaciofluvial sands and gravels and glaciofluvial sands of alluvial fans. In the southern part of the map area, there are belts of sand dunes of parabolic and star-like shapes. The youngest (Holocene) sediments, filling stream valleys, are represented by silts, clays, sands and peats.

Mineral deposits. Carboniferous hard coal deposits, Triassic clays, limestone and marl deposits and Quaternary sands occur in the presented area. Zinc and lead ore deposits are no longer mined – most of the ore bodies were worked-out between the 13th and 19th centuries.

Almost half of the mining area of the Kazimierz-Juliusz Coal Mine is located in the south-western part of the map area (Preidl *et al.*, 1995). Surface facilities of this mine are located outside its western boundary (in the Dąbrowa Górnicza Map Sheet). The beginnings of the Feliks opencast **hard coal** mine located near the Ostrowy Górnicze district of Sosnowiec date back to the 19th century (Kopalnia…, 2008). At the end of the 19th century, there were two deep mines, which extracted coal from the 510 seam (Reden) of the Saddle Beds. The Kazimierz-Juliusz mine was established after the merger of the mine workings, and it has operated until the present day. The mine covers an area of 23 km^2 and extracts coal from a 21 m thick seam. High quality low-sulphur (0.2–1%) steam coals are mined here. Methane risk in the mine is low (methane hazard category I), but there is a high water inflow (I–III degree of water flooding hazard threat) and rock burst danger (III degree). The mine discharges large quantity of mining water, some of which is mineralized water (brine).

In the late 19th and the early 20th centuries, the Wojciech mine in Grabocin mined coal from the Saddle and Ruda beds. The mine covered an area of 9 ha and developed shallow underground and opencast mining operations. In 1912–1915, the coal was extracted in the same area from the Zdzisław and Zdzisław I coal mine fields. Other mining areas, located today in Dąbrowa Górnicza, were only planned at those times (Obroślak, 2002; Cabała, Cabała, 2004).

Small **clay** deposits have mostly been worked-out. In the eastern part of the map area there is a deposit of Lower Permian variegated clays (Sławków clays). The exploitation is conducted in the Sławków Map Sheet area, where the clays are used in a local brickyard. Extraction of clays from the Strzemieszyce deposit located nearby the ArcelorMittal steelworks (near the national road from Dąbrowa Górnicza to Olkusz) has been abandoned. Lower Buntsandstein clays of this deposit were used for the building ceramics production.

The history of the Zn–Pb ore mining in the study area dates back to the 13th century, when silver-bearing **galena** was extracted (Cabała, Sutkowska, 2006). In the early 19th century, mines extracting **galmei** (oxidized zinc ore) operated on the outcrops of Triassic ore-bearing dolomites near Strzemieszyce. Ore mining was carried out in two open pits (Anna and Barbara).

Limestones of the Middle Triassic Gogolin Beds were mined in the 1960s from the small Strzemieszyce deposit located north of Strzemieszyce Wielkie. The limestones from the deposit, developed for the lime industry, contain an average of 54.09% of CaO, 0.50% of MgO and 1.71% of SiO_2. Nowadays deposit represents no economic value (Preidl, 1997) and its exploitation is abandoned.

The most common mineral deposit is large quantity of Pleistocene glaciofluvial **sands** of an ancient stream valley and alluvial fans. In the south-eastern flank of the map area, there is only the part of the Szczakowa-Pole I sand deposit, used mainly as filling sands and sometimes as building material. These are fine- to medium-grained sands containing from 93 to 95% of the 0.1–2.0 mm fraction. The excavations have been gradually subjected to reclamation by afforestation. Similar sands were extracted from the Staszówka deposit in the 1970s.

In the western part of the map sheet, there are small peat-bogs where peat thickness rarely exceeds 0.5 m. The peat exhibits characteristics of brown coal, with a relatively small content of lignite. They are not applicable as fuel (Preidl, 1997). High peat-bogs in the

Ostrowy Górnicze district of Sosnowiec have been established an ecological site due to the occurrence of rare and protected plant species.

In addition to the proven reserves, sand, limestone and dolomite deposits are periodically extracted in many places for the local needs.

HUMAN IMPACT

Industrial plants, along with highly developed infrastructure (railways, power lines, material and handling stations), and landfills are the main sources of environmental pollution of the region. Industrial activity also causes transformation of the landscape, modification in the natural terrain and changes of channels of watercourses.

Atmospheric air. The greatest source of emissions of dust and gas is the steelworks of ArcelorMittal (former Huta Katowice steelworks). Its main objects and the Przyjaźń coke plant are located outside the northern boundary of the map area. In the northern part of the Strzemieszyce Sheet, there are auxiliary facilities of the steelworks: an ore preparation plant and transfer railway stations.

Construction of the Huta Katowice steelworks, launched in 1972, caused remarkable transformation of the area: changes in urban planning, building a broad-gauge railway and conveyor belt transporting iron ore as well as a number of ancillary plants (Huta…, 2008).

