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title: **Impact of currently remediated industrial waste disposal sites on groundwater quality in the area of Tarnowskie Góry (Southern Poland)**

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The region of Tarnowskie Góry constitutes a perfect example of negative environmental impact caused by casually locating waste site that takes into account no environmental considerations. In the considered area, there are the biggest in Poland industrial (chemical) waste disposal sites (of a former chemical plant) covered an area of over 27 ha with about 1.4 million tonnes of wastes. This situation together with the naturally high groundwater vulnerability to pollution has resulted in a progressing degradation of water quality in the multi-aquifer system (two Quaternary porous aquifers and two Triassic karst–fissured ones) Locating the wastes in the watershed area has additionally complicated the situation leading to multidirectional contamination spreading. Both Quaternary aquifers are a transit type being a source of recharge of lower Triassic aquifers. Horizontal flow in the Triassic aquifers is predominant while within the upper one (Muschelkalk) weak downward component is also observed. Natural groundwater flow pattern is modified by active wells.

The mentioned sites have been systematically monitored since 1999 (Rubin, Witkowski, 2002). The groundwater quality monitoring network has been subjected to multiple modifications and in 2004 consisted of 42 observation wells which monitor the Quaternary (20 wells) and the Triassic (22 wells) aquifers (Fig. 1).

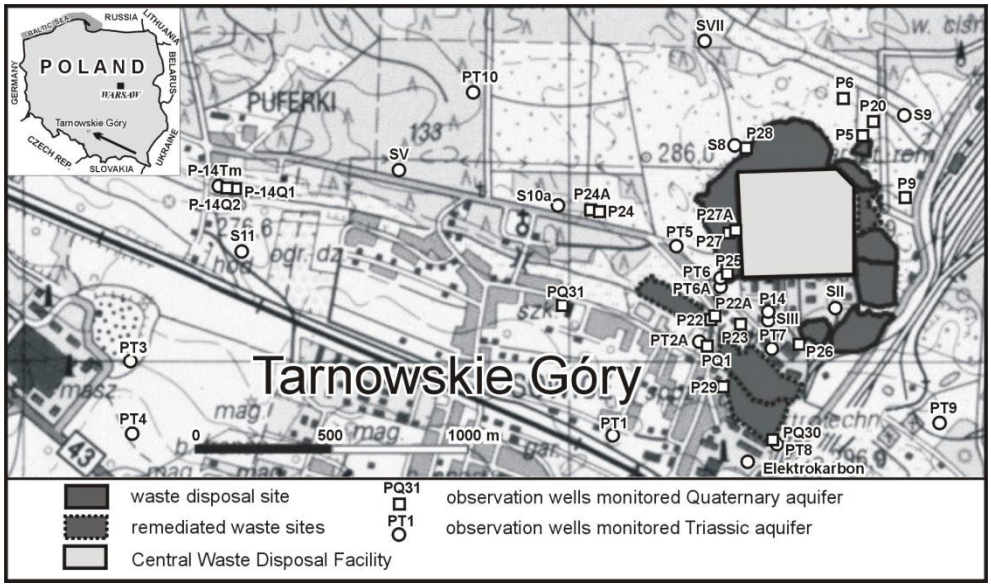

Figure 1. Location of the waste disposal sites and groundwater quality monitoring network.

Groundwater quality of the Quaternary aquifers is very changeable but generally highly contaminated (TDS — up to about 3000 mg/dm^3, Cl — up to 868 mg/dm^3, SO_4 — up to 1130 mg/dm^3, B — up to 275 mg/dm^3, Ba — up to 722 mg/dm^3, Sr — up to 30.6 mg/dm^3). Groundwater of the Triassic aquifers is generally less contaminated. Significantly contaminated water (even locally more than in Quaternary aquifer) has been noticed in the top part of the Mushelkalk in the area of waste disposal sites and adjacent downgradient areas (up to about 1 km from sites) (TDS — up to 2150 mg/dm^3, Cl — up to 275 mg/dm^3, SO_4 — up to 630 mg/dm^3, B — up to 116 mg/dm^3, Ba — up to 1.6 mg/dm^3, Sr — up to 1.25 mg/dm^3) (Rubin, Witkowski, 2003). Better quality water in base parts of the Mushelkalk in the area of considered sites and at the distance up to about 2 km

downgradient from them has been observed. Water of better quality was observed in base parts of the Muschelkalk aquifer in the area of the considered sites and at a distance of up to about 2 km downgradient from them (TDS — up to 694 mg/dm^3, Cl — up to 78,8 mg/dm^3, SO_4 — up to 127 mg/dm^3, B — up to 1.49 mg/dm^3, Ba — up to 0.1 mg/dm^3, Sr — up to 0.327 mg/dm^3) Groundwater of the fourth lowest aquifer (Roethian) have been practically uncontaminated by the considered facility (TDS — up to 306 mg/dm^3, Cl — up to 41 mg/dm^3, SO_4 — up to 67 mg/dm^3, B — up to 0.47 mg/dm^3).

The high concentration of boron has been perceived as particularly dangerous since it reached 275 mg/dm^3 in the Quaternary aquifer, and 116 mg/dm^3 in the Triassic one. This critical situation resulted in closing of many water intakes situated nearby. Therefore a complex remediation of that area together with gradual removal and relocation of wastes to the new built lined Central Waste Disposal Facility has been begun in 2001.

In the course of ten years from 1999 to 2009 a general improvement of groundwater quality of the Quaternary aquifer and some relative stabilisation of the groundwater quality of the Triassic aquifer were observed. A significant differentiation in contaminants migration intensity has been observed within the Quaternary and Triassic aquifers depending on water flow direction.

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