FACT SHEET: Vistula River Basin

The Vistula (Wisla, Vistule, Weichsel) River Basin has a drainage area of 193,894 km^2 and it includes close to 60% of Poland. The river originates from the Barania Góra Mountains and drains into the Baltic Sea near Gdańska. The basin water bodies comprise 2,660 rivers, six near-sea rivers, five channels, 484 lakes, and 94 groundwater water reservoirs. The population (2015) is close to 23.5 million inhabitants and 53.9% of the basin is agricultural land. Table 1 presents the main characteristics of the basin.

Figure 1. Vistula River drainage basin.

Table 1. Vistula River Basin characteristics

Vistula
COUNTRIES: POLAND, UKRAINE, BELARUS
Pedo-climate: Continental region and zone
Drainage Area 193,894 km^2
Maximum altitude: 2576 m
Annual average rainfall 641 mm/year
Main land uses: Agriculture 53.9%; Forest 39.2%, and Urban 5.5%
Population in 2015: 23,657,254
River length 1058 km
Strahler Order – 8
Discharge at outlet 688.8 m^3/s
Outlet coordinates: 49°36'21" N, 19°00'13"E

The main pressures on water result from several economic activities, that include heavy industry, chemical and petrochemical, power-generating, intensive agriculture and forestry, and urban activities, including emissions of collected and not collected domestic waste.

The agricultural pressure to water bodies is significant throughout Poland. According to Polish CSO data, an average of 75.5 kg N/ha/y of nitrogen fertilizers (mostly as ammonium nitrate, urea and nitro-chalk) and 24.3 kg N/ha/y of phosphorus fertilizer was used in Poland in 2014, which resulted in the consumption of 1,098.4 thousand tons of nitrogenous fertilizers and 341.1 thousand tons of phosphate fertilizers.

Agriculture and water in the Vistula River Basin

The negative impacts of agricultural activities to the groundwater quality of Poland are documented in scientific literature as herein summarized. Nitrate concentrations in excess of drinking water standards have been reported by Zurek et al. (2015), Sapek (2002), Zabłocki et al. (2015), Krolak and Raczuk (2018), and Czekaj et al. (2016).

Excess of nutrients in agricultural activities can be considered as the main potential source of soil and groundwater pollution (Sapek, 2002). Best management practices, particularly animal waste storage and treatment, nutrient management, precision agriculture and crop choices are effective in preventing deterioration of groundwater quality (Sapek, 2002; Fronsyzk et al. 2016; Sieczka et al., 2018).

Sapek (2002) studied the groundwater impacts in 22 dairy production farms located in the Ostroleka region (northern Poland). The fertilization rate was 120 kg N/ha/y from poultry dung. Groundwater under manure, animal waste heaps, and slurry is at high risk of nitrogen leakage, as demonstrated by measurements in well water and soil samples. Concentrations of nitrates, ammonium, and phosphorus in water samples were above the acceptable drinking water standards, up to 312 mg $N\text{-}NO_3^-$/L, 250 mg $N\text{-}NH_4^+$/L, and 250 mg $P\text{-}PO_4^{3-}$/L. The study concluded that farming best management practices, particularly with regard to nutrient management, must be applied to protect groundwater quality.

Czekaj et al. (2016) measured nitrates in the Goczałkowice reservoir basin (26 km^2) groundwater located in the Upper Silesian industrial region in southern Poland. Nitrate concentrations ranged from 0.53 to 255 mg NO_3^-/L. The isotopic composition of groundwater allowed backtracking sources of nitrates to sewage and agricultural fertilization. Seasonal variability of groundwater quality, linked to recharge variations, resulted in higher nitrate concentrations in spring.

Froncyzk et al. (2016) focused on three experimental sites in Poland; the Chociwel site (20 ha) near Wroclaw city in southern Poland; the Damno site (40 ha) near Słupsk city in northern Poland; and the Imielin site (22 ha) near Warsaw in central Poland. The study monitored nitrogen (nitrate, nitrite, ammonium) and phosphate sources in north, south and central Poland using precision cultivation of winter wheat. Average concentration of phosphates in groundwater samples, linked to phosphorus fertilization, was 1.075 mg PO_4^{3-}/L. Water quality in Damno groundwater was good, whereas it was poor in a local depression in Imielin. The study concluded that precision fertilization could reduce groundwater impacts.

Krolak and Raczuk (2018) sampled groundwater in several provinces in the eastern part of Poland (Warmian and Mazury, Podlaskie, Lublin, Subcarpathian and the eastern part of Mazovia) to determine risk of methemoglobinemia in infants due to high nitrate concentrations in drinking water. Nitrate sources were identified in organic and mineral over-fertilization and leakage from septic tanks, farm buildings, and manure piles. In Poland, the nitrate concentration for drinking water is assumed to be lower than 5 mg NO_3^-/L (Dz. U. 2008, No. 143, item 896). Groundwater nitrate concentration ranged from 0.51 to 47.12 in deep wells, and from 2.45 to 161.1 mg NO_3^-/L in dug wells (Krolak et al., 2018). Nitrate concentration in dug wells exceeded 50 mg NO_3^-/L in about 60% of cases, and measured from 5 to 50 mg NO_3^-/L in over 30%. Krolak and Raczuk (2018) concluded that the highest health risk for infants came from consuming water from dug wells.

