The research of the nitrate migration in the regional recharge area of water supply aquifers (Wielkopolska region, Poland)

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In the regional recharge zone of a Quaternary groundwater flow system distinct groundwater contamination was investigated, reflected mainly by high nitrate concentration. The main objectives of presented study were the investigation of the behavior of nitrate in relation to the flow system and the documentation of the denitrification processes. The examination of groundwater chemistry was performed using data from dedicated groundwater sampling and studies of the gaseous N_2 dissolved in the groundwater. This work was made possible by the financial support of the Ministry of Science and Higher Education Poland (grant no. 2164/BT02/2007/33) and by support of the National Science Centre Poland (grant no. 2014/15/B/ST10/00119).

The study area is located in the highest elevation area of the Lwowek-Rakoniewice Rampart, central Poland (Fig. 1). For a detailed analysis of the water chemistry, the central part of the recharge area was selected, where there are locally unconfined conditions that cause intensive aquifer recharge (Fig. 2). This part of the aquifer system is the most vulnerable to groundwater contamination.

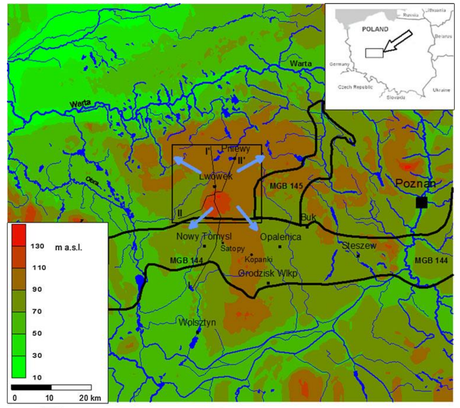

Fig. 1 The location of the study area on a background of the land relief.
1 The boundaries of the major groundwater basins, 2 surface water, 3 general groundwater flow directions, 4 the study area, 5 the lines of cross sections

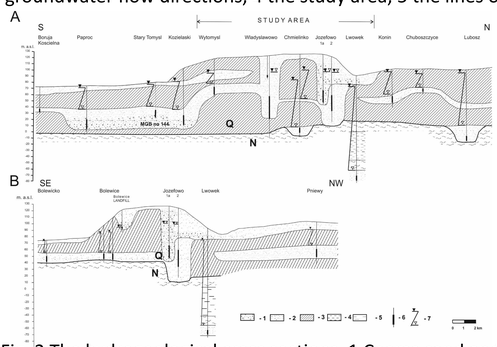

Fig. 2 The hydrogeological cross sections. 1 Coarse sand and gravel, 2 medium and fine sand, 3 till, 4 clay, 5 brown coal, 6 silt, 7 the location of the well screen, 8 ground water level, Q Quaternary, N neogene

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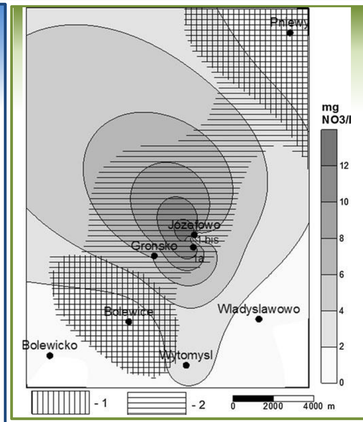

For such a small study area, relatively distinctive groundwater chemistry variations were present. In the central part (Fig.3) high nitrate concentrations are observed and systematic decrease of its concentrations along flow path. The total hardness and sulphate concentrations (products of the denitrification) are the lowest in the central part of the area and its increase along flow lines is visible. Moreover relative high concentrations of these parameters during wells exploitation is also observed (Dragon, 2013).

Fig. 3 Changes in the hydrochemical parameters against a background of the nitrate concentrations.
1 Total hardness >6.0 mval/l, 2 sulphate >70 mg/l

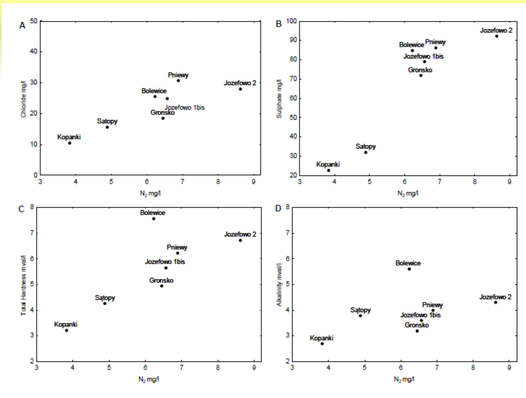

Fig. 4 The scatter diagrams of gaseous N_2 and some hydrochemical parameters

The study of excess N_2 indicated denitrification occurence. The excess of N_2 is much lower in wells located in part of the recharge area covered by forests (the Kopanki and Sapowice wells). The denitrification was documented in the entire study area across both: the confined and unconfined parts of the flow system. It is believed that the confined part is more favourable for denitrification but the high concentration of excess N_2 indicates that denitrification is also present in the unconfined parts of the flow system (Fig. 4).

