INTRODUCTION

Geochemical mapping at the scale of 1:25 000 on the Chrzanów map Sheet M-34-63-D-b (82.5 km^2) is a continuation of detailed mapping works initiated in the years 1996–1999 by a pilot elaboration entitled “Detailed geochemical map of Upper Silesia 1:25 000 Sławków map sheet M-34-63-B-b” (Lis, Pasieczna, 1999). The project was ordered by the Ministry of the Environment and it was financed by the Polish National Fund for Environmental Protection and Water Management.

The Chrzanów Sheet area is located in the southern part of the Silesia-Cracow Upland. In this region distinct geochemical anomalies of Pb–Zn–Cd occur in soils, aqueous sediments and surface water (Lis, Pasieczna, 1995a, b, 1997). The main source of geological-anthropogenic anomaly originates from outcrops of ore-bearing dolomites hosting zinc-lead ores, their historical exploitation (Matylda Zn–Pb ores mine) as well as their current mining and treatment (Trzebionka Minning Company). Another geological-anthropogenic factor causing both chemical changes in the natural environment and landscape transformation is exploitation of rock raw deposits (dolomites, limestones and clay rocks).

The extraction and treatment of Pb–Zn ore around the Silesia-Cracow region have caused environmental pollution similar to that found in other regions of Europe where mining for non-ferrous metal ores e.g.: Plovdiv region in Bulgaria (Atanassov, Angelova, 1995; Velitchkova *et al*., 2003), Pribram in Czech Republic (Rieuwerts, Farago, 1996), Smolnik region in Slovakia (Cicmanova, 1996), Plombiers–La Calamin district in Belgium (Swennen *et al.,* 1994; Cappuyns *et al*., 2005), Derbyshire area in central England (Cotter-Howells, Thornton, 1991; Thornton, 1994), the Harz Mountains in Germany (Gäbler, Schneider, 2000) or pollymetallic mineralization – the border between the Czech Republic and Germany (De Vos *et al*., 2005) is common.

The north-western part of the Chrzanów Sheet area is an industrialized one (mining, smelting, metallurgical, and petrochemical industries) whereas forests are dominant in its central part. There are also towns Trzebinia and Chrzanów.

The area under study also has high natural values – it is characterized by diverse forms of landscape under protection. In its eastern part there is a compact forest area – Puszcza Dulowska, which is under protection due to special flora occurrence. It is planned that inanimate nature shall also be protected (Triassic rocks in the vicinity of Bolęcin village and Pogorzyce gully).

Internet version of atlas is available at http://www.mapgeochem.pgi.gov.pl/.

The following specialists contributed to this work:

· **J. Lis, A. Pasieczna** – concept and project proposal, project leadership, supervision and coordination of research, databases, compilation of geochemical maps, interpretation of results;

· **P. Dobek, T. Kołecki , P. Kaszycki, T. Psiuk, T. Sztyrak, J. Szyborska-Kaszycka** – sample collection;

· **P. Pasławski, K. Jakimowicz-Hnatyszak, E. Włodarczyk** – leadership and coordination of analytical works;

· **Z. Dobieszyńska, M. Cichorski, J. Duszyński, Z. Prasol, K. Stojek** – mechanical preparation of samples for analyzes;

· **I. Witowska, E. Maciołek** – chemical preparation of samples for analyzes;

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· **W. Wolski, Z. Frankowski, P. Dobek** – grain size analyzes;

· **A. Pasieczna, H. Tomassi-Morawiec, A. Bliźniuk** – statistical calculations;

· **M. Szuwarzyński, A. Dusza-Dobek** – characteristics of the map area;

· **M. Szuwarzyński** – geology and mineral deposits;
· **A. Dusza-Dobek, A. Witkowska** – human impact.

CHARACTERISTICS OF THE MAP AREA

Geographical and administrative setting. In terms of administrative setting the area of the Chrzanów Sheet M-34-63-D-b belongs to the western part of the Małopolska voivodeship. It consists of a part of the Chrzanów district including the administrative communes Chrzanów and Trzebinia in the central part, a small part of Babice administrative commune in the south-western part of the map sheet, and the Alwernia administrative commune in the south-eastern part.

The whole area under study belongs to the southern part of the Cracow-Częstochowa Upland (Kondracki, 2000).

Relief and geomorphology. Upland areas dominate around the map sheet. A belt of horsts built up of Triassic limestones and dolomites occurs in its southern and western part. Elevations reach up to 300 m a.s.l. A denudation cuesta built up of the Upper Paleozoic and Mesozoic rocks with parallel extension and with altitude of about 390 m a.s.l. occurs in the north-eastern part of the map sheet (Bogacz, 1967). Northwards of the Chechło River valley there is the Niecka Dulowska Trough filled with Quaternary sands. South of the Niecka Dulowska Trough tectonic Garb Tenczyński horst is located. This area is a belt of hills with steep slopes and flattened area up to about 400 m a.s.l. composed mainly of Triassic rocks. The slopes are covered with loess (Plate 1).

The area of the Chrzanów Sheet is mostly changed due to exploitation of mineral deposits (Nieć *et al*., 2001; Szuwarzyńska *et al*., 2001). Only a few abandoned open-pits (extracting clay and sand) became recultivated. Others are used more often for storing communal wastes. Other changes within the Chrzanów Sheet are industrial waste dumps, which belong to the mining and treatment factories (Trzebionka Mining Company, Płaza Lime Plant, Żelatowa Dolomite Mine, Matylda – a historical Zn–Pb ore mine).

Numerous pits as well as mine and treatment waste dumps are the remains of the historical open-pit exploitation of lead, zinc, and iron ores. Some of the pits form artificial water reservoirs. Location of historical dumps of metal smelters in the area of Trzebinia and Chrzanów is difficult to distinguish in relief in many cases but it is clearly noticeable on the basis of geochemical anomalies. Removal of historical waste dumps in the 70's and 80's of the 20th century by usage of material stored there for levelling and improvement of roads led to scattering the wastes over vast areas (Szuwarzyński, Kryza, 1995).

Southwards and eastwards of Chrzanów there are big dolomite and limestone quarries in Płaza and Żelatowa. In the town of Trzebinia there is a petroleum refinery and a large post-flotation Zn–Pb ores waste pond of the Trzebionka Mining Company.

The area of the Chrzanów Sheet is hydrographically complex. The Chechło River catchment is the biggest one in terms of the size and runoff. A small western part is drained by the Matylda Canal belonging to the Przemsza River catchment. The regulation of the Chechło River and the Matylda Canal beds was done within the major part of their watercourses. Poor quality of surface water results from sewage discharge from Chrzanów and Trzebinia and also from mining drainage (Motyka *et al*., 2003; Szuwarzyński, 2003; Czop *et al*., 2005).

Land use. The majority of the area under study is of industrial-agricultural use (Plates 2 and 3). About 20% of the area is occupied by the industrial and urban development of Chrzanów and Trzebinia towns. Farmlands (about 8%) are mainly located in the south-eastern and north-western part. Forest areas make up about 30% and barren lands cover 30% of the total map area.

Economy. Currently the dominant industry of the Chrzanów map sheet area is manufacturing industry rather than mining. The main sectors of industry are: chemical, power supply, mining, engineering, building, clothing and food. The biggest companies of the area are: Trzebinia Oil Refinery and Bumar-Fablok – building machines and locomotives factory in Chrzanów, Śląsk Tinning-Plant in Chrzanów, Żelatowa Dolomite Mine, Płaza Lime Factory, asphalt factory and refractory materials factory in Chrzanów. Numerous minor companies representing different industrial sectors are also active in the area (Projekt..., 2004).

