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INFILTRATION HAZARDS TO SURFACE AND UNDERGROUND WATERS WITHIN THE AREA OF LEGNICA COPPER WORKS

The intensified industrial production in the Legnica-Głogów Copper Region leads to disadvantageous changes in this environment. The research works initiated by "Cuprum" and conducted by many institutions are aimed both at preventive action and reduction of the negative effects caused by the output and processing of the copper ore in soils, water and air. Some works from water protection are the investigations on the hazard of the industrial pollutants from copper works to the underground waters, undertaken by the Institute of Metreorology and Water Management (IMWM) in 1973 and continued by "Cuprum" in the years 1976-1977 under the government program PR-2. The research works were to determine the effect of Walecky Copper Works on the degree of pollution of the surface and underground waters and intakes of potable water "Przybków" and to show the method allowing to remove or reduce the pollution of water by the copper works. The results obtained are presented in this paper.

Investigations were conducted by using the existing wells and holes dug for other (geotechnical and research) purposes: the samples of water were collected also from rain-water, water course, stagnant water as well as from ponds and wells from the "Przybków" intake. The analyses of water covered the results from 92 hydrogeological holes [3], 78 points sampled by the IMWM in 1974 and 12 points sampled by the authors. The tests included indicators used to determine general physicochemical composition of water as well as constituents characterizing industrial pollution, i.e. sulphates and heavy metals (Cu, Ni, Zn, Pb and As).

From the analysis it follows that water pollution is due to point and linear sources located within the region of the copper works as well as regional sources covering practically the whole research area. Pollution in the region of copper works is chiefly due to leaky devices and installations in both electrorefining and sulphuric acid sections discharging large amounts of sulphuric acid with dissolved heavy metals. Pollutants from regional sources are represented by the substances washed by rain-waters from the piles of metallurgic wastes and from the soils and air polluted with emission components containing also sulphates and heavy metals which alkalize the underground waters. The alkalizing effect of the substances emitted by Legnica Copper Works was already stated by SOKOŁOWSKA-CWYNAR [4] and TYRALSKI [5]. Fig. 2 presents the pH values in underground waters of the investigated region. The area of strongly acid waters, enclosed by isoline pH 4, is restricted to direct infiltration of polluting acid solutions. Waters occurring here and characterized by rather low pH (reaching in extreme case the value of 0.4) contain high amounts of sul-

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phates and metals. Mineral acidity, amounting to 600 mval/dm^3 and 230 mval/dm^3 in underground waters of sulphuric acid section and electrorefining section, respectively, indicates that the concentration of free sulphuric acid in the water amounts to 30 and 11 g/dm^3, respectively. Due to high acidity of these waters high amounts of metals can remain in the solution, namely: 12.0 g Cu/dm^3, 6.7 g Ni/dm^3, 6.5 g Zn/dm^3, 2.0 g Fe/dm^3, 0.1 g Mn/dm^3 and 0.03 g Pb/dm^3, the total content of SO_4 reaching 97 g/dm^3 [4].

The zone of medium and low acid waters, enclosed by isoline of pH 7, is the region of pollutants coming from point sources. In this area one observes the neutralization with alkalizing solutions being washed from the surface of the polluted region. A great number of the test stands available in that area allowed to state explicitly that acid waters from the copper works flow to the North into the river Pawłówka and to show that they can also propagate in the reverse direction to the Kaczawa valley. This two-directional water flow is, moreover, justified by geological structure and configuration of the land as well as by the position of copper works on the watershed of the two rivers (fig. 1). A high drop of pollutant concentration, stated on short distance with the region of acid water flow, has proved a low dynamics of the flow and confirmed previous statements [1] that the polluted underground waters are drained by leaking sewerage. The analyses of samples taken from several points within the zone of the pollutants flow to the Pawłówka river have shown that pH of these waters ranges within 5.7–6.8, and the contents of the industrial pollutants are the following: 364–1 929 mg $SO_4^{=}$/dm^3, 0.025–2.46 mg Cu/dm^3, 0.05–2 375 mg Ni/dm^3, 0.025–0.56 mg Zn/dm^3, and 0.020–0.480 mg Pb/dm^3. The average concentrations of sulphates exceed 10 times the corresponding values of the background determined for the comparative region, while the concentrations of heavy metals exceed the assumed hydrochemical background 60 times for Ni, 20 times for Cu, 15 times for Pb and 2 times for Zn. It should be emphasized, moreover, that ionic composition of those waters was homogeneous and much different from that of waters of the remaining parts of copper works (fig. 3).