Currently, the steelworks has three blast furnaces, three rolling mills, two lines of continuous steel casting and its own power plant. It produces mainly railway and tram rails and emits more than 100 000 Mg of gas pollutants (carbon monoxide, sulphur dioxide, nitrogen oxides) and about 8 000 Mg of dust.

Emission of odour occurs in the vicinity of the sewage treatment plant at Strzemieszyce. Due to the poor condition of the sewage treatment plant, it is expected to be closed down with a simultaneous rearrangement of water and sewage management in the Dąbrowa Górnicza municipality.

Additionally the air is polluted by emissions from dumping sites, not large industrial plants, heating plants, individual house furnaces, transportation activities and by far-reaching dust emission from Upper Silesian Industrial Region.

Surface water and groundwater. Deterioration of surface water quality is caused mainly by discharge of sewage from the ArcelorMittal steelworks, Przyjaźń coke plant and incinerating plant of the SAPRI company located in Dąbrowa Górnicza, outside the northern boundary of the map sheet. Sewage from the ArcelorMittal steelworks, contaminated with metals, is disposed to the Rakówka Stream. Sewage from Przyjaźń coke (containing chlorides, phenols, PAHs and metals) is discharged after treatment to the Bobrek Stream (Ocena..., 2006).

Until 1984, the wastes from the ArcelorMittal steelworks (mainly metallurgical slag) were stored at the Zakawie landfill and they are currently disposed at the Lipówka landfill located north-east of Strzemieszyce Małe. The landfill has no liner system, so it is a source of contamination to surface water and local aquifers (Labus, 1999).

The main source of pollution of the Biała Przemsza and Sztoła River water is the exploitation of zinc and lead ores in the Pomorzany and Olkusz mines and its processing in the mining and smelting plant (ZGH Bolesław) (Różkowski, Siemiński eds., 1995; Liszka, Świć, 2000; Paulo, Krobicki, 2001). These plants are situated in the Sławków and Olkusz map sheets areas, far away from the eastern boundary of the Strzemieszyce Sheet, but wastewater discharged by the plants moves along with the water of the Biała Przemsza River and the Sztoła Stream. Municipal sewage that is discharged to the Biała Przemsza River and its tributaries causes bacterial contamination of water, oxygen deficits, and enrichment in phosphates and ammonia.

In the past, a significant source of pollution of surface water and groundwater was the STREM chemical plant in Strzemieszyce Wielkie (now in bankruptcy). Since the late 19th century, it has produced paraffin, bone meal, detergents and glycerin and some other products.

Pollution affecting the quality of surface water also contaminates groundwater reservoirs. In the south-eastern part of the map area there is the Quaternary Major Groundwater Basin 453 Biskupi Bór (Kleczkowski, 1990). This is a reservoir of ancient valleys, with a large thickness of water-bearing zones and considerable water resources. The shallowest depth of the water table is found in the Szczakowa sand pit excavations (0.4–1.0 m). The groundwater reservoir is unconfined, open to contamination, and it requires the utmost protection.

In the north-eastern part of the map sheet there is the Triassic Major Groundwater Basin 454 Olkusz–Zawiercie. The thickness of the aquifer is over 100 m. This is a fissure-karst reservoir exposed to areal contamination in the area of Triassic outcrops.

Permanent drainage of groundwater reservoirs (due to intensive coal and sand mining and through the wells) results in the formation of cones of depression, lowering of the water table and decreasing of its resources.

Soils used for agricultural purposes occupy a small area. The possibility of their use is reduced by a significant degree of contamination caused by both natural and anthropogenic factors (Lis, Pasieczna, 1997). The greatest hazards to the soil quality are the industrial activities, leachates from municipal and industrial landfills and emissions of dust and heavy metals from transport facilites.

Due to the soil contamination, the land surrounding the ArcelorMittal steelworks is completely out of use. It is also prohibited to graze animals in this area. In other parts of the map sheet, the soils are locally strongly contaminated with heavy metals and sulphur. They can be cultivated selectively, using special agricultural treatment (Preidl *et al.*, 1995).

A serious threat to the soil quality are warehouses of metallurgical products, iron ore, coal and bauxite in the areas of railway sidings in Rudna, Groniec, Burki and Niwa, and near the terminals of the broad gauge railway in Sławków as well as closed stockyard of scrap materials in Zakawie, stockyard of waste products of ArcelorMittal (Lipówka I) steelworks and municipal landfill Lipówka II in Dąbrowa Górnicza.

MATERIALS AND METHODS

The 2005–2008 research included studying published and archival materials, selecting sampling sites in topographic maps at the scale of 1:10 000, collecting samples, coordinate surveying at sampling sites, chemical analyses of samples, setting up field and laboratory databases, preparing a vector topographic map, statistical calculations, constructing geochemical maps and a geological map, and finally interpretation of results. The sequence of investigations is shown in Figure 1.