GEOLOGY AND MINERAL DEPOSITS

The area of the Chrzanów Sheet is located within the Upper Silesia Depression, at Carpathian Foredeep (Bukowy, 1974). The geological structure consists of three structural units (Żero, 1956; Nieć *et al.,* 2001; Szuwarzyńska *et al*. 2001): Upper Paleozoic (Carboniferous, Permian), Mesozoic (Triassic, Jurassic) and Cenozoic.

The oldest rocks exposed on the surface are the **Upper Carboniferous** Kwaczała arkoses (Plate 1). Thickness of the Upper Carboniferous rocks folded during Variscan Orogen exceeds 1000 m (Szuwarzyński, 2003).

A younger Variscan structure in the form of a depression in the north-eastern part of the map sheet is Permian graben filled with the Lower Permian Myślachowice carbonate conglomerates, tuffs and tuffites.

The **Triassic** consists of two formations: carbonate including the Roethian and the Muschelkalk and clastic – the Keuper (Szuwarzyński, 1984). Carbonate formation (about 160 m thick) forms vast outcrops in the western and southern part of the map area (Plate 1). It includes dolomites, marls and limestones with clastic intercalations at the top and at the bottom. One of the components of the carbonate formation – zinc-lead ore-bearing dolomites – is characterized by differentiated lithology. In some places dolomites are replaced by limestones. Zn–Pb ore-bearing dolomites contain ore bodies composed of minerals of zinc, lead, and iron whereas their limestones equivalents are barren (Szuwarzyński, 1993). Clastic formation of the Triassic (Upper Keuper) is not exposed on the surface. It contains mud-clay deposits 100 m thick with intercalations of dolomites and gypsum veins.

The **Jurassic** rocks are marls and limestones over 100 m thick occurring in the northern and central part of the map area.

The **Neogene** includes clays and freshwater limestones outcropping in the central part of map sheet as well as marine clays sporadically exposed in the north.

Quaternary deposits build a cover of varied thickness in the whole area. The thickest deposits occur in the Chechło River valley and in the sandy dune areas (Żelatowa–Pogorzyce). Pleistocene glaciofluvial sands, gravel, and eolian sands are dominant among them. They are accompanied by clay deposits – tills and different types of colluvium. Loesses (from several tens of centimetres thick on elevations to dozens of metres thick on the slopes of valleys) occur in the southern part.

Holocene deposits occurring on the slopes of elevations are various types of colluvium – sands and clays with debris of local rocks. Sediments of watercourses are muds and sands (rarely gravel and peat).

In some parts of the sheet area anthropogenic grounds – industrial and communal waste dumps play an important role.

Mineral deposits. The area of the Chrzanów Sheet has various mineral resources. **Lead-zinc ores** have been exploited there since the 13th century (Szuwarzyński, 1993). In the beginning the exploitation of Zn–Pb ores was carried out above the groundwater surface and was focused on galena as the main source of silver and lead. The first drainage adit was built at the beginning of the 15th century. Exploitation of oxidized zinc ores for production of brass was initiated in the 16th century. In the 18th century exploitation of iron ores, which accompany zinc-lead ores commenced and lasted until the middle of the 19th century. Intense exploitation of oxidized zinc ores for the production of metallic zinc began in the 19th century (Szuwarzyński, 2003).

The beginning of the 20th century was the time of liquidation of the Zn–Pb mining industry mainly due to decreasing of Zn–Pb ores resources. In the first half of the 50's the Matylda mine was reopened (finally closed down in 1973). In 1962 the Trzebionka Mining Company was established and it operates to date. Northwards of the Chrzanów Sheet boundaries (at the Myślachowice Sheet) there are the Trzebionka Mining Company buildings but most of its mining area and the post-flotation pond of Zn–Pb ores are located within the map boundaries. Exploitation of several tens of millions of tonnes of Zn–Pb ores was carried out at depths from 170 to 200 m. In the near future, due to the low resources of ore left, the mine will be closed down and flooded.

In the southern part of Trzebinia town there was a non-ferrous metal smelter producing zinc and lead, among others, until the 40's of the 20th century.

The type of Zn–Pb ores is similar to that of other areas of the Upper Silesia region. Plate-like ore bodies are dominant and lie in accordance with the bedding of the ore-bearing dolomites. Ore nests, veins and mineralization zones are rare (Szuwarzyński, 1996). Sulphide ores have simple chemical composition. The main sulphide minerals are sphalerite and galena accompanied by iron sulphides – marcasite and pyrite. Oxidized ores, occurring close to the surface and tectonic zones, contain smithsonite, galena, and cerusite. Hemimorphite, hydrozincite, anglesite, and vein minerals – dolomite, calcite, chalcedony, and barite are rare (Górecka, 1996; Szuwarzyński, 1996). The host rock for ore bodies and sulphide ores is dolomite. Sulphide ores occur in dolomite in two forms: they replace carbonate rock (layered aggregates) or they fill in openings in the rock (veins, crusts and cements in breccias).

Part of the abandoned Siersza hard coal mine area is located in the north of the map sheet whereas most of the mine area and its surface infrastructure are located within the Myślachowice Sheet (Motyka *et al.*, 2003). The Siersza hard coal mine was closed down in 2000 and it is being flooded.

Carbonate and **clay raw materials** were exploited in open-pits. Large dolomite and limestone quarries are located southwards and eastwards of Chrzanów town and two of them, which are still operating, are located in Płaza and Żelatowa. Exploitation of till has ceased.

HUMAN IMPACT

The natural environment of Chrzanów Sheet is the most degraded part of Małopolska province. The source of the pollution is exploitation and treatment of zinc–lead ores, hard coal, rock raw materials, and industry – long duration of factory activity concentrated mainly in the towns of Chrzanów and Trzebinia as well as improper communal management.

Atmospheric air pollution. The sources of air pollution are not only local but also far-reaching emissions coming from the industry located in the Silesia province (22% of fly ash dust and 31.5% of gas emissions of the total pollution in Poland originates from the Silesia province).

The greatest volume of emissions comes from the industrial areas of Trzebinia and Chrzanów towns. Anthropogenic sources of pollution includes: combustion of fuel for power supply and heating (resulting in emission of fly ash dusts, sulphur and nitrogen dioxides and carbon oxides), combustion of fuel oil by vehicle engines (hydrocarbons, carbon oxides, dust and lead), production processes (hydrocarbons, fluorine, sulphur and cement dusts, hydrogen sulphide and other specific substances), agricultural production and heating of individual houses. The heating of individual houses emits mostly PM 10 dust and its concentration exceeds permissible values (Ocena..., 2005) during heating seasons. The most serious source of pollution is road transportation on the highway A4 Katowice–Cracow.

Surface water and groundwater pollution. The source of surface water and groundwater pollution originates from factories and their post-production waste dumps. Among those still open are the waste dumps: of the heat-generating factory, refractory material plant, Bumar-Fablok factory of building machines and locomotives, and the asphalt factory in Chrzanów as well as Żelatowa Dolomite Mine. The waste dumps of abandoned factories are: Płaza Lime factory; reservoirs of acidic post-refining tars of Trzebinia Petroleum Refinery (undergoing closure), Trzebinia Metallurgy Company, slag waste dump in Trzebinia, and Śląsk Tinning-Plant in Chrzanów.