Waters being directly affected by regional pollutants cover the main part of the region and are characterized by pH ranging within 7.1–11.6, sulphate content within 120–543 mg SO_4/dm^3; the concentrations of heavy metals vary from 0.01 to 0.15 mg Cu/dm^3, 0.025 to 0.2 mg Ni/dm^3, 0.025 to 0.937 mg Zn/dm^3, and from 0.065 to 0.44 mg Pb/dm^3. These waters, when compared with those affected by both point and linear sources, have much lower concentration of sulphates, exceeding 2.5 times the comparative value of the background, and lower contents of Cu and Ni, while the levels of Zn and Pb concentrations are similar in both regions. Waters from this region show a high differentiation in their ionic composition and amount of pollutants. This fact results from both natural and artificial conditions of the region. The former being characterized by nonuniform coverage of the terrain with impermeable formations protecting the hydrogeological environment against pollution, the latter by the content and location of metallurgic wastes stored on the surface and by the configuration of the land with respect to the source of the pollutants emission.

While estimating the usefulness of quaternary waters in the investigated region, it has been stated that waters from the immediate area of copper works buildings should be classified among the wastewaters because of their quality and concentration. They distinctly affect the waters of the northern part of the investigation area. Water composition within the whole area surrounding copper works does not satisfy the requirements of drinking water. From the comparison of the current state of water quality with binding standards, it follows that permissible concentrations of sulphates, Pb, dry residue and general hardness are exceeded. Considering the values of the average concentrations of sulphates, it should be stated that they exceeded 4 times the permissible value in the flow of acid waters area, and 2 times in the remaining region. The factors reducing usable value of waters are the following: total hardness ranging for most tests within 21.6–62.8^{0}n and dry residue varying from 536 to 1 769 mg/dm^3. Concentrations of Cu, Ni and Zn in all tests are below the permissible value, while content of Pb in most tests exceeds it by 0.1 mg/dm^3.

Underground waters within the largest part of the investigated area are highly agressive with respect to concrete because of pH lower than 6, lack of transient hardness and the sulphates content higher than 500 mg $SO_4^{=}$/dm^3. The area of strongly agressive waters spreads beyond the area of copper works and is almost in line with the zone of the flow of acid waters and with the region of highly basic waters being under the influence of piles and refuse dumps.