FIELD WORKS

Soil samples were collected at a regular grid of 250x250 m (16 samples per 1 km^2). The total number of soil sampling sites was 1295. At every site, two samples were collected from two depths: 0.0–0.3 (topsoil) and 0.8–1.0 m (subsoil). If the parent rock was found shallower in the soil profile the subsoil sample was collected at a smaller 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 aqueous sediments and surface water were collected from rivers, streams, melioration ditches, canals, settling ponds, pools and ponds. The distance between watercourse sampling sites was about 250 m. 500 g sediment samples (of possibly the finest fraction) were taken from water reservoir shores using a scoop. They were subsequently placed in 500 ml plastic containers labelled with numbers.

Surface water samples were collected at the same sites as aqueous sediment samples. Specific electrical conductivity (EC) and acidity (pH) of water were measured on site. EC was measured using conducometer with automated temperature compensation, assuming the reference temperature of 25^{o}C. Water samples were filtered on site 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, type of soil and aqueous sediment). The 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 database safety reasons, all the field data were also noted on special sampling cards (Fig. 2).

LABORATORY WORKS

Sample preparation. The soil samples were air-dried and sieved through a 2 mm nylon sieve. Each topsoil sample (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 (0.8–1.0 m) was sieved and split into two portions: one of them was submitted for chemical analysis and the other was archived (Fig. 1). The soil samples for chemical analyses were pulverized in agate planetary ball mills to a grain size <0.06 mm.

Aqueous sediment samples were air-dried and then sieved through a 0.2 mm nylon sieve. The <0.2 mm fraction was divided into two portions: one of them was used for chemical analysis and the other was archived (Fig. 1).

All the archive samples are stored in the Polish Geological Institute-National Research Institute in Warsaw.

Chemical analyses were carried out in the Central Chemical Laboratory of the Polish Geological Institute-National Research Institute in Warsaw.

Soil and aqueous sediment samples were digested in aqua regia (1 g of sample to final volume of 50 ml) for 1 hour at the temperature of 95^{o}C in the aluminium heating block thermostat.

Contents of Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Ni, P, Pb, S, Sr, Ti, V and Zn in the soil and aqueous sediment samples were determined by an inductively coupled plasma atomic emission spectrometry (ICP-AES) method. Mercury content was measured using a cold vapour atomic absorption spectrometry (CV-AAS) method. Soil pH was measured by water extractions using a pH-meter. Organic carbon content was measured using a coulometric method. Determination of Al, B, Ca, Fe, K, Li, Mg, Na, P, SiO_2, Ti and Zn in surface waters was performed by an ICP-AES method. Contents of Ag, As, Ba, Cd, Cl, Co, Cr, Cu, Mn, Mo, Ni, Pb, Rb, Sb, SO_4, Sr, Tl and U were analysed using an inductively coupled plasma atomic mass spectrometry (ICP-MS) method. The applied analytical methods and the detection limits of measured elements are shown in Table 1.

Quality control was performed through analysis of duplicate samples (about 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). "Reagent blank samples" and "preparation blank samples" were used. Purity of reagents and vessels was controlled with "reagent blank samples". "Blank samples" (*sea sand extra pure Merck*) were used to monitor for possible contamination introduced during the sample preparation procedure.

For the solid samples, analytical precision is ±10–15%. For the surface water samples, analytical precision is about ±10–20% (depending on the element's concentration).

Grain size analyses of topsoils (0.0–0.3 m) were carried out in the Hydrogeology and Engineering Geology Laboratory of the Polish Geological Institute-National Research Institute in Warsaw, using a laser particle size analyzer. Direct use of laser method results does not allow soil classification according to pedological criteria. However, the data are very useful for interpretation of geochemical analyses.

The results of grain size analyses (recalculated to percentage ranges) are presented in the maps with regard 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 (Plates 4–6).

DATABASES AND GEOCHEMICAL MAPS CONSTRUCTION

Base topographic map. The 1:25 000 scale topographic base map was constructed using the most up-to-date *1992* coordinate system topographic map at the scale of 1:50 000, Jaworzno Map Sheet M-34-63-B (vector map VMap L2). The topographic map contains the following vector information layers: relief, hydrography (including dividing into rivers, streams, ditches and stagnant water reservoirs), road communication network (with road classes indicated), railway network, land development (including classification into rural, urban and industrial development), forests, industrial areas (industrial objects, mine shafts, mine excavations, mine dumps and tailing ponds).

Geological map. Geological map was constructed on the base of Detailed geological map of Poland Jaworzno Sheet (Kurek *et al*.,1999) 1:50 000. Particular vector layers of geological map were combined with topographic base producing a geological map at the scale of 1:25 000 (Plate 1).

Database management. Separate databases were prepared for: topsoil (0.0–0.3 m), subsoil (0.8–1.0 m), aqueous sediments and surface water.

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

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

Statistical calculations. Information from the databases were used to create subsets for statistical calculations according to different environmental criteria, e.g. concentrations of elements in soils of industrial areas, in forest soils, in aqueous sediments and water of individual water bodies, as well as for geochemical map construction. Statistical calculations were made for both whole datasets and subsets created for soils, aqueous sediments and surface water. In 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, minimum and maximum values were calculated. These data specified for individual elements, pH and EC are shown in Tables 2–5 and presented in the geochemical maps.