The biggest waste dump is the post-flotation waste pond of the Trzebionka Mining Company. The waste pond contains grounded dolomite with admixtures of zinc and lead sulphides. This material is derived in the form of water suspension from the Zn–Pb ores treatment plant located 1 km northwards of the pond. The coarse fraction of the post-flotation wastes, separated in the site, is used for the building of embankment of the post-flotation pond. The rest of the waste is discharged into the pond where sedimentation of solid parts takes place whereas water above the sediment, which is cleaned from suspension, is then moved back to the Zn–Pb ores treatment plant or is used for spraying the embankments in order to keep vegetation during dry periods. The post-flotation pond embankments are located at the highest altitude within the vicinity of Chrzanów, 28–36 m above the ground level and the pond area covers c. 68 ha (Szuwarzyńska *et al.*, 2001).

Two waste dumps were left after the exploitation of the Matylda Zn–Pb ore mine was finished in 1972: Zn–Pb ore waste dump mostly of the 20's of the 20th century and old post-flotation pond. Nowadays material stored in the waste dumps is used for road building and the area of the old waste dumps is partly recultivated.

Within the Żelatowa Dolomite Mine there is a waste dump containing about 1 mln m^3 of wastes (Szuwarzyńska *et al.*, 2001). The height of the dump ranges from 6 to 18 m and its area is c. 7.2 ha. The material from the dump may be used for fertilizers production.

The dump of Płaza Lime Plant contains lime and sandy wastes (as much as ca 2 mln m^3) of various granulometric composition. It comprises over 4 ha and ranges from 40 to 60 m in height.

The biggest amount of industrial liquid wastes is produced in the Trzebionka Mining Company (7 461 000 m^3/yr) and in the Trzebinia Petroleum Refinery (588 259 m^3/yr). In both factories there are sewage treatment plants as well as in Żelatowa Dolomite Mine, whereas the rest of the factories discharge their waste into the communal sewage system.

The communal sewage-treatment plant in Chrzanów discharges liquid wastes into the Chechło River, which is significantly polluted (Raport..., 2005) and shows features of eutrophication.

The hydrology (quality, movement and distribution) of surface water and groundwater is mainly related to the mining activity within the Chrzanów Sheet. The most important changes include decrease of spring discharges or their disappearance in numerous tributaries of the Chechło River by the already closed Siersza Hard Coal Mine located northwards of the map area (Czop *et al.*, 2005). It is possible that after the mine inundation the springs will be reappear. The source of surface water pollution is discharge of mine waters from the Trzebionka Mining Company into the Chechło River by the Luszówka Stream since the first half of the 50's of the 20th century (Szuwarzyński, 2003).

There are several artificial water reservoirs within the map sheet boundaries. The artificial reservoir – Chechło Lake – was created as a result of the dam built on the Chechło River. In the vicinity of Trzebinia and Bolęcin there are reservoirs in abandoned open-pits.

Exploitation of mineral resources cause drawdown of groundwater table level (Różkowski, Siemiński, 1995; Szuwarzyński, 2003; Czop *et al.*, 2005) and increase of its total mineralization (especially the concentration of sulphates) – despite the influence of mining drainage on surface waters.

Other branches of industry and housing are sources of communal and industrial sewage, which increase surface water mineralization, their biological degradation and eutrophication. Regulation of riverbeds and building of flood-control infrastructure pollute water ecosystems and degrade landscape. Systems of drainage ditches affect natural water relationships and cause excessive drainage of natural habitats of flora and fauna.

Soil pollution. Chemical degradation of soils is related to industrial activity, transportation, influence of industrial waste dumps and sewage discharge. In soils of the Chrzanów Sheet area high concentration of metals especially zinc, lead and cadmium was noted. It originates from the non-ferrous mining-treatment industry as well as the natural geochemical background in soil developed from the ore-bearing rocks.

The soils are also degraded due to improper farming activity. Common use of pesticides and mineral fertilizers enrich soils in metals, nitrogen compounds, phosphoric-organic compounds and chlorinated hydrocarbons.

Both natural and anthropogenic sources cause reduction of soil fertility. As a result the quality and amount of humus, changes in acidity, removal of alkaline cations and in consequence – a decline of soil fertility is observed.

MATERIALS AND METHODS

Studies done in years 2003–2005 comprised study of published and archival materials, choosing sampling sites at topographic maps at a scale of 1:10 000, samples collection, coordinate surveys at the sampling sites, laboratory works, set up of field and laboratory databases, elaboration of a vector topographic map 1:25 000, statistical calculations, construction of geochemical maps and geo- logical map, and interpretation of results. Mentioned herein works are shown on Figure 1.

FIELD WORKS

Soil samples were collected at the regular grid 250x250 m (16 sites per 1 km^2). The total number of soil sampling sites was 1312. At every site were collected two samples from two depths: 0.0–0.3 m (topsoil) and 0.8–1.0 m (subsoil). In case of shallow deposited parent rocks the subsoil sample was collected from shallower depth. Soil samples (of about 500 g) were collected by means of a hand probe and were initially dried at the field storage.

Samples of aqueous sediments and surface water were collected from various bodies of water – streams and rivers, melioration ditches, canals, pools and ponds. The distance between watercourse sampling sites was about 250 m. Samples of sediments of 500 g weight were collected from water reservoir shores by means of a scoop.

Samples of surface water were collected from the same sites as sediment samples. Electrical conductivity (EC) and acidity (pH) of water were measured on site. Water samples of 30 ml were filtered in the field (by filters of 0.45 μm) and acidized with nitric acid.

Locations of all sampling sites were defined with GPS. Direct measurement with GPS equipment GS 20 Leica has accuracy of ±2–10 m. A GS 20 Leica was equipped with external antenna and system which can register not only coordinates but also additional information (pH and EC of water samples, data on land development and land use as well as type of soil and aqueous sediment). Coordinates of soil sampling sites were put into read-only memory of GPS equipment, before going out in the field and the sites were next found in the field. For safety reasons all the field data was noted on sampling cards (Fig. 2).

LABORATORY WORKS

Sample preparation. All solid samples were air-dried. Soil samples were sieved to <2 mm using nylon screening (ISO 11464). Each topsoil sample was then split into three portions; one was archived, the second submitted for grain-size analysis and the third was pulverized in agate planetary mill to a grain size <0.06 mm submitted to chemical analysis Each subsoil sample was split into two portions; one was archived and the other was pulverized in agate planetary mill to a grain size <0.06 mm and submitted to chemical analysis (Fig. 1).

Aqueous sediment samples were sieved to a grain size <0.2 mm. Each sample was then split into two portions; one was archived and other was used for chemical analysis.

Chemical analyses were done at the laboratory of the Polish Geological Institute, Warsaw.

Soil pH (water extraction) was measured with pH-meter. The total organic carbon content of topsoil samples was determined using a Coulomat analyser. The content of Ag, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Ni, P, Pb, S, Sr, Ti, V and Zn in soil and aqueous sediment samples was determined after a hot *aqua regia* digestion by inductively coupled plasma-atomic emission spectrometry (ICP-AES) method. The mercury content was measured using a cold vapour-atomic absorption (CV-AAS) method.

The determination of Al, B, Ca, Fe, K, Li, Mg, Na, P, SiO_2, Ti and Zn content in surface water samples was done by ICP-AES while the content of Ag, As, Ba, Cd, Cl, Co, Cu, Mn, Ni, Pb, Rb, Sb, SO_4, Sr, Tl and U was determined by inductively coupled plasma-mass spectrometry.

