INTRODUCTION

Geochemical mapping of Poland (Lis, Pasieczna, 1995a, b) has proved that the most polluted soils, aqueous sediments and surface water occur in the Silesian region. In the area of the discovered regional anomaly of heavy metals mapping works on 'Detailed geochemical map of Upper Silesia (SMGGŚ)' scale 1:25 000 started in 1996 with the pilot project of the Sławków Map Sheet (Lis, Pasieczna, 1999).

Geochemical mapping at the scale of 1:25 000, carried out in the Katowice Map Sheet M-34-63-A-c area is the continuation of detailed serial mapping works conducted by the Polish Geological Institute – National Research Institute since 1996. The project is ordered by the Ministry of the Environment and financed by the National Fund for Environmental Protection and Water Management. The purpose of the study is to identify areas degraded due to long-lasting hard coal mining, smelting, power supply and other industries activity.

The Katowice Map Sheet area is situated in the central part of the Upper Silesian Coal Basin (USCB, GZW in Polish), where mining industry and processing of ore deposits have shaped the natural environment and landscape for centuries, contributing to the development of urban settlement and subsequently giving rise to Poland's largest urban and industrial region.

Since the 14th century, bog ore deposits were mined locally in the Murcki forests, and charcoal was produced for purposes of ore reduction.

In the mid-17th century, hard coal mining started in the Boże Dary and Murcki areas. Initially, coal was used in the process of zinc and lead smelting. Intense development of hard coal mining occurred during railway network development in the 19th century, and the peak coal production took place in the late 20th century.

Since the late 1990s, mining industry and related branches have diminished due to industrial restructuring. Simultaneously, the economic use of post-mining tailings has increased, significantly contributing to the reduction of the environment contamination.

Land use of the Katowice Map Sheet area has an urban and industrial character with a large proportion of industrial facilities and transportation routes. Large areas are covered by forests with two nature reserves, one nature and landscape protected area, one ecological site and areas of valuable forest stands.

Within the Dolina Trzech Stawów valley (Katowice Forest Park), there is the recreation complex including the sport airfield in Muchowiec. Popular recreation sites are the Kościuszko Park, Bolina recreation centre in Katowice and Wesoła Fala recreation centre in Mysłowice-Wesoła. A cycleway network, tourist routes and walking tracks have been developed in the region.

Information on the soils, aqueous sediments and surface water quality in the Katowice 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.

CHARACTERISTICS OF THE MAP AREA

Geographical and administrative setting. The Katowice Map Sheet covers some of the area of Silesian Voivodeship and includes parts of the cities (urban districts) of Katowice, Mysłowice and Tychy. Most of the map area lies within the boundaries of Katowice (Brynów, Muchowiec, Janów-Nikiszowiec, Giszowiec, Murcki and Kostuchna districts), its eastern part belongs to Mysłowice (Janów Miejski, Bończyk, Ćmok, Wesoła, Morgi, Krasowy and Ławki districts), and a small south-western part is situated within the limits of Tychy.

According to the physiogeographic subdivision of Poland, the study area belongs to the Katowice Upland, which is the central part of the Silesian Upland (Kondracki, 2000).

Relief and geomorphology. The basement of the Katowice Upland is composed of Carboniferous hard coal-bearing rocks cut by a number of faults; hence, the relief is conspicuous by horst-like plateaus separated from one another by tectonic depressions. This is a low relief area characterized by small hills and shallow topographic lows. The flat-topped and gently sloping hills are composed of Carboniferous claystones and siltstones. On outcrops of thick-layered sandstones prominent hills occur. The hills form sublongitudinal belts reaching the elevation of 300–357.6 m a.s.l. The distinctive landforms in the landscape are the Las Murckowski ridge (with the Wanda Hill), Stara Wesoła and Wesoła-Krasowy hill belts and some culminations in the centre of Mysłowice (Studium..., 2008).

In hard coal mining areas, huge piles of barren rocks arose. The original topography was disturbed by terrain depressions formed as a result of underground mining-induced subsidence.

Most of the map area belongs to the Vistula River drainage basin (Wagner, Chmura, 1997). Its northern part is within the Rawa River and Bolina Stream drainage basins, which are the tributaries of the Czarna Przemsza River. Seepages spring areas of the Rów Murckowski, Pstrążnik and Przyrwa rivers are located in the southern part of the map area. These rivers flow into the Mleczna River, outside the southern border of the map sheet. A small area in the west is drained by the Odra River tributaries – Kłodnica and Ślepiotka rivers. Over the whole area, especially in its southern part, there is a well-developed system of unnamed watercourses (streams, ditches and canals) carrying water only during wet periods.