Maps construction. The following maps were produced for the Strzemieszyce Sheet (Plates 2–63): land development, land use, contents of organic carbon and grain size of topsoil (sand, silt and clay fractions); acidity of topsoil and 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 topsoil, subsoil and in aqueous sediments; acidity, specific electrical conductivity and contents of Ag, Al, As, B, Ba, Ca, Cd, Cl, Co, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Rb, Sb, SiO_2, SO_4, Sr, Ti, Tl, U and Zn in surface water; topsoil classification indicating appropriate soil use.

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

To show the distribution of grain size classes (Plates 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 acidity (Plates 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 Strzemieszyce Sheet and the datasets of 1:25 000 scale of neighbouring sheets. Thus any disagreements at the sheet borders were avoided. After interpolation the Strzemieszyce Sheet was extracted from each mono-element maps and combined with the topographic base map.

The geochemical maps of aqueous sediments and surface water were elaborated separately for the Strzemieszyce Sheet area only. 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 (Plate 63), indicating appropriate soil use, the results of geochemical analyses were referred to the permissible levels of metals, defined in the Regulation of the Ministry of the Environment (Rozporządzenie..., 2002), according to the recommendation that "soil or land is considered polluted if the concentration of at least one substance exceeds the permissible limit value".

Based on the contents of individual metals analysed (specified in the 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 (for arsenic, barium and cobalt), the soil was categorized into class A, which is more advantageous to the user and enables multifunctional land use.

For publication purposes, the geochemical maps were constructed by combining the maps into pairs: the topsoil map is presented together with the aqueous sediment map, and the subsoil map is shown with the surface water map. This method of presentation provides the possibility of direct comparison of geochemical images of various media. Taking into account the comfort of potential users, the maps (with a bar scale shown) have been printed out in a slightly smaller format (A3). This operation did not cause omitting any important details of the maps. The whole report or its individual plotter printed maps are available for those who are interested in 1:25 000 scale maps.

RESULTS

SOILS

The parent rocks of the soils in the study area are differentiated in terms of both lithology and age (Plate 1), that gave rise to a variety of soil types. The types of soils clearly reflect the chemical composition of the bedrock. *Rendzinas* developed on Triassic limestones and dolomites. Quaternary tills are the parent rocks of *Cambisols* and *Luvisols*. *Podzols* developed on Quaternary glaciofluvial sandy deposits. *Histosols* occur locally in boggy topographic lows and *Fluvisols* in stream valleys (Program…, 2003, 2004).

Economic activity has contributed to significant changes in soil profiles and their physicochemical properties. Degradation processes occur primarily in the areas of industrial facilities, at landfill sites, building areas, close to transportation routes and in the areas of mineral extraction.

Grain size. Almost all chemical and physical properties of soils are either directly or indirectly related to their mechanical composition. Determination of the grain size of soils provides information about their origin and vulnerability to contamination. This is one of the most important parameters controlling mobility of chemical elements within the soil profile.

Soils rich in the clay (<0.02 mm) and silt (0.1–0.02 mm) fractions are commonly characterized by the highest concentrations of many elements and their lower migration ability under hypergenic conditions. The standards and recommendations on permissible concentrations of metals in soils commonly take account of the soil property, allowing higher limiting concentrations for clay fraction-rich soils and lower limiting concentrations for sand fraction-rich soils (Kabata-Pendias *et al.*, 1995).

Grain-size variability of the soils in the surveyed area is related to parent rocks lithology. The most common are sandy soils containing >75% of the 1.0-0.1 mm fraction, which developed on Pleistocene sands of alluvial fans. These soils contain 5-10% of the silt (0.1-0.02 mm) and clay fraction (<0.02 mm). Sandy soils, occurring in the central and southern parts of the map area, are commonly overgrown with forests. In the western part of the map sheet (outcrops of Quaternary glaciofluvial sands, gravels and tills, and Carboniferous rocks), the proportion of soils rich in the clay and silt fractions increases. The content of these fractions varies mostly within the range of 15–30%.

Acidity. In the central part of the map sheet neutral soils (pH 6.3-7.4) predominate in both the topsoil and subsoil. Locally, the topsoils are acidic (14% of the sheet area), which is mainly observed in woodlands. The lowest acidity (pH <5) was measured in the soil of the railway siding area in Burki, where shipment of iron ore and coal takes place.

Alkaline soils occur in the northern and southern parts of the map sheet (it refers to both the topsoil and subsoil). The pH is associated with both the soils origin and the method of their use. In the northern part of the map area, alkaline soils developed on Triassic carbonate outcrops. Additionally, strong alkalization of the topsoil may relate to scattering of alkaline dust and industrial waste containing calcium and magnesium compounds. This suggestion is supported by the fact that the area occupied by highly alkaline soils is reduced at the depth of 0.8-1.0 m.