Analytical methods applied along with detection limits of measured elements are shown in Table 1.

The quality control of the analysis was performed by:

– analysis of duplicate samples (5% of total samples),

– analysis of reference materials with certified content of elements studied (2% of total samples),

– analysis of laboratory control samples confirming correct instrument calibration (5% of total samples),

– blank samples (5% of total samples).

The reagent blank samples and the preparation blank samples were used. Purity of acids, water and vessels was controlled with the reagent blank samples. The preparation blank samples (*sea sand extra pure Merck)* were used to monitor for possible contamination during the sample preparation procedure.

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

Grain size analyses of topsoil. Grain-size distribution of topsoil samples measured by a laser particle size analyzer (Analysette 2) is expressed as fractions:1.0–0.1 mm (sand), 0.1–0.02 mm (silt) and <0.02 mm (clay).

DATABASES AND GEOCHEMICAL MAPS PRODUCTION

Base topographic map. The 1:25 000-scale topographic base map was constructed using selected elements of the Vector Map Level 1 (VMap Level 1) 1:50 000. Topographic map contains vector-information layers: relief, hydrography (with division into rivers, streams, canals, ditches, lakes, pools, ponds), road communication net (with division into classes of roads), railway net, land development (with division into compact development, suburban development, industrial development, non-built areas), forests, industrial objects, mine excavations and mine dumps.

Geological map. Geological map was constructed on the base Detailed geological map of Poland Chrzanów Sheet 1:50 000 (Żero, 1956). 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. The databases and material archives comprise: archives sample materials (topsoil, subsoil and aqueous sediments) stored at the Polish Geological Survey, field observation sheets, work maps, databases for field observations, analytical data files and GIS layers.

Separate databases were prepared for: topsoil, subsoil, aqueous sediments and surface water.

Soil databases contain: number of samples, sampling coordinates, a site description (land development, land use, district, commune, and town), soil texture, date of collection, sampler name and analytical data.

Aqueous sediment and surface water databases contain: number of samples, sampling coordinates, a site description (land development, land use, district, commune, and town), type of water body (river, stream, canal, ditch, lake, pond) type of sediment (sand, mud, clay, peat) date of collection, sampler name and analytical data. For surface water database additional data were included – field measurements of pH and EC.

Statistical calculations. Statistical parameters were calculated (average, median, minimum and maximum values) both for the whole sets and subsets of soil, sediments and surface water (Tables 2–6). Subsets for statistical calculations were distinguished according to different media criteria, e.g. concentrations of elements in soils under cultivation, forest soils, urban soils and elements content in aqueous sediments and water of particular bodies of water. In the case of some elements (e.g. Ag, As, Cd, Hg) with the content lower than the value of detection limit for the applied analytical method, all values were converted to half of the detection limit value before making statistical calculations and map production.

Geochemical maps production. The following maps were made for the Chrzanów Sheet: geological map, land development and land use, the content of organic carbon and grain size of topsoil (1.0–0.1 mm, 0.1–0.02 mm and <0.02 mm); acidity of topsoil and subsoil; acidity and electrical conductivity of surface water; the content 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 aqueous sediments; the content 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.

The distribution of elements is presented with a combination of proportional dot maps (for element distribution in sediments and surface water) and colour surface maps (for element distribution in soils). Dot maps revealing the actual sampling density were produced individually for Chrzanów Sheet. Colour surface maps were constructed for several neighbouring sheets to avoid disagreement of element distribution at the sheet borders. The data was interpolated to generate a regular grid using Inverse Distance to a Power method. A multi-grade colour scale was selected to present the elements distribution. The 1:25 000-scale map sheet of interest was then cut out from several neighbouring sheets after interpolation. The colour surface maps were produced using arbitrarily chosen colour classes (most often using geometric progression).

In the case of soil pH accepted level values according to the division used in soil science (soils very acidic, acidic, neutral and alkaline).

For publication reasons, geochemical maps were made by presenting the following pairs in one plate: topsoils and aqueous sediments as well as subsoils and surface waters. This method of presentation gives a direct comparison of geochemical images of various media (Plates 7–62).

Taking into account comfort of usage by potential customers maps were printed out in slightly smaller format (A3) in relation to the 1:25 000 scale. This operation did not cause omitting any important details of maps.

RESULTS

SOILS

Grain size. The grain size of soil particles affects the ability to retain water as well as 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 (Kabata-Pendias *et al.*, 1995).

Diversity of the grain size of topsoil at the Chrzanów Sheet M-34-63-D-b is related to the lithology of the parent rocks. The most abundant are sandy soils containing >75% of 1.0–0.1 mm fraction (Plate 4), developed on Pleistocene glaciofluvial sands and gravel as well as on eolian sands (Plate 1). Low silt and clay fractions prevail in these soils. Silt (0.1–0.02 mm) and clay (<0.02 mm) fractions are dominant in soils formed on Triassic and Jurassic carbonates. Content of silt fraction in the soils ranges from 15 to 30% (Plate 5), whereas clay fraction from 10 to 20% (Plate 6). In soils developed on loesses, occurring in the southern part of the map area, sand fraction content rarely exceeds 10% whereas silt (often >40%) and clay (>20%) fractions are dominant.

Acidity. Both topsoils and subsoils developed from Quaternary glaciofluvial and eolian sandy deposits are acidic. The biggest area of strongly acidic soils (pH<5) was noted in the forests southwards of Młoszowa (Plates 7 and 8).

Neutral and alkaline soils are dominant in the northern and western part of the map sheet. Locally (near the limestone and dolomite open-pits) pH exceeds 8. Such high pH is related to scattering of dust particles and wastes during long-lasting exploitation. Within the boundary of Chrzanów and Trzebinia towns the source of alkaline soil pH are occurrences of Triassic and Jurassic carbonate rocks in the bedrock and scattering of industrial dust particles enriched in calcium and magnesium. This observation is confirmed by decrease of surface of alkaline soil at the depth of 0.8–1.0 m. An exception is the area of Żelatowa Dolomite Mine where alkaline subsoil (pH >8.0) occupies the bigger surface than alkaline topsoil.

Comparison of median pH values in topsoil shows a clear relationship of pH to land use (Table 3). In non-urbanized areas median pH value is 6.4, whereas in urban areas with low development and in industrial areas rises up to 7.4, and within the areas with compact urban development reaches 7.7.

Geochemistry. Various types of soils at the Chrzanów Sheet area originated from the parent rocks diversified in terms of age and lithology (Plate 1). Their geochemistry generally coincides with chemical composition of the bedrock. The physical-chemical conditions of soil-forming processes led to chemical changes of soils in relation to their parent rocks, however geochemistry of parent rocks is clearly visible. Rendzinas developed from the Triassic and Jurassic limestones whereas Cambisols and Luvisols originated from glaciofluvial clayey sands (Projekt..., 2004). Cambisols and Luvisols originated from loess (in the southern part of the map sheet) belong to a separate group. Grasslands include mostly mineral-peat soils.

Distribution of some elements (aluminium, barium, calcium, cobalt, chromium, nickel, phosphorus, strontium, titanium and vanadium) in soils points out a strong relationship with the bedrock lithology. High values of these elements occur in soils developed from Triassic and Jurassic rocks as well as from Quaternary loesses while their low values were observed for soils developed from Pleistocene glaciofluvial sandy deposits covering most of the map area. It concerns both the topsoils and the subsoils. The low values of these elements in soils are related to their low content in soil parent material and acidic reaction, which make them susceptible to leaching.