The characteristic feature of the hydrographic network is water reservoirs (post-mining depressions and shallow flow-through ponds) that developed as a result of either open-cast mining or post-mining subsidence. Some of them are used as the recreation sites or fish ponds. Reservoirs of special use are represented by tailings ponds, industrial settling tanks etc.

Land use. About 70% of the study area is covered by forests (Plate 2). For natural forests protecting, a number of reserves have been created: the Ochojec and Las Murckowski nature reserves, a nature and landscape protected area at the Kłodnica River spring and the Płone Bagno ecological site (near the south-eastern edge of the map sheet). Urban and industrial areas cover approximately 15% of the total area. These are parts of residential areas of Katowice and Mysłowice, situated mainly in the north and east of the map sheet (Plates 2 and 3), as well as hard coal mining areas, road transport bases and building factories. Small areas of grassland and agricultural land (about 10% of total area) are located mostly in the east. The remaining area is used as urban parks, water reservoirs, roads, railway tracks, barren lands etc.

Economy of the region is based mainly on hard coal mining. Exploitation is currently conducted by the Katowice Coal Holding company (Katowicki Holding Węglowy: KWK Murcki-Staszic, KWK Wieczorek) and KWK Mysłowice-Wesoła Centrum Coal company (Centrum Wydobywcze KWK Mysłowice-Wesoła)(Katowicki…, 2010).

The mining area of the KWK Murcki-Staszic coal mine is located in the central and western part of the map sheet. The beginning of hard coal mining dates back to 1657 here, when coal was mined from seams outcropping at Rudne Kotliska. In 1755, the first mine shaft was built, and by 1815, the mine already had 30 mine shafts. In 1976, the Murcki mine and the Boże Dary coal mine joined. The Boże Dary mine is probably the oldest hard coal mine in Poland (Jaros, 1984). Its objects are located near the Kostuchna residential area in the south-western part of the map sheet. In 1956–1964, three opencast pits existed at the Murcki mine in addition to its underground extraction. The KWK Staszic mine, one of the most modern coal mines in Poland, started its production in 1964. In 2010, it was incorporated into the KWK Murcki-Staszic Company.

The KWK Wieczorek mine has had almost two hundred-year tradition. It produced coal (in the Katowice districts of Nikiszowiec, Giszowiec and Janów) already at the beginning of the 18th century, and the first coal mine named Bergthal was founded in 1788. In the next years, a number of small mines operated in this area. They were integrated in 1884 into one company named Giesche. In 1945, the company was renamed to Janów mine. Since 1951, it has operated under the name of KWK Wieczorek mine. The mine produces high quality coal using modern production techniques.

KWK Mysłowice-Wesoła Centrum Coal company was established in 2007 when the Mysłowice and Wesoła mines joined. The Mysłowice mine started its production in 1887. An important event in its history was the introduction of the hydraulic filling for the first time in the world's mining in 1901. The KWK Wesoła mine was founded in 1942. In the period of 1967–1989, it was called KWK Lenin.

The KWK Katowice mine was closed in 1999; however, some of its buildings in Muchowiec have been retained as interesting historical objects.

In addition to mining industry, retail and service industries, transportation and building sectors are well developed in this region (mainly in city centres). The restructuring carried out during the last several years gave rise to a decreasing trends in production output, number of factories and the proportion of industry sector jobs in the employment structure. This trend is observed in the whole Upper Silesian region.

GEOLOGY AND MINERAL DEPOSITS

The map area is situated in the central part of the Upper Silesian Coal Basin (USCB) within the Main Trough cut by a number of faults (Biernat, 1970; Biernat, Krysowska, 1956). Carboniferous and Quaternary deposits are exposed at the surface.

Lower **Carboniferous** deposits are known from boreholes and mine excavations. Coal is extracted from Upper Carboniferous seams of the Saddle Beds (Namurian B–C), Ruda Beds (Westphalian A) and Orzesze Beds (Westphalian B).

The Saddle Beds (60–70 m thick) are composed of sandstones, conglomerates and shales with coal seams of the total thickness of 14–17 m. No outcrops of the beds are observed on the surface in the map area.

The Ruda Beds are exposed at two small sites near the northern boundary of the map area (Plate 1). Their thickness varies between 250 and 330 m. The rocks are represented by sandstones and grey shales with coal seams. The lower part of the succession contains six thin coal seams, whereas the upper part contains about 30 coal seams, 1–7 m in thickness (Biernat, 1970).