Geochemistry. Chemical composition of parent rocks is the most important factor affecting the chemistry of soils. The main geochemical features of parent rocks are best legible in deeper sections of the soil profile. A spatial distribution of elements inherited from the parent rocks often allows recognizing geochemical background variability and identifying natural anomalies.

Distribution patterns of aluminium, barium, cobalt, calcium, iron, nickel, phosphorus, strontium, titanium and vanadium in the soils indicate their clear relationship to the chemical composition of the bedrock. The lowest contents of these elements were observed in the soils developed on Pleistocene glaciofluvial sands covering the central and southern parts of the map area. In the northern part of the map sheet, the soils developed on Triassic carbonates contain much higher amounts of almost all elements. Elevated contents of certain geogenic elements also occur in the western part of the map area, in the regions of outcrops of Carboniferous clastic rocks and Quaternary tills.

Local anthropogenic anomalies of a number of elements were noted in topsoil. The most pronounced metal anomalies occur near waste dump of metallurgical slag at Lipówka and Zakawie. Around the Lipówka waste dump, the following maximum values were measured: 23% of aluminium, 470 mg/kg of chromium and 4900 mg/kg of copper. Anomalies of iron (>4%), manganese (>1600 mg/kg), nickel (>20 mg/kg), strontium (>80 mg/kg), vanadium (>40 mg/kg) and zinc (>1000 mg/kg) were observed both in the vicinity of the ArcelorMittal rolling mill and in the area of metallurgy supply headquarters (Centrala Zaopatrzenia Hutnictwa) between Cieśle and Groniec, which has dealt with storage, processing and handling of steel products, iron ore, coal and bauxite for 60 years.

Anomalies of arsenic, cadmium, lead and zinc occur in both topsoil and subsoil near the sites of historical extraction of Zn–Pb ores (Strzemieszyce Wielkie–Zakawie). In the topsoil and subsoil, the concentrations of ore-related elements are as follows, respectively: cadmium 4–95 mg/kg and 4–201 mg/kg; lead 100–6100 and 100–16 200 mg/kg; and zinc 500–19 700 and 500–55 500 mg/kg. Moreover, the soils in the anomaly area are characterised by high contents of calcium (>1%), magnesium (>0.50%) and manganese (>800 mg/kg). They are also enriched in arsenic (>20 mg/kg) that occasionally accompanies Zn–Pb ores in the form of sulphosalts (Małkiewicz, 1983), but it is a common as significant admixture to iron sulphides associated with Zn–Pb ores (Mayer, Sass-Gustkiewicz, 1998; Paulo, Strzelska-Smakowska, 2000). The highest concentrations of arsenic, up to 659 mg/kg, were detected in the soils near Kołdaczka.

Cadmium, lead and zinc are concentrated mainly in topsoil, and a very strong reduction in the area of the anomalies is observed in subsoil (Table 6).

Arsenic, cadmium, lead and zinc contaminate also the soils of the Biała Przemsza River valley. The elements are sourced from industrial sewage discharges from the ZGH Bolesław zinc smelter as well as Olkusz and Pomorzany Zn–Pb ore mines. Arsenic and cadmium anomalies were found only in the top layer of alluvial soils, whereas lead and zinc anomalies occur in both the topsoil and subsoil.

Clear anomalies of strontium (>80 mg/kg) were revealed in topsoil in the north of the map sheet around the industrial facilities. The four times higher median value of strontium in topsoil suggests a significant influence of the anthropogenic factor on the accumulation of this element.

Extensive silver anomalies were recorded in both the subsoil and topsoil, but in different locations. In the topsoil, the belt of anthropogenic anomalies occurs at the western boundary of the map sheet (in the vicinity of settling ponds in Maczki, abandoned coal mine shafts of the Kazimierz-Juliusz mine and in the centre of Strzemieszyce). In the subsoil silver anomalies occur around the Lipówka waste dump, near the factory of mirrors and car windows, and in the area of the historical extraction of silver-bearing galena (Strzemieszyce Wielkie–Zakawie). Silver originates from outcrops of Zn–Pb ore-bearing dolomites, and from discharges of sewage from the ArcelorMittal steelworks and the Saint–Gobain Glass Company that uses silver compounds for mirrors production.

Mercury anomalies (>0.40 mg/kg) were found in the topsoil in the areas of ArcelorMittal steelworks facilities, around the chemical plant (near the sewage treatment plant of the steelworks) and at the Lipówka waste dump of slag. In the western part of the map area (Strzemieszyce region), the mercury content often exceeds 0.10 mg/kg, and some of anomalies reach down to the depth of 0.8-1.0 m.

The sulphur content in topsoil usually varies within the limits of 0.010-0.080%. Enrichment in sulphur occurs in industrial areas and wetlands (in the Biała Przemsza River valley and other watercourse valleys). The subsoil map shows the greater area of sulphur content of <0.010%.