Topsoils are enriched in some elements due to the anthropogenic factors. South of Trzebinia town, in the area of the Trzebinia Metallurgy Company and their waste dumps, an anomaly of aluminium (>3.20%: up to 11.98%) was noted (Plate 11). The anomaly is suggested to originate from the smelting of many metals, including aluminium, produced by the plant after World War II (Szuwarzyński, Kryza, 1995). High content of barium (Plate 16), cobalt (Plate 24), chromium (Plate 26), nickel (Plate 42), and titanium (Plate 55) occur in the same industrial area. The pollution of the Trzebinia Metallurgical Company area with metals has lasted for several hundreds of years. The Jadwiga zinc smelter was established there in 1890 at the location of the old lead smelter (Cygorijni, 1970). Significant anomalies of silver (Plate 9), arsenic (Plate 13), copper (Plate 28), and mercury (Plate 32) occur both at the Trzebinia Metallurgical Company area and its waste dumps (gathering wastes after zinc, copper and other metals production) in topsoil. Within the anomaly area the maximum content of silver reaches 60 mg/kg, arsenic – 4132 mg/kg, copper – 1094 mg/kg and mercury – 66.50 mg/kg. They are anthropogenic anomalies, which is confirmed by their disappearance with depth (Plates 10, 14, 29 and 33). High concentrations of arsenic (up to 45 mg/kg) and copper (up to 1000 mg/kg) were found during earlier soils studies of that area (Górecka *et al.*, 1995; Bellok *et al.*, 1997). Besides contamination of the area with solid waste, the source of metals can be scattering of industrial dust particles from technological processes, enriched in metals and also use of slag for levelling of some areas in Trzebinia town (Szuwarzyński, Kryza, 1995).

High content of silver and arsenic was noted in the area of the former Matylda Zn–Pb ore mine. Enrichment of soils with mercury (>0.40 mg/kg) occurs in the area of Trzebinia Petroleum Refinery and in the north-eastern part of Chrzanów town. Mercury anomalies were noted in subsoil too (Plate 33).

Anthropogenic anomalies of copper occur in topsoil in the forest areas at the vicinity of Młoszowa and in the industrial district of Chrzanów town (Bumar-Fablok factory of building machines and locomotives). An even more noticeable copper anomaly in the same area is observed in subsoil (max. 2761 mg/kg).

Elements that are related to Zn–Pb ore deposits and the mining-smelting activities within the Chrzanów Sheet include: cadmium, zinc and lead. Anomalies of those elements occur in the north-western part of the map sheet, in the area of abandoned Matylda Zn–Pb ore mine in Chrzanów as well as the Trzebinia Metallurgical Company area and its waste dumps. In topsoil concentrations noted are as follows: cadmium >32 mg/kg (Plate 21), lead >1000 mg/kg (Plate 46) and zinc >5000 mg/kg (Plate 61). High contamination of the area with heavy metals has been observed for a long time. According to Bellok *et al.* (1997) concentration of cadmium reaches 35 mg/kg, zinc – 2400 mg/kg, and lead – 2400 mg/kg.

High values of cadmium, lead and zinc in topsoil (diminishing in the subsoil) were noted at the vicinity of post-flotation pond of Trzebionka Mining Company (Plates 21, 46 and 61). Cadmium, lead and zinc anomalies occupy bigger areas in topsoil than in subsoil (Table 7). In subsoil, southwards of Chechło River and Pstrużnik Stream valleys, contamination with those elements disappears.

High concentrations of cadmium, lead, and zinc occur in alluvial soils of Chechło River valley at the area of Chrzanów town. The source of metals is water and sediments of Luszówka Stream (tributary of the Chechło River), which are the receiver of liquid sewage and mine waters of Trzebionka Mining Company.

Content of sulphur in soils of Chrzanów Sheet rarely exceeds 0.16% (Plates 49 and 50). Only at the Trzebinia Metallurgical Company area and its waste dumps in topsoil the sulphur concentration is higher – up to 3.11% (Plate 49).

Total organic carbon (TOC) content in topsoil ranges from 0.70 to 3.00 % (Plate 18) with a median 1.53%. Higher TOC values (3–12%) occur in the north-eastern part of the map sheet area and in some forest soils its concentration rises up to 24%.

Topsoil is clearly enriched in phosphorus in relation to subsoil (Plates 44 and 45). The median of phosphorus in topsoil (0.028 %) is twice as big as in subsoil (0.014%) (Tables 3 and 4).

The median values of calcium and magnesium are higher in the topsoil than in subsoil (Tables 3 and 4) whereas their distribution maps are very similar. Distinct calcium anomalies (Plates 19 and 20) occur in the areas of outcrops of Triassic and Jurassic carbonate rocks. High calcium values (>8%) were noted at the vicinity of Żelatowa Dolomite Mine and Płaza Lime Factory. High magnesium values (>1%) were observed in soils developed from Triassic carbonates (Plates 36 and 37).

Strontium content in soils is related to the parent rocks chemistry and scattering of dust particles from anthropogenic sources. High strontium values (>40 mg/kg) were noted in topsoil and subsoil (Plates 53 and 54). The strontium subsoil map is very similar to topsoil map, but shows no anomaly in the area of Płaza Lime Factory.

Distribution maps of iron, manganese and vanadium show slight elements relation to chemical composition of parent rocks. Topsoil and subsoil developed from loesses are enriched in cobalt, chromium, iron, titanium and vanadium. At the area of Trzebinia Metallurgical Company and its waste dumps the topsoil anthropogenic iron anomaly (>8%) disappears completely in the topsoil.

The heavy metal contamination of soils is a problem for the local authorities and should be discussed with respect to the land use. To fit the geochemical data to the local authorities' needs the topsoils of the Chrzanów Sheet were classified applying current guideline values (Table 8) established by the Polish Ministry of the Environment (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) (Table 8).

The rule of the classification is that the sample is classified to a particular soil use group if the content of at least one element reaches or exceeds the permissible limit values of this group. Using this classification method, 20.81% of the topsoil samples were classified into group A, 38.03% into group B, and 41.16% into group C (Table 8).

Topsoil classified into group C occurs mainly in the northern and western part of the map sheet, at the industrial areas and on the outcrops of ore-bearing dolomites (Plate 63). The biggest pollutants are zinc, cadmium, and lead (Table 8). Pollution by arsenic is limited to the Trzebinia Metallurgical Company area and its waste dump as well as point occurrences in the valleys of the Chechło River and Luszówka Stream.

AQUEOUS SEDIMENTS

Aqueous sediments of the Chrzanów Sheet include: alluvial sediments of the Chechło River and its tributaries (Luszówka, Wodna, and Pstrużnik Streams and unnamed streams) as well as sediments of canals and ditches. The biggest water reservoir is Chechło Lake. The water and sediments of the Chechło River and streams are seriously polluted by discharge of industrial and communal waste (Ciszewski, 1994; Bellok, 1996).

Pollution of the Chechło River sediments is caused mostly by mining and treatment of Zn–Pb ores at the Trzebionka Mining Company. Its post-flotation waste pond is located between the Luszówka Stream and the Wodna Stream valleys. Saline mine water of the Trzebionka Mining Company is discharged directly to the Wodna Stream in its upper course (Bellok, 1996). Both streams (the Luszówka Stream and the Wodna Stream) discharge their water and suspended matter contaminated with metals and other compounds from Zn–Pb ore mining as well as from drainage ditches of the post-flotation pond into the Chechło River. Additional pollution of sediments with metals is related to the activity of Trzebinia Metallurgical Company (former zinc smelter) and the Trzebinia Petroleum Refinery (discharging industrial wastes via the Pstrużnik Stream).