Sandstones and claystones of the Orzesze Beds contain hard coal seams and occur right on the surface (Plate 1). They are represented by shales and sandstones with siderites, and include over 50 coal seams, with two of them exceeding 1.5 m in thickness. The Orzesze Beds are approximately 220 m thick in the Wujek coal deposit (in the west) and 850 m thick in the Wesoła coal deposit (in the east).

Neogene deposits are known only from boreholes and mine excavations. These are mostly Miocene clays and sands attaining a thickness of a few tens of metres.

Quaternary deposits, covering topographic lows and river valleys, are variable in their lithology and origin. The oldest Pleistocene deposits are represented by tills of the South Polish and Middle Polish glaciations, overlain by glacial sands and gravels with boulders. Extensive till covers are observed north of the Bolina Stream and in small areas of the Rów Murckowski and Przyrwa river valleys. Odranian Glaciation deposits are represented by glaciofluvial sands and gravels, most frequent near the southern boundary of the map area. Thickness of the Pleistocene series varies from less than 1 m to several tens of metres. Present-day river valleys are filled in with several-metres thick Holocene sands, gravels and muds.

Mineral deposits. Almost the whole sheet area is occupied by mining areas of active hard coal mines. Coal extraction is carried out in difficult geological-mining conditions due to a complicated tectonic setting, variable depth of coal seams and their different thicknesses, hazard from water, dust, fire and methane bursting in mining pits as well as due to rock burst. The following hard coal deposits occur within the boundaries of the map sheet: Murcki, Staszic, Mysłowice, Wesoła, Wieczorek and Wujek (Kowalska, 1997).

The Murcki deposit comprises coal seams of the Orzesze Beds (of the group 300). Steam, gas and gas-flame coal of average heating value 26 100 kJ/kg, average ash content 15.3% and average sulphur content 0.89% is extracted from the deposits. Thicknesses of the coal seams (economic reserves) varies from 1.0 to 2.9 m (Jochemczyk, *et al.*, 2002).

Steam coal of the Saddle and Ruda beds is exploited from the Staszic coal deposit. Thicknesses of the economic coal seams ranges between 1.0 and 11.6 m. They are characterised by the average ash content 9.0%, total sulphur content 0.6% and heating value 28 518 kJ/kg.

Steam coal of the groups 500 and 400 with the average calorific value 26 584 kJ/kg, ash content 8.89% and sulphur content 0.78% is extracted from the Saddle and Ruda beds of the Mysłowice coal deposit. Thicknesses of the economic coal seams varies from 1.0 to 11.0 m.

The Wesoła coal deposit produces steam coal (from the Saddle and Ruda beds) from 1.0−12.5 m thick seams. The average parameters are as follows: ash content 12%, total sulphur content 0.6%, and heating value 26 700 kJ/kg.

The Wieczorek coal deposit contains steam coal of the average ash content 6.0%, average total sulphur content 0.6% and average heating value 29273 kJ/kg. The coal seams, 1.0–11.5 m in thickness, are represented by the Ruda and Saddle beds (Jochemczyk *et al.*, 2002).

The Wieczorek and Wesoła coal deposits contain economic reserves of coal-bed methane extracted only at the Wesoła Coal Mine and used by a local heating station (Program…, 2008).

Raw rock materials. The following clay deposits have been proved within the map area: Park Kościuszki, Karbowa, Wesoła, Wesoła II and Silesia B. The rocks are represented by Carboniferous clay shales and clays and Quaternary tills (Jochemczyk *et al.*, 2002).

Extraction of most of the deposits is limited by land-use type of the areas (Wołkowicz *et al.*, 2009). Tills and sands were also exploited for local purposes in the past, and currently the working pits are commonly filled with water.

HUMAN IMPACT

Due to activity of mining and other industries (including historical smelting of non-ferrous metals), the natural environment of Mysłowice, Jaworzno and Sosnowiec has been highly altered. Human activity resulted in changes in the topography, and hydrographic network. The soils and alluvial deposits have also been chemically altered.

Atmospheric air. The air quality is affected mainly by coal combustion and related emissions of dust, carbon oxides, nitrogen dioxide, hydrocarbons and heavy metals.

Most of the air pollution originates from industrial emissions: from heating stations of mines, local heating stations in Kostuchna and Murcki and from heating of individual houses in Nikiszowiec, Giszowiec and western districts of Mysłowice. The air quality is also affected by pollution from industrial plants located beyond the the map area borders, e.g. a heating plant and the iron smelter in Katowice and the Chorzów power plant (Program..., 2006). A serious source of the air contamination along transportation routes and city roads is engine exhaust fumes containing hydrocarbons, nitrogen dioxide, carbon oxide and lead compounds.