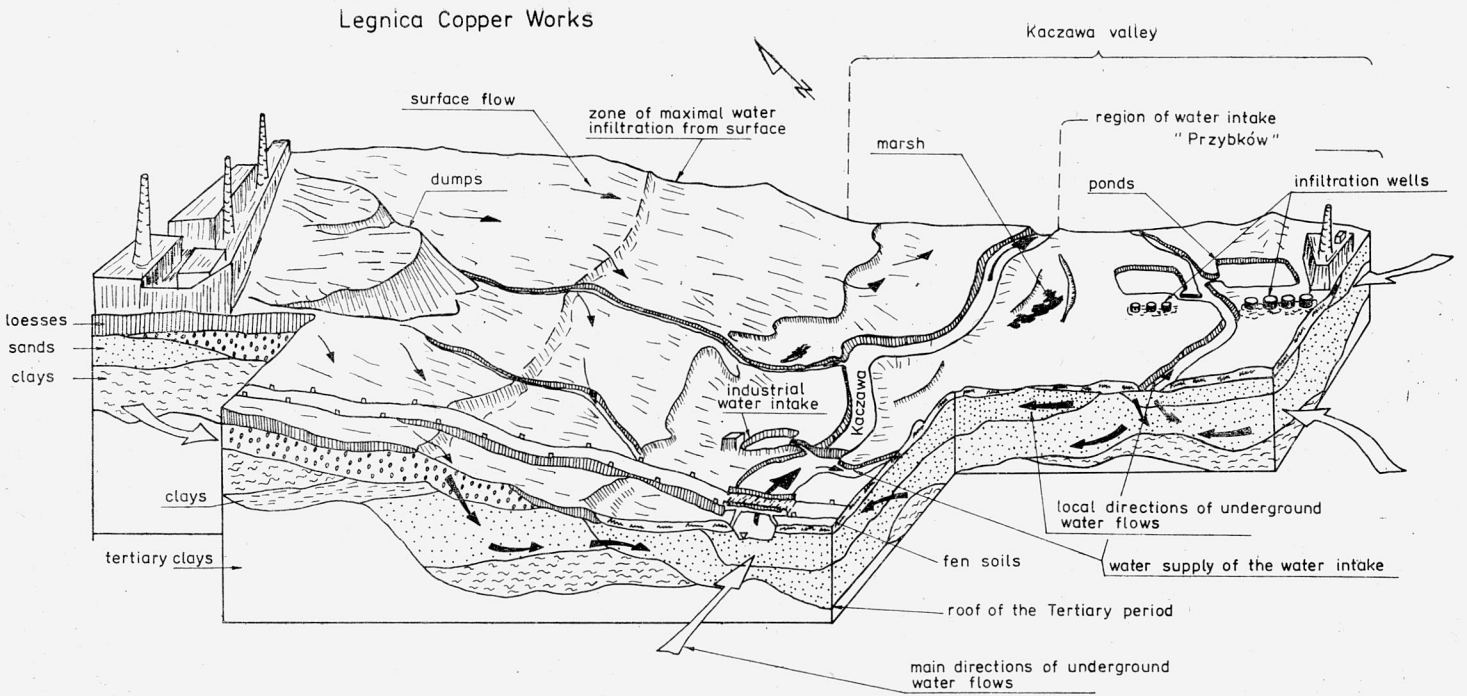

Fig. 1. Local flow directions of surface and underground waters within the region of Legnica Copper Works

Rys. 1. Lokalne kierunki przepływu wód powierzchniowych i gruntowych w rejonie Huty Miedzi „Legnica"

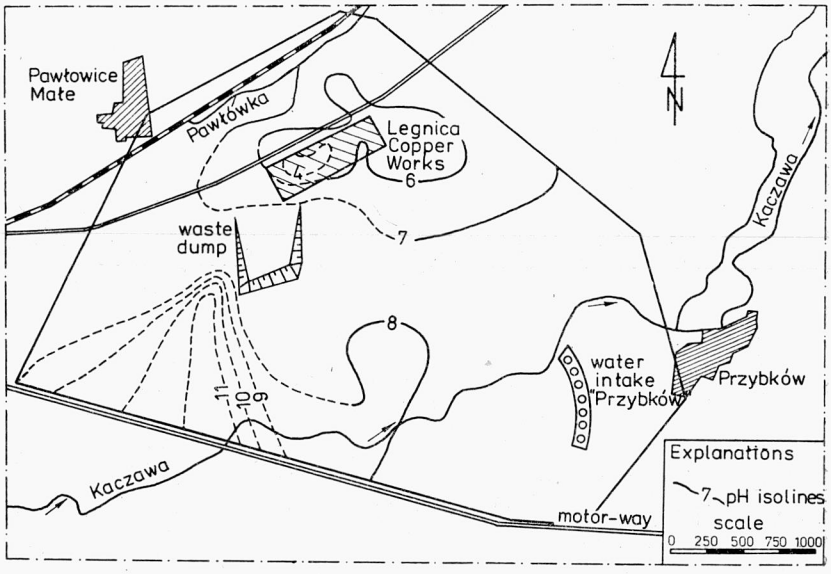

Fig. 2. pH of the underground water in the region of Legnica Copper Works
Rys. 2. Odczyn wód podziemnych w rejonie Huty Miedzi „Legnica"