The geogenic source of aluminium, barium, calcium, cobalt, chromium, iron, manganese, nickel, phosphorus, titanium, and vanadium in the alluvium of the Chechło River and its tributaries are bedrocks of the catchment. The content of the elements differs slightly over the whole length of the Chechło River, the Luszówka and Pstrużnik Streams, as well as smaller unnamed watercourses. The source of high calcium values down the Chechło River is mine water discharged by the Wodna and the Luszówka Streams. Above the mouths of the streams into the Chechło River the content of calcium in the sediments rarely exceeds 0.50%. Below the stream mouths it most often ranges from 2.50 to 5.00% (Plate 19).

Pollution of alluvial sediments of the Chechło River with metals and sulphur was observed below the mouths of the Pstrużnik and Luszówka Streams. Anthropogenic enrichment sediments of the Chechło River with chromium derives from sediments of the Pstrużnik Stream contaminated with metals by sewage discharge from the Trzebinia Metallurgical Company and its waste dumps (Plate 26). Above the Pstrużnik Stream mouth chromium content in the Chechło River sediments ranges from 2 to 8 mg/kg, and below the mouth its concentration locally rises up to 60 mg/kg. In the upper course of the Chechło River content of silver in sediments does not exceed 1 mg/kg (Plate 9). In sediments of the Pstrużnik and Wodna Streams as well as downstream of the Luszówka Stream silver concentration ranges from several to 87 mg/kg. In the Chechło River sediments below the mouths of these streams silver content ranges from 3 to 7 mg/kg.

Arsenic content in sediments of upstream Chechło River (including Chechło Lake) reaches several tens of mg/kg (Plate 13). In the Pstrużnik Stream sediments, draining waste dump of Trzebinia Metallurgical Company, arsenic concentration increases up to 2261 mg/kg (Table 5). The sediments of the Wodna Stream, downstream of the Luszówka Stream and watercourses of the former Matylda Zn–Pb ore mine area are enriched with arsenic too.

Mine water discharged from the Trzebionka Mining Company causes sediments contamination of the Wodna and Luszówka Stream and finally the Chechło River with cadmium (Plate 21), lead (Plate 46) and zinc (Plate 61). In the upstream of the Chechło River and below the Luszówka Stream mouth values of <8 mg/kg and >64 mg/kg of cadmium, <250 mg/kg and >1000 mg/kg of lead and <500 and >10 000 mg/kg of zinc were found respectively.

In sediments of the Luszówka Stream cadmium content usually ranges from 200 to 400 mg/kg. Anomalies of cadmium occur also in sediments of small right bank tributaries of the Luszówka Stream (up to 150 mg/kg), watercourses of the area of former Matylda Zn–Pb ore mine (up to 215 mg/kg) and the canal dewatering the highway A4 and flowing into Chechło Lake (up to 113 mg/kg).

The maximum concentration of lead (1–4%), zinc (3–6%) and sulphur (1.5–2.7%) were found in sediments of the Wodna Stream and downstream of the Luszówka Stream. In the Chechło River sediments below the Luszówka Stream mouth lead content ranges from 1800 to 5500 mg/kg, zinc from 1.5 to 2.6% and sulphur from 0.5% to 1%. In these watercourses concentration of zinc reaches up to 14% and lead up to 5% in the sediments fraction <0,063 mm (Ciszewski, 1996). Such high concentrations of cadmium, lead, zinc, and sulphur are the result of discharge of water from Zn–Pb ore mine and from a post-flotation pond (water containing sulphide ores) (op. cit.). The presence of galena and sphalerite in the sedi- ments of the Wodna and Luszówka Streams was documented by X-ray analysis (Bellok, 1996). High concentration of cadmium, lead and zinc put the Chechło River sediments among the most polluted ones in Poland.

In the sediments of the Pstrużnik Stream, draining the Trzebinia Metallurgical Company area and its waste dumps, cadmium content ranges from 120 to 300 mg/kg (max. 6353 mg//kg) and zinc from 3000 to 9000 mg/kg.

Discharge of mine waters from the Trzebionka Mining Company causes enrichment of the Chechło River sediments in magnesium (Plate 36). Magnesium content of the upstream river rarely exceeds 0.10% and downstream it ranges from 1.5 to 3%. High magnesium values 3–4% (max. 7.95%) occur in the Luszówka Stream sediments.

The source of strontium in the Chechło River sediments (up to 60 mg/kg) is also mine water. Its content (Plate 53) is high too in the Luszówka Stream sediments (>80 mg/kg).

Anthropogenic anomalies of copper and mercury are related to the drainage of the Trzebinia Metallurgical Company area and its waste dumps by the Pstrużnik Stream. Copper content in sediments of most watercourses of the Chrzanów Sheet area ranges from 5 to 25 mg/kg (Plate 28). In sediments of the Pstrużnik Stream median copper value is 177 mg/kg (Table 4), and maximum – 1711 mg/kg. The highest copper concentration (2217 mg/kg) in sediments was found in the canal dewatering the highway A4 and flowing into Chechło Lake. Sediments of that canal contain high contents of mercury (0.30–0.40 mg/kg) and probably cause enrichment of Chechło Lake sediments in this element (Plate 32). In some sediments of Chechło Lake mercury content reaches up to 0.85 mg/kg (Table 4). The most polluted with mercury are the Pstrużnik Stream sediments. In its upstream the mercury content often exceeds 1 mg/kg, and reaches maximum of 10.10 mg/kg. The waters and sediments of the Pstrużnik Stream (the Chechło River tributary) cause pollution of the Chechło River sediments with mercury. Below the Pstrużnik Stream mouth into the Chechło River mercury content in sediments reaches 0.50–2.20 mg/kg, and above usually does not exceed 0.05 mg/kg.

In sediments of the little watercourses located in the southern part of the Chrzanów Sheet the content of studied elements are within values of the geochemical background.

SURFACE WATER

The surface water acidity at the Chrzanów Sheet area ranges from 7.8 to 8.9 (Table 6). In the Chechło River and its tributaries the most frequent pH values were noted between 7.7 and 8.0. The highest pH (8.7–8.9) was measured in an unnamed watercourse draining the Trzebinia Petroleum Refinery and railway station area in Trzebinia (Plate 7). Water of ditches draining the area of the post-flotation waste pond of the Trzebionka Mining Company is slightly alkaline (pH 8).

Electrical conductivity of water in watercourses of the southern and eastern part of the Chrzanów Sheet area range from 0.15 to 0.70 mS/cm (Plate 8). High EC (>1mS/cm) was found in the Luszówka Stream and downstream of the Chechło River reflecting the water pollution (Witczak, Adamczyk, 1994). EC in water of the Chechło River is far different above the confluence of the Luszówka Stream (0.20–0.60 mS/cm) and below that site (1.20–1.70 mS/cm). The highest conductivity in surface water (2–5 mS/cm) was found in the Luszówka

Stream and in ditches draining the area of the post-flotation waste pond of the Trzebionka Mining Company (Plate 8).

High content of some elements in the Chechło River water is observed below the mouths of the Pstrużnik and Luszówka streams. In water of the Pstrużnik Stream high values of arsenic, boron, calcium, cadmium, cobalt, copper, lithium, magnesium, molybdenum, sodium, nickel, antimony, thallium, uranium and zinc were found. The water of the Luszówka Stream, with its tributaries, was enriched in boron, calcium, cadmium, chlorine, lithium, magnesium, manganese, molybdenum, nickel, lead, sulphates, strontium, thallium, uranium and zinc.