The results of state monitoring indicate that permissible concentrations of most of air pollutants are not exceeded in the map area. The average annual concentrations of sulphur dioxide, nitrogen dioxide, carbon oxide, lead and ozone fall within class A (highest quality). Concentrations of PM 10 dust and benzo(α)pyrene remain within class C (Program…, 2006; Stan…, 2008). In 2004–2007, permissible values of phenol and cadmium were sometimes exceeded (Program…, 2008).

Surface water and groundwater. The quality of surface water is poor due to discharges of mining water causing chemical alterations and disturbance in natural supply of watercourses (Ocena…, 2007).

Mining waters are characterised by mineralization increasing with depth, which is regularity observed in many coal basins throughout the world, and is called as the normal hydrochemical zonation (Pluta, 2005). The uppermost water-bearing horizons commonly contain fresh water and the mineralization value increases with depth, so that the lowermost horizons contain brines mainly. The coal mines selectively pump up water from different water-bearing horizons, discharging fresh water, saline water or brine to the streams and rivers.

About 60% of all water from the hard coal mines is discharged to the watercourses, resulting in both increased water flow rates and salinity. The amount of mining water varies from 746 m^3/day from the Mysłowice-Wesoła hard coal mine to 5040 m^3/day from the Staszic hard coal mine. The poor quality of mining waters is mainly due to the concentrations of chlorides and sulphates (Gabzdyl, Pozzi, 2001; Razowska-Jaworek, 2007). Despite preliminary desalinization processes in mine tunnels, the permissible limits of both physicochemical and bacteriological indicators are exceeded.

Mining waters flow to the Czarna Przemsza and Mleczna rivers via their tributaries (Nałęcki, 1990). The KWK Wieczorek hard coal mine discharges highly mineralized water to a tailing pond, where it mixes with sewage from the Nikiszowiec sewage treatment plant. Low mineralization mining waters are preliminarily purified in mine tunnels and settling ponds. All the water is discharged to the Bolina Stream, which also receives mining water from the KWK Staszic hard coal mine and purified sewage from habitable districts – Giszowiec and Janów (Różkowski, Siemiński, 1995).

Serious hazard to the quality of surface water and groundwater is caused by eluates from mining dumps. Over 40% of barren rocks mined together with coal are stored there. Mining dumps of various size and age are distributed near Giszowiec, Nikiszowiec, Boże Dary, Murcki and Wesoła. Eluates from mining dumps are usually acidic due to pyrite oxidation and combined with water make sulphuric acid. The acidic environment cause mobilization of many elements and their transfer to the water.

A potentially hazardous source of surface water contamination is also sediments that accumulate during hard coal processing in settling ponds (Nałęcki, 1990).

The quality of surface water is affected by unregulated waste management and sewage discharge from municipal and industrial wastewater treatment plants in Giszowiec, Janów-Nikiszowiec and Mysłowice (Program…, 2006, 2008). Some of the industrial plants of the region posses their own sewage treatment stations, but many others discharge sewage to the municipal sewage system and the degree of purification is often insufficient.

No major groundwater basins are distinguished within the Katowice Sheet (Kleczkowski, 1990). The boundary of the Mikołów-Sosnowiec useful aquifer runs from Brynów in the West through Giszowiec to the centre of Mysłowice. The aquifer found in Carboniferous fissured and porous rocks (Różkowski, Chmura, 1996) is supplied directly from the surface or indirectly through Quaternary deposits.

Soils. Soils of the sheet area are polluted due to long-lasting hard coal mining and other industrial activity, development of transport systems and intensive urbanization.

Changes in soil properties result from e.g. dumping of mine tailings (in mine dumps and tailing ponds) and disturbing of hydrogeological conditions due to coal extraction. Industrial dusts, gases, and exhaust fumes, eluates from waste dumps as well as alluvial soil salinization (in result of floods) play an important role too.

Soil contamination by heavy metals results mainly from the activity of industrial plants, repair and service stations as well as transportation services. On a local scale, such contamination is due to dumping of outdated pesticides, mine tailings, smelting wastes and other hazardous substances. The soils in Katowice and those situated along main transportation routes are enriched with cadmium, zinc and lead (Lis, Pasieczna, 1997; Program…, 2006).