Organic carbon in topsoil has a simple distribution pattern. Its content varies between 0.7-3.0%, increasing to 24.0% in peaty soils. The maximum TOC concentration (55.3%) was recorded at the railway siding in Groniec near coal depot.

Phosphorus-enriched soils developed on Triassic carbonates and Quaternary tills in the northern part of the map area. It is a rule that all the topsoils contain more phosphorus than subsoils. The average phosphorus content in topsoil (0.020%) is almost three times higher than the content (0.007%) measured in the subsoil (Tables 3 and 4). This is probably the result of fertilization. Local phosphorus anomalies (>0.120%) were observed in the topsoil in the premises of the STREM chemical plant producing detergents and in peaty soils of the Rudna vicinity.

Contents of many elements depend on the soil use. The lowest contents are observed in forest soils, higher – in soils of rural areas. Urban built-up areas are characterised by high concentrations of arsenic, cadmium, lead and zinc. The maximum concentrations were observed in industrial areas and wasteland regions, which are often brownfield land.

The heavy metal contamination of soils is a problem for the local authorities and should be discussed with respect to the appropriate land use. To fit the geochemical data to the local authorities' needs the topsoils of the sheet were classified applying current guideline values (Table 7) established by the Polish Ministry of the Environment (Rozporządzenie…, 2002). The guideline values are based on the average of particular elements in soils for Poland as a whole and also on the assessment if the content of a particular element may have negative influence on the ecosystem or on human health. Guideline values are applied for three-level scale: A (protected areas), B (agricultural, forest and residential areas) and C (industrial areas).

The estimation of the degree of contamination by metals was carried out for the topsoil, classifying them with respect to soil use into the groups A, B and C based on permissible limit values (Rozporządzenie…, 2002). The total classification was calculated using the rule that the sample is classified to a particular soil use group if the content of at least one element exceeds the permissible limit value. With respect to contents of metals, 17.61% of the topsoils were included into group A, 37.76% into group B and 44.63% into group C (Table 7). The classification (Plate 63) indicates recommended land use according to guidelines provided in Rozporządzenie..., (2002). Much of the soils are currently improperly used and require monitoring or local reclamation. Concentrations of metals in the soils of some forest, agricultural, grassland and garden areas are so high that the land should be used for industrial purposes only.

The only soils that meet requirements of multi-purpose use are those categorized into classes A and B. The soils classified into group C are mainly found in the northern part of the map sheet in the outcrops of Zn–Pb ore–bearing dolomites, in urban and industrial areas, as well as in the Biała Przemsza River valley. The main pollutants in the soils are zinc, cadmium and lead.

AQUEOUS SEDIMENTS

The sediments were sampled from: Biała Przemsza River and its tributaries (Kanał Główny Canal, Kozi Bród and Sztoła streams), Bobrek Stream and its tributaries (Jamki and Rakówka streams), drainage ditches and stagnant water reservoirs.

Biała Przemsza River and its catchment. The Biała Przemsza River valley is natural, but the chemical composition of alluvial sediments has been strongly transformed by anthropogenic factors.

The Biała Przemsza River sediments are contaminated by silver, arsenic, cadmium, mercury, lead, sulphur, and zinc throughout the whole section under study. They also contain high amounts of calcium, magnesium, manganese and strontium (Table 4). The maximum values in the analysed catchment area are as follows: 14 mg/kg of silver, 393 mg/kg of arsenic, 154 mg/kg of cadmium, 16 400 mg/kg of lead, 3.490% of sulphur and 27 100 mg/kg of zinc. These elements are sourced from wastewater discharges from the ZGH Bolesław zinc smelter and Olkusz and Pomorzany Zn-Pb ore mines as well as from other sources located outside the eastern boundary of the map area. Wastewater is discharged into the Biała Przemsza River by the Kanał Roznos Canal and by the Biała and Sztoła streams (Labus, 1999).

The maximum concentration of mercury (1.56 mg/kg) was recorded in sediments of a small water reservoir in Zagródki, near an illegal waste dump. These sediments are also enriched in aluminium (1.54%), copper (215 mg/kg), chromium (70 mg/kg) and strontium

(196 mg/kg). The pollution originates from waste stored in an uncontrolled way around and inside the reservoir.

Sediments of the Kozi Bród Stream (tributary of the Biała Przemsza River) are contaminated by chromium (>150 mg/kg) derived from the discharge of sewage from the Szczakowa tannery.

Kanał Główny Canal and its catchment. The canal, together with a network of drainage ditches, drains the excavations of the Szczakowa open-pit sand mine. In this area, alluvial deposits of some watercourses are enriched in barium, cobalt, iron, manganese, nickel, strontium and zinc. The highest concentration of manganese (262 558 mg/kg) was found in sediments of the Kanał Główny Canal tributary, that drains a reclaimed part of the Szczakowa sand mine. Sediments enrichment in metals can be related to sorption of elements by iron hydroxides, commonly found in peat bogs that form as a result of an unplanned effect of reforestation of abandoned mine workings.