The nature of the groundwater chemistry changes (low alkalinity, high sulphate and total hardness) suggests that autotrophic denitrification prevails in the studied system.
The presence of a very high nitrate concentration in the shallow part of the flow system and a downward gradient that displaces the contamination front to the deeper parts of the aquifer generate a ‘‘time bomb’’ with an ‘‘explosion’’ that is accelerated by water extraction. The mixing of contaminated groundwater with unpolluted groundwater from deeper parts of the flow system is the factor that reduces the risk of deep-water contamination.

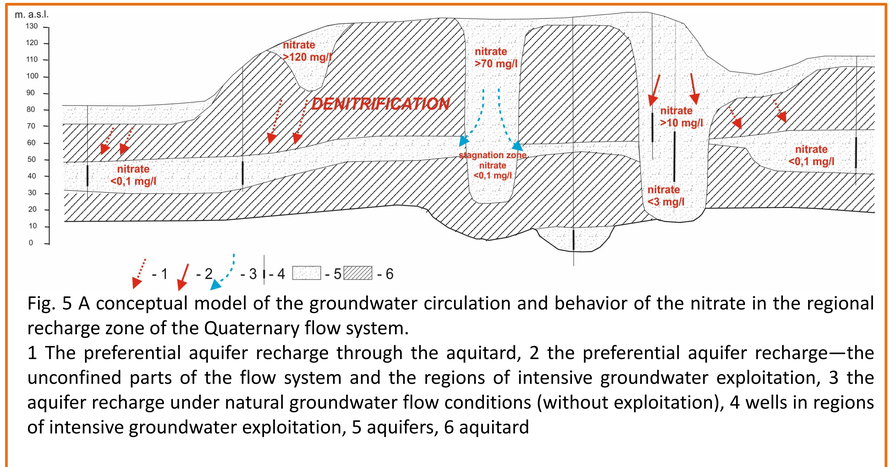

Fig. 5 A conceptual model of the groundwater circulation and behavior of the nitrate in the regional recharge zone of the Quaternary flow system.
1 The preferential aquifer recharge through the aquitard, 2 the preferential aquifer recharge—the unconfined parts of the flow system and the regions of intensive groundwater exploitation, 3 the aquifer recharge under natural groundwater flow conditions (without exploitation), 4 wells in regions of intensive groundwater exploitation, 5 aquifers, 6 aquitard

The distinct groundwater contamination was detected in the near-surface zone of the unconfined aquifers, indicated mainly by high nitrate concentrations (>70 NO_3mg/l). These contaminants migrate to the deeper parts of the flow system at the regions of intensive groundwater exploitation, where concentration of nitrate at depth of 80 m exceed 10 NO_3mg/l. In the regions where the water extraction is not performed the nitrate concentrations are low, even if in the shallow part of the aquifer the concentration of nitrate exceed 70 NO_3mg/l. Low nitrate concentrations occur also in the regions of confined aquifers occurrence (Fig. 5).

Conclusions

It was detected that denitrification is the process of nitrate removal from groundwater. As a result, an increase in the sulphate concentration and total hardness appears in the groundwater. The process of denitrification was confirmed by the existence of a high gaseous N_2 concentration. The potential for denitrification is higher in the confined conditions and leads to an overall decline in nitrate in the deep aquifers. Based on research performed the conceptual model of groundwater circulation was formulated. It was documented that recharge areas are extremely vulnerable to pollution by nitrate. It was also concluded that the monitoring of groundwater chemistry should be performed for both shallow and deep parts of the flow system, even though the shallow part is not used for water supply purposes.

Reference:

Dragon K., 2013 – Groundwater nitrate pollution in the recharge zone of a regional Quaternary flow system (Wielkopolska region, Poland). Environmental Earth Sciences 68: 2099-2109.