Arsenic values in the Pstrużnik Stream water range from 8 to 13 μg/dm^3 (Plate 14). The highest arsenic content (22 μg/dm^3) was noted in a little tributary of the Pstrużnik Stream receiving liquid industrial wastes from the sewage-treatment plant of the Trzebinia Metallurgical Company. The Pstrużnik Stream water contains high values of cadmium (7.0–418.5 μg/dm^3), copper (772.3–1061.2 μg/dm^3), molybdenum (6.7–11.8 μg/dm^3), nickel (20–40 μg/dm^3), thallium (0.39–0.82 μg/dm^3), and zinc (700–3000 μg/dm^3) and it is enriched in sodium (40–90 mg/dm^3), rubidium (5–10 μg/dm^3), antimony (0.4–0.8 μg/dm^3) and uranium (0.37–1.16 μg/dm^3).

Increased content of boron (100–600 μg/dm^3), lithium (5–10 μg/dm^3), nickel (5–7 μg/dm^3), rubidium (4.1–16.1 μg/dm^3), and strontium (350–900 μg/dm^3) was noted in water of the Luszówka Stream. Downstream of the Luszówka Stream and in the Wodna Stream water is polluted by arsenic (up to 3 μg/dm^3), cadmium (0.7–3.8 μg/dm^3), molybdenum (1.77–2.87 μg/dm^3), lead (13.6–32.0 μg/dm^3), sulphates (500–4593 mg/dm^3), thallium (0.60–10.79 μg/dm^3), uranium (1.10–1.20 μg/dm^3), and zinc (1200–6602 μg/dm^3) and enriched in magnesium (up to 671 mg/dm^3). The source of those elements is mine water from the Trzebionka Mining Company, discharging into the Wodna Stream eluates from its post-flotation waste pond and also run-off from outcrops of Triassic ore-bearing rocks area in the upstream of the Luszówka Stream.

The water of the Matylda Canal (draining the waste dump of historic Matylda Zn–Pb ore mine) and little watercourses in the western part of the map sheet are enriched in aluminium (Plate 12), boron (Plate 15), chlorine (Plate 23), iron (Plate 31), magnesium (Plate 37), lithium (Plate 35), sodium (Plate 41), nickel (Plate 43), rubidium (Plate 48), antimony (Plate 51), uranium (Plate 58) and zinc (Plate 62).

High content of aluminium, cobalt, iron, manganese, sodium, and zinc noted in water of the Chechło River upstream is possibly related to the geologic sources. The content of silver (Plate 10), boron (Plate 17), potassium (Plate 34), silica (Plate 52) and titanium (Plate 56) in water of the Chechło River and the little watercourses is similar. Enrichment of the little watercourse water in the south-western part of Chrzanów Sheet in titanium (10–49 μg/dm^3) is an exception.

Increased content of calcium (Plate 20) and manganese (Plate 39) in surface water is found in the north-western part of the Chrzanów Sheet area.

In most of the studied surface water the phosphorus value does not exceed 0.20 mg/dm^3 (Plate 45). High phosphorus content was noted in the Płażanka Stream (up to 2.24 mg/dm^3; median 0.68 mg/dm^3) receiving run-off from agricultural areas fertilized with phosphorus fertilizers. High phosphorus content was also found in waters of watercourses in the vicinity of the sewage treatment plant in Trzebinia (up to 6.97 mg/dm^3) and in water of an unnamed watercourse in Chrzanów (11.43 mg/dm^3). Water of the watercourse is also polluted by cadmium (7.7 μg/dm^3), cobalt (7.0 μg/dm^3), copper (52.7 μg/dm^3), sodium (111 mg/dm^3), nickel (25.3 μg/dm^3), rubidium (16.8 μg/dm^3), sulphates (262 mg/dm^3), thallium (2.82 μg/dm^3) and zinc (585 μg/dm^3).

CONCLUSIONS

1. The content of analysed elements indicates the significant pollution of topsoil, subsoil, aqueous sediments and surface water with heavy metals and other chemical elements at the Chrzanów Sheet area.

2. The results show an excellent correlation between topsoil and subsoil geochemistry (as well as between soil geochemistry and chemical composition of underlying geological formations).

3. Historical mining and processing of zinc–lead ores as well as their current mining and treatment are the main sources of anthropogenic pollution of soils, aqueous sediments and surface water. Other important sources of pollution are connected with the related activities (e.g., mine dumps and disposal of saline mine waters into surface water).

4. The natural (geological) sources of pollution are outcrops of Triassic carbonate deposits with zinc–lead ores.

5. During next several years the Zn–Pb ore mine will be closed down. Reducing this activity will result in a lower pollution of natural environment, but the abandoned industrial areas and non-recultivated waste dumps could be menace themselves.

6. In south-eastern part of the map sheet environment pollution is not significant.

LITERATURA
REFERENCES

ATANASSOV I., ANGELOVA I., 1995 – Profile differentiation of Pb, Zn, Cd and Cu in soils surrounding lead and zinc smelter near Plovdiv (Bulgaria). *Bulg. J. Agricult. Sc.*, **1**: 343–348.

BELLOK A., 1996 – Wpływ górnictwa cynkowo-ołowiowego na zanieczyszczenie metalami i siarką wód powierzchniowych i osadów wodnych na obszarze Trzebinia-Chrzanów. *Prz. Geol.*, **44**, 1: 70–74.

BELLOK A., GÓRECKA E., KRYZA A., SZUWARZYŃSKI M., 1997 – Wpływ zakładów przemysłowych na rozmieszczenie metali ciężkich w glebach i podglebiu obszaru Trzebinia-Chrzanów. *Prz. Geol.*, **45**, 5: 513–517.

BOGACZ K., 1967 – Budowa geologiczna północnego obrzeżenia rowu krzeszo- wickiego. Pr. Geol. PAN, Oddz. Kraków, **41**.

BUKOWY S., 1974 – Monoklina śląsko-krakowska i zapadlisko górnośląskie. W: Budowa geologiczna Polski. T. 4, cz. 1: 213–232. Wyd. Geol., Warszawa.

CAPPUYNS V., SWENNEN R., VANDAMME A., NICLAES M., 2005 – Environmental impact of the former Pb–Zn mining and smelting in East Belgium. *J. Geochem. Explor.*, **88**: 6–9.

CICMANOVA S., 1996 – Hydrogeological and hydrogeochemical problems of the Smolnik pyrite deposit. Guide to excursion environmental geochemical baseline mapping in Europe: 12–15. Geological Survey of Slovak Republic, Spisska Nova Ves.

CISZEWSKI D., 1994 – Rozprzestrzenienie metali ciężkich w osadach dennych rzeki Chechło. *Prz. Geol.*, **42**, 2: 116–121.

CISZEWSKI D., 1996 – Rozprzestrzenienie metali ciężkich w osadach dennych zlewni rzeki Chechło. *Inż. Środ. AGH,* 1: 159–168.

COTTER-HOWELLS J., THORNTON I., 1991 – Sources and pathways of environmental lead to children in a Derbyshire mining village. *Environ. Geochem. Health*, **13**: 127–135.

CYGORIJNI K., 1970 – Hutnictwo cynku w XIX wieku w okręgu krakowskim. *Rudy Metale*, **5**: 280–283.