Mechanical modification of soil structure takes place due to settlement activity, hardening, compacting, soil cover removal, mixing with foreign materials, formation of ditches and embankments, and due to surface levelling. Rock bursts contribute to terrain modification, and in consequence to the formation of post-mining lakes (Chwastek *et al.*, 1990) and thus soil alterations.

MATERIALS AND METHODS

The 2007–2010 researches 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 vector topographic sheet, 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 1329 (Plate 2). 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 form 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 ladle. 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 marked at topographic maps at the 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 type of soil and aqueous sediment). The coordinates were taken with the 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 at the Polish Geological Institute–National Research Institute in Warsaw.

Chemical analyses were carried out at 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°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 (H_2O) was measured using a pH-meter. Organic carbon content was measured using a coulometric method. Determination of B, Ba, Ca, Cr, Fe, K, Mg, Mn, Na, P, SiO_2, SO_4, Sr, Ti and Zn in surface waters was performed by an ICP-AES method. Contents of Ag, Al, As, Cd, Cl, Co, Cu, Li, Mo, Ni, Pb, Rb, Sb, Tl and U were analysed using an ICP-MS method. The applied analytical methods and the detection limits of measured elements are shown in Table 1.

The control of the determinations was performed through analysis of duplicate samples (about 3% of all samples), analysis of reference materials with certified content of elements studied (2.5% of all samples) and analysis of laboratory control samples confirming correct instrument calibration (10% 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 below 25%. For the surface water samples, analytical precision is about 15–25% (depending on the element's concentration).

Grain size analyses of topsoil (0.0–0.3 m) samples were carried out at the Hydrogeology and Engineering Geology Laboratory of the Polish Geological Institute–National Research Institute in Warsaw, using a laser particle size analyzer. Advantages of the laser technique include the following: small sample volume (<1 g), quick measurement and high determination accuracy with regard to some grain sizes (Dębicki *et al.*, 2002).

The comparisons of the results of grain-size analyses obtained using a sieve-sedimentation method (according to the international classification of FAO and USDA) and the laser technique show significant differences in the proportions of individual fractions (Kasza, 1992; Issmer, 2000). Thus, 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 MAP 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, Katowice Map Sheet M-34-63-A (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 basis of Detailed Geological Map of Poland, 1:50 000, Katowice Map Sheet (Biernat, Krysowska, 1956). Individual elements of the geological map were digitized to create their vector images which were subsequently combined with the topographic base, producing the 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, forest soils, urban soils and 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 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, pH and EC are shown in Tables 2–5 and presented in the geochemical maps.

Map construction. The following maps were produced for the Katowice 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, Zn in surface water and 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 most often 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 Katowice Sheet and the datasets of 1:25 000 scale neighbouring sheets. Thus any disagreements at the sheet borders were avoided. After interpolation from mono-element maps the Katowice Sheet was extracted and combined with the topographic base map.

The geochemical maps of aqueous sediments and surface water were elaborated separately for the Katowice 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 soils have been affected by natural soil-forming processes and modified by anthropogenic processes, which contribute to the changes in their physico-chemical properties and soil profile.

Soil degradation processes are observed mainly in the areas of industrial facilities, dump sites, river valleys, urbanized areas and near transportation routes.

Lithology and age of soils parent rocks in the map area are various (Plate 1). They gave rise to development of different soil types, that reflect the geochemistry of bedrock. Carboniferous sandstones and Quaternary glaciofluvial deposits are *Podsols* parent rocks. *Cambisols* and *Luvisols* develop on glacial tills. Large areas are covered by anthropogenic soils (Program..., 2006, 2008).

Chemical composition of soil determines their use. Areas of sandy soils, depleted in nutrients, are covered by forests, whereas those rich in nutrients are used as agricultural land and grazing land (Table 2).

Grain size. Grain size of soils is one of the factors controlling the chemical elements content. For soils of dominant clay (<0.02 mm) and silt (0.1–0.02 mm) fractions permissible limit values of elements are higher than for sandy soils due to lower migration ability within the soil profile (Kabata-Pendias *et al.*, 1995).

Grain size variability of the soils is clearly dependent on the parent rock lithology. The most abundant are sandy soils containing >75% of the 1.0–0.1 mm fraction (Plate 4), developed on Carboniferous sandstones, Pleistocene glaciofluvial sands and gravels, and fluvial deposits (Plate 1). These soils are characterised by a small proportion (<10%) of the silt fraction (0.1–0.02 mm) and clay fraction (<0.02 mm), and are covered by forests.

The proportion of soils enriched in the silt and clay fractions is higher along the outcrops of Carboniferous shales and Pleistocene tills. The percentages of the fractions