Bobrek Stream and its catchment. The Bobrek Stream springs at Groniec are situated in the middle of the map sheet. In addition to the tributaries of Rakówka and Jamki streams, the Bobrek Stream is recharged by a canal flowing through Strzemieszyce from the Przyjaźń coke plant, and by numerous drainage ditches.

The sediments in the upstream course of the Bobrek Stream are enriched in aluminium, arsenic, cadmium, chromium, mercury, iron, manganese, strontium, vanadium and zinc. It can be related to covering this area by peaty and silty-clay soils with a high sorption potential, which are the main alluvium component. The metals are derived from discharges of sewage from terminals of the broad gauge railway in Groniec.

Alluvial sediments also contain high contents of barium (500–1000 mg/kg). The source of the element is barite used in gravity separation of iron by ore crushing plant (located within the rail terminals).

The sediments of right-bank side tributaries of the Bobrek Stream (Rakówka and Jamki streams and an unnamed watercourse flowing from the Przyjaźń coke plant area) are enriched in chromium, copper, iron, manganese, nickel and strontium. These elements come mainly from discharge of liquid sewage from industrial plants located at the northern boundary of the map sheet.

Sediments of the lower course of the Rakówka Stream and the Bobrek Stream, downstream of the Rakówka Stream mouth, contain high amounts of silver (5- 40 mg/kg). Contamination is presumably related to discharges of sewage from the Saint-Gobain Glass company that uses silver compounds for the mirrors production.

Aqueous sediments of watercourses in the Strzemieszyce Wielkie and Zakawie area, draining Triassic Pb–Zn ore-bearing carbonates, contain high concentrations of lead (up to 4000 mg/kg), zinc (up to 18 500 mg/kg), cadmium (up to 43 mg/kg) and arsenic (up to 107 mg/kg). They are also enriched in calcium and magnesium.

Throughout the whole drainage basin, particularly in the Ostrowy Górnicze district of Sosnowiec, high phosphorus concentration, often exceeding 0.640%, was recorded. The anomalies are probably of a mixed geological-anthropogenic nature. Anthropogenic pollution is mainly related to discharge of municipal and industrial sewage (mainly from the STREM chemical company producing detergents). The spatial distribution of phosphorus is similar to the patterns of iron, phosphorus and manganese, in both aqueous sediments and soils.

SURFACE WATER

Biała Przemsza River and its catchment. Water acidity in the Biała Przemsza River drainage basin varies from 5.7 to 9.2 (Table 5) and most samples show slightly alkaline pH. Their electrical conductivity ranges from 0.10 to 2.73 mS/cm. The highest conductivity values were observed in the water of unnamed streams in the vicinity of Korzeniec (2.73 mS/cm) and in the Kozi Bród Stream valley (1.08 mS/cm), whereas the lowest values – in the watercourses draining the Szczakowa sand mine area (0.30-0.40 mS/cm).

The water of Biała Przemsza River (and their tributary Sztoła Stream) contains high content of arsenic, cadmium, cobalt, magnesium, lead, zinc, and is enriched in calcium and sulphates. Water enrichment in these elements occurs along the Biała Przemsza River and the Sztoła Stream, downstream of sewage discharge from the ZGH Bolesław zinc smelter and Zn–Pb mines in the Olkusz and Sławków map sheets.

A serious threat is posed by the thallium concentration ranging mostly between 15 and 20 μg/dm^3, reaching a maximum of 32.00 μg/dm^3. The median value of this element in the analysed catchment (22.00 μg/dm^3) is much higher than the median for the entire map sheet (0.06 μg/dm^3). In the water of the Silesia-Cracow region, the thallium content is usually high, varying from 0.16 to 3.24 μg/dm^3 (Paulo *et al.*, 2002), while the geochemical background in surface water of Poland is 0.006 μg/dm^3 (Salminen ed., 2005). Thallium and many of its compounds, especially sulphates, have been considered very toxic substances, whose concentration in the environment is particularly hazardous for living organisms.

High concentrations of aluminium (800–2000 μg/dm^3), cadmium (>3.2 /dm^3) and zinc (800–2800 μg/dm^3), and enrichment in lead (up to 33 μg/dm^3) and thallium (up to 0.62 μg/dm^3) were noted in unnamed endorheic watercourses near the Korzeniec. The bedrock in this part of the drainage basin is represented by Pleistocene sandy deposits of poor mineral composition. Water pollution can be therefore related to anthropogenic factors, like the high content of boron (1069 μg/dm^3) and uranium (3.6 μg/dm^3) in a small stagnant water reservoir located north of Zagródki (around which there is a illegal waste dump).

The water of the lowest reach of the Kozi Bród Stream is enriched in several elements (boron, chlorine, potassium, lithium, molybdenum, sodium and sulphates, and is enriched in rubidium and uranium). High contents of these elements were also found in the water of the upper reach of the stream, in the east of the sheet border. They are related to discharge of cooling water from the Siersza Power Plant, which draws water for technological processes from the Arthur mine shaft (abandoned KWK Siersza coal mine). High amounts of chlorine and sodium are also due to sewage discharges from the Szczakowa tannery.