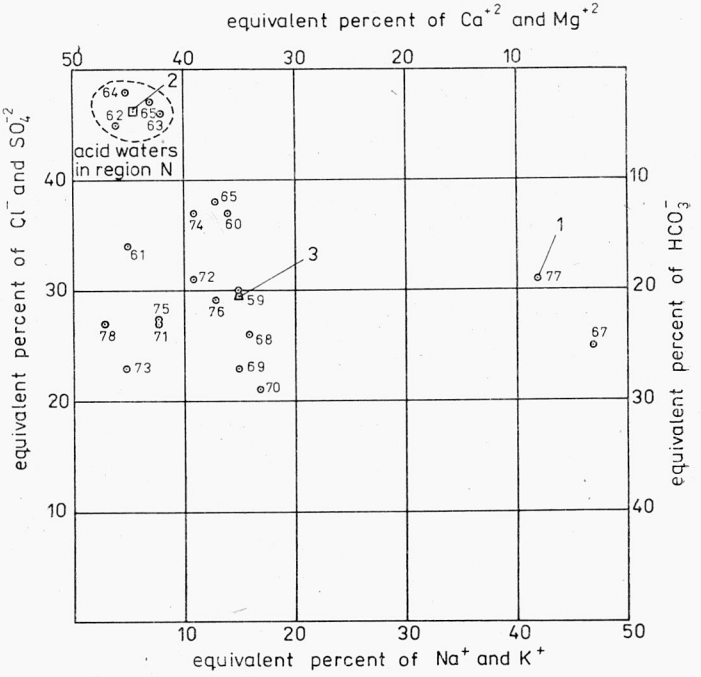

Fig. 3. Composition of the underground waters in the region of Legnica Copper Works (diagram mode according Tołstichin method)
Rys 3. Skład wód podziemnych w rejonie Huty Miedzi „Legnica" (diagram według metody Tołstichina)

"Przybków" intake of drinking water for the town of Legnica, situated 2 km from the copper works on the right bank of the river Kaczawa, is polluted by dusty-gaseous pollutants produced by copper works and emitted to the atmosphere. At the eastern and north-eastern winds (46% of all the winds) the intake is covered with metal dusts. Several tests of water sampled from wells of the intake did not show the presence of heavy metals though they were stated in ponds (Cu — 0.1 mg/dm^3, Zn — 0.1 mg/dm^3, Pb — 0.1 mg /dm^3, Cd — 0.15 mg/dm^3). Content of Zn after treatment of water increased, however, to 0.85 mg/dm^3.

The scheme of the water flow from the region of copper works and intakes of drinking water is presented in fig. 1.

On the turn of 1977/78 year an intensive modernization undertaken by the copper works included: the top gases dedusting, the converter precipitators, wastewater treatment, construction of a new sulphuric acid factory and exchange of installation for technological waters. Lead-carrying dusts were no longer stored on the piles since they were the source of high pollution of the flow coming from the pile. The assumed program of the technical-technological undertakings is to substantially reduce the direct hazard in the region of the copper works and the surrounding area, i.e. within the range of the delimited zone of sanitary protection which is going to be realized in the nearest future.

CONCLUSIONS

1. The pollution degree of the surface and shallow underground waters stated within the region of Walecky Copper Works in Legnica and its area is caused by: a) infiltration of electrolyte and other acid solutions penetrating to the soil from the leaky devices and industrial installation; b) elution of the polluting substances from the piles of metallurgic wastes and soils polluted with the emission constituents and washing out of the pollutants by rain-waters; c) pollution of the atmospheric air.

2. In the region of the two electrorefining and sulphuric acid sections the underground waters are of wastewaters type characterized by mineral acidity and content of sulphates amounting 97 g $SO_4^{=}$ /dm^3 and heavy metals (Cu, Ni, Zn, Pb) of the concentrations of about 27 g/dm^3. From the distribution of the concentrations it follows that these waters expand into the regions of neighbouring sections and beyond the area of the copper works buildings.

3. Polluted waters flow in northern direction to the river Pawłówka, impending this collector, and in south direction to the Kaczawa river valley.

4. Pollution of the surface and underground waters within the area outside the buildings of both electrorefining and sulphuric acid sections is caused by the substances being washed out from the piles, refuse dumps and soils polluted with emission constituents, as well as from atmospheric air.

5. Underground waters from the largest area are agressive to concrete.

6. The tests performed on drinking water from "Przybków" intake have not shown the presence of heavy metals in the wells though they were found in the infiltration ponds.

7. Reduction of the effect of the found sources of underground water pollution is urgent because of buildings security and protection of the present and planned water intakes.

8. The achieved image of the state of pollution and range of industrial pollutants propagation in the region of Legnica Copper Works shows the necessity of the systematic, hydrochemical observations allowing to determine exactly the dynamics of underground waters pollution changes.

9. The taken program of modernization enterprises and sanitary protection zone management is to a high extent to reduce the effect of the copper works on the surrounding environment.

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