CZOP M., MOTYKA J., SZUWARZYŃSKI M., 2005 – Wstępne wyniki badań odbudowy stosunków wodnych w rejonie likwidowanej kopalni KWK Siersza. W: Współczesne problemy hydrogeologii (red. A. Sadurski, A. Krawiec), t. 12: 128–132. Wyd. UMK, Toruń.
DE VOS W., BATISTA M.J., DEMETRIADES A., DURIS M., LEXA J., LIS J., MARSINA K., O'CONNOR P.J., 2005 – Metallogenic mineral provinces and world class ore deposits in Europe. W: Geochemical Atlas of Europe. Part 1: 43–49. Geol. Survey of Finland, Espoo.
GÄBLER H.E., SCHNEIDER J., 2000 – Assessment of heavy-metal contami- nation of floodplain soils due to mining and mineral processing in the Harz Mountains, Germany. *Environ. Geol.*, **39**: 774–782.
GÓRECKA E., 1996 – Mineral sequence development in the Zn–Pb deposits of the Silesian-Cracow area, Poland. *Pr. Państw. Inst. Geol.*, **154**: 26–36.
GÓRECKA E., BELLOK A., KIBITLEWSKI S., 1995 – Badanie stanu skażenia gleby, wody i osadów wodnych na obszarze Trzebinia-Chrzanów. Centr. Arch. Geol. Państw. Inst. Geol., Warszawa.
ISO 11464. 1999. Soil quality – pretreatment of samples for physico-chemical analyses. International Organization for Standardization.
KABATA-PENDIAS A., PIOTROWSKA M., MOTOWICKA-TERELAK T., MALISZEWSKA-KORDYBACH B., FILIPIAK K., KRAKOWIAK A., PIE- TRUCH C., 1995 – Podstawy oceny chemicznego zanieczyszczenia gleb. Metale ciężkie, siarka i WWA. Biblioteka Monitoringu Środowiska, Warszawa.
KONDRACKI J., 2000 – Geografia regionalna Polski. Wyd. Nauk. PWN, Warszawa.
LIS J., PASIECZNA A., 1995a – Atlas geochemiczny Polski 1:2 500 000. Państw. Inst. Geol., Warszawa.
LIS J., PASIECZNA A., 1995b – Atlas geochemiczny Górnego Śląska 1: 200 000. Państw. Inst. Geol., Warszawa.
LIS J., PASIECZNA A., 1997 – Anomalie geochemiczne Pb-Zn-Cd w glebach na Górnym Śląsku. *Prz. Geol.*, **45**, 2: 182–189.
LIS J., PASIECZNA A., 1999 – Szczegółowa mapa geochemiczna Górnego Śląska 1:25 000. Promocyjny arkusz Sławków. Państw. Inst. Geol., Warszawa.
MOTYKA J., CZOP M., SZUWARZYŃSKI M., WOJNICKA-PUT B., 2003 – Określenie wpływu na środowisko dokonanej i planowanej działalności gór- niczej oraz likwidacji zakładów górniczych, dla terenów górniczych Siersza I, Trzebionka I i Górka, położonych w granicach gminy Trzebinia. Fund. Nauka i Tradycje Górnicze, Kraków.
NIEĆ M., KAWULAK M., SALAMON E., 2001 – Mapa geologiczno-gospo- darczo-sozologiczna w skali 1:25 000 miasta i gminy Trzebinia. Inst. Gosp. Sur. Miner. i Energią PAN, Kraków.
OCENA jakości powietrza w województwie małopolskim w 2004 r. WIOŚ Kraków 2005. WIOŚ Kraków. Internet. http://www.krakow.pios.gov.pl/
PROJEKT powiatowego programu ochrony środowiska wraz z planem gospo- darki odpadami dla powiatu chrzanowskiego. 2004 – Internet. http://wrotamalopolski.pl/
RAPORT o stanie środowiska naturalnego w województwie małopolskim w 2004 r. WIOŚ Kraków 2005. Internet. http://www.krakow.pios.gov.pl
RIEUWERTS J., FARAGO M., 1996 – Heavy metal pollution in the vicinity of a secondary lead smelter in the Czech Republic. *Appl. Geochem.*, **11**: 17–23.
ROZPORZĄDZENIE Ministra Środowiska z dnia 9 września 2002 r. w sprawie standardów jakości gleby oraz standardów jakości ziemi. D.U. Nr 165 z dnia 4 października 2002 r., poz. 1359.
RÓŻKOWSKI A., SIEMIŃSKI A. (red.),1995 – Mapa ognisk zanieczyszczeń wód podziemnych Górnośląskiego Zagłębia Węglowego i jego obrzeżenia, 1:100 000. Państw. Inst. Geol. Warszawa.

SWENNEN R., VAN KEER I., DE VOS W., 1994 – Heavy metal contamination in overbank sediments of the Geul river (East Belgium): its relation to former Pb–Zn mining activities. *Environ. Geol*., **24**: 12–21.
SZUWARZYŃSKA K., BOGACZ A., SZUWARZYŃSKI M., BĄK M., KRYZA A., 2001 – Mapa geologiczno-gospodarczo-sozologiczna miasta i gminy Chrzanów w skali 1:25 000. Przeds. Geol., Kraków.
SZUWARZYŃSKI M., 1984 – Stratygrafia utworów triasu w kopalni Trze- bionka. *Rudy Metale*, **29**: 527–532.
SZUWARZYŃSKI M., 1993 – The lead and zinc ore deposits in the vicinity of Chrzanów. *Geol. Quart*., **37**, 2: 209–228.
SZUWARZYŃSKI M., 1996 – Ore bodies in the Silesian-Cracow Zn–Pb Ore District, Poland. *Pr. Państw. Inst. Geol*., **154**: 9–24.
SZUWARZYŃSKI M., 2000 – Zakłady Górnicze Trzebionka S.A. PDT Kadra, Trzebinia.
SZUWARZYŃSKI M., 2003 – Rejon chrzanowski. W: Hydrogeologia polskich złóż kopalin i problemy wodne górnictwa, t. 2: 316–385. Wyd. Nauk.-Dydakt. AGH, Kraków.
SZUWARZYŃSKI M., KRYZA A., 1995 – Ocena wpływu zakładów prze- mysłowych – ZG Trzebionka, ZM Trzebinia, Rafinerii Nafty w Trzebini, ZSO Górka i in. na rozmieszczenie metali ciężkich w glebach i wodach obszaru Trzebinia–Chrzanów. W: Badanie stanu skażenia gleby, wody i osadów wodnych na obszarze Trzebinia–Chrzanów. Centr. Arch. Geol. Państw. Inst. Geol., Warszawa.
THORNTON I., 1994 – Mining on the environmental; local, regional and global issues. *Appl. Geochem*., **11**: 355–361.
VELITCHKOVA N., PENTCHEVA E.N., DASKALOVA N., 2003 – ICP-AES investigation on heavy metal water and soil pollution in Plovdiv Region (Bulgaria). Scientific Publications "Ecology", 141, Book 2.
WITCZAK S., ADAMCZYK A., 1994 – Katalog wybranych fizycznych i chemicznych wskaźników zanieczyszczeń wód podziemnych i metod ich oznaczania. T. 1. Biblioteka Monitoringu Środowiska, Warszawa.
ŻERO E., 1956 – Szczegółowa mapa geologiczna Polski w skali 1:50 000, ark. Chrzanów. Państw. Inst. Geol. Warszawa.