The average silica content <0.1–16.5 mg/dm^3 is typical for surface water (median 8.3 mg/dm^3).

Kanał Główny Canal and its catchment. The water in the catchment is characterised by neutral pH. The exceptions are small reservoirs in the railway siding area at the southern boundary of the map sheet, where the water shows alkaline pH (>8.0). Electrical conductivity of the drainage basin water is low, varying between 0.13 and 0.50 mS/cm (Table 5).

Some water reservoirs are characterised by high contents of boron (200-400 μg/dm^3). The water enrichment in barium (100–150 μg/dm^3), cobalt (up to 4.2 μg/dm^3), iron (up to 7 mg/dm^3) and manganese (up to 680 μg/dm^3) was observed in the tributaries of the Kanał Główny Canal, in the area of anomalies of these elements in bottom sediments. It can be a result of the development of intermediate peat bogs at these sites. The water of the drainage basin's streams contains low amounts of silica (average 7 mg/dm^3).

Bobrek Stream and its catchment. The drainage basin water pH values range from 2.8 to 9.4 (Table 5), with the most common value of 7.5. The lowest pH value was noted in a small pond in the Feliks residential district of Sosnowiec.

Electrical conductivity of the Bobrek Stream water is definitely different upstream of the confluence with the Rakówka Stream together with the stream flowing from the Przyjaźń coke plant area (0.46–0.80 mS/cm), and downstream of this site (1.63–2.16 mS/cm.) The EC value in the Rakówka Stream water reaches 1.82 mS/cm downstream of discharge sewage from the ArcelorMittall steelworks. In the water of the canal carrying leachates from the Przyjaźń coke plant average EC value is 4 mS/cm and the maximum value reaches 6.11 mS/cm.

Conductivity values in the Jamki Stream water (north-western part of the map) are invariable ranging between 0.75 and 0.87 mS/cm. EC values of the water from minor watercourses and reservoirs in the Ostrowy Górnicze district of Sosnowiec are around 1 mS/cm.

Similarly to the sharp change of EC, there is also an increase in the concentrations of a number of elements in the Bobrek Stream, downstream of the confluence with the Rakówka Stream. The content of chlorine in the upstream reach of the Bobrek Stream does not exceed 80 mg/dm^3, whereas downstream of the confluence with the Rakówka Stream, it ranges from 400 to 570 mg/dm^3. The following contents were measured in both sections of the stream, respectively: potassium <12.9 mg/dm^3 and 30–60 mg/dm^3, lithium <8 μg/dm^3 and 20–30 μg/dm^3, molybdenum <4.00 μg/dm^3 and 4.70–9.40 μg/dm^3, sodium <50 mg/dm^3 and 220–350 mg/dm^3 and rubidium <19 μg/dm^3 and 250–570 μg/dm^3.

The high EC and high concentration values of many elements result from discharge of industrial sewage. High salinity of wastewater from the Przyjaźń coke plant is the result of purification waste water and combustion gas. The presence of metals in sewage from the ArcelorMittal steelworks is mainly associated with the activities of its sinter plant (Program…, 2003).

The water of the Bobrek and Rakówka streams is enriched in thallium (0.20-6.70 μg/dm^3) and molybdenum (5-20 μg/dm^3) transported by sewage from the ArcelorMittal steelworks.

In streams flowing across the central area of the map sheet and those of the canal carrying sewage from the Przyjaźń coke plant waters are enriched in cobalt, nickel and sulphates. In the western part of the Bobrek Stream drainage basin, they are enriched in boron and uranium, probably originating from outcrops of Carboniferous rocks and old tailings piles of abandoned mine shafts the Kazimierz-Juliusz coal mine. The uranium values in the Bobrek Stream catchment range from <0.05 to 18.00 μg/dm^3. The enrichment of this element is related to draining of organic matter-rich soils and Carboniferous coal-bearing formations (Bojakowska *et al*., 2008).

CONCLUSIONS

1. The topsoils and subsoils are enriched in heavy metals in areas of Triassic carbonates and Carboniferous rocks (in the northern and western parts of the map sheet). The anomalies occur mainly in topsoil. At a depth of 0.8–1.0 m, there is a reduction of their extent accompanied by increasing anomalies intensity (particularly noticeable in the case of cadmium, lead and zinc).

2. Aqueous sediments and surface water are contaminated with heavy metals and show high concentrations of other elements.

3. The metals are sourced from outcropping Triassic Zn–Pb ore-bearing deposits, and, to a lesser extent, from Carboniferous coal-bearing formations.

4. Anthropogenic sources of the environmental pollution are the historical extraction and processing of Zn–Pb ore, ferrous metallurgy and discharges of industrial sewage (from power and coke plants, railways terminals, chemical plants), and leachates from old mining waste dumps.

5. The permissible limits in soils are most exceeded for zinc, cadmium and lead. These elements are primarily of geogenic origin.

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