The groundwater of a 40 ha agricultural field site in the middle Vistula valley was studied by Sieczka et al. (2018). The rate of nitrogen application was found to be between 55 and 105 kg N/ha/y and the main fertilizer was ammonium nitrate. Measured field nitrate concentrations ranged from 0.1 to 0.3 mg NO_3^-/L. The authors concluded that precision fertilization can minimize the impacts of agriculture to groundwater.

Witkowski and Rubin (1997) reported on the results of the regional monitoring surveys in the Krakow and Katowice regions of the upper Vistula basin. The Katowice Regional Water Management Council is in charge of the area, covering over 7380.2 km^2. Monitoring was conducted in 55 sites from 1993 to 1996. During this period, nitrate concentration increased markedly (>20% change in concentration) over most of the area, caused by urban and industrial pollution. Increases ranging from 0 to 10% or 10 to 20% were reported for agricultural areas.

Zabłocki (2015) studied the groundwater in the upper part of the Osownica catchment, which is a predominantly agricultural catchment located in Central Poland near Warsaw. He reported annual nitrogen mineral fertilization rates of 33-46 kg N/ha/y plus organic rates of 21-44 kg N/ha/y. Concurrently, nitrate concentrations in groundwater ranged from 22.58 to 44.28 mg NO_3^-/L. Therefore, nitrate leaching into the soil creates a groundwater hazard; a 40% decrease in nitrates should be achieved to meet the regulatory value of 10 mg NO_3^-/L.

Różkowski et al. (2017) worked on agricultural impacts in the karstic cave waters of the Kraków-Częstochowa upland, in southern Poland. Agricultural impacts included agrichemicals, farming intensification, as well as anoxic conditions. In 2014, the concentration of nitrate at pump stations in Wierzchowisko, Tobodno, Olsztyn, and Mirów varied between 19 to 43 mg NO_3^-/L. The groundwater nitrate concentration in the Częstochowa area varied from 0.71 mg NO_3^-/L to 201 mg NO_{3e}^-/L (average of 40.76 mg NO_3^-/L, 16 samples from 2012 to 2015). Nitrate concentration in the caves in the Kraków area was similar, but reached a maximum of 485.4 mg NO_3^-/L. At the same time, in the Częstochowa area, the average groundwater phosphate concentration was 1.55 mg PO_4^{3-}/L. In the Kraków area, phosphate maximum measured phosphate concentration was 6.872 mg PO_4^{3-}/L.

Finally, Zurek et al. (2015) used geochemical monitoring and groundwater modeling to quantify the anthropogenic impact on groundwater dependent terrestrial ecosystems, the Niepolomice forest and the Wielkie Bloto fen near Kraków. The Niepolomice forest includes nature reserves, the European bison breeding centre, and provides recreational services. Groundwater is over-exploited to satisfy increasing water needs. The lowering groundwater table seriously affects the terrestrial ecosystems. Isotopic data provided strong evidence of an upward movement of groundwater from the Neogene aquifer to the quaternary aquifer.

Impact on coastal areas

Poland is the major country that influences the nutrients balance in the Baltic Sea and national programs have been developed for developing waste water treatment and implementing the Nitrates Directive, to reduce the impact of riverine nutrient fluxes at the coastal zone (Kowalkowski 2009). However, as indicated by the author, regional actions are needed for further reducing eutrophication.

The Gulf of Gdansk, a semi-enclosed coastal system, is strongly impacted by the Vistula riverine deliveries of nitrogen and phosphorus so that dinoflagellates and blue green algae are regularly an important component of the phytoplankton (Kudryavtseva et al., 2019). The bay ICEP (Indicator for Coastal Eutrophication Potential; Billen and Garnier, 2007) is positive for both nitrogen (ICEP-

N of 4.8 kg C/km^2/d) and phosphorus (ICEP-P of 0.3 kg C/km^2/d) , which means a nutrient imbalance of nitrogen and phosphorus in excess to silica leading to a shift from diatoms to potentially harmful algal blooms.

The Vistula, together with the Oder and the Nemunas deliver to the Baltic Basin, 75% of nitrogen and 84% of phosphorus. According to Eriksson et al. (2005), expectation for reducing nutrients would rely more on the management of urban point sources unless agriculture would rapidly intensify as in other EU founder countries.

Conclusion

Poland has designated 4.54% of its territory as Nitrate Vulnerable Zone (NVZ) in 2012 and it plans (as part of the NVZ revision) to include the whole country in the restrictions for fertilizer application in order to conform with the Nitrates Directive.

Overall, the scientific literature documenting the impacts of agriculture to groundwater of Poland is still limited. Despite groundwater surveys have been conducted, data have not been analyzed systematically, or at least the results have not been extensively reported in the scientific literature. The lack of such analysis hinders the identification of actions to improve the groundwater quality as required by EU Directives.

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