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THE INFLUENCE OF THE LAND RECLAMATION DRAINAGE SYSTEMS ON GROUNDWATER QUALITY

WPŁYW SYSTEMÓW MELIORACYJNYCH NA DEGRADACJĘ JAKOŚCI WÓD PODZIEMNYCH

1. Introduction

Land reclamation drainage systems (LRDS) generally play a positive role in groundwater quality protection. These systems work as drainage elements of soil water and shallow groundwater, which are usually strongly contaminated and reduces amount of groundwater which can infiltrate to deeper aquifers. However, in some specific conditions the LRDS can facilitate the migration of drainage water to deeper water supply aquifers. This concerns natural flow systems as well as (even first of all) groundwater flow conditions changed by exploitation of water by wells, thus contributing to a high downward gradient. As a consequence these conditions can lead to degradation of groundwater quality.

The article presents the identification of the influence of the LRDS on groundwater quality deterioration. Two examples are analysed: Wilkowyja well-field supplying water for Jarocin town and Tursko well-field supplying water for Pleszew town. The Wilkowyja well-field is an example of the influence of an old unrecognised LRDS built before the II World War. Its functioning was identified on map which show an old reclamation drainage system originating from 1912. The Tursko well-field is an example of the influence of LRDS that have led to bacterial contamination of groundwater quality. As a consequence the exploitation of the well-field was stopped and which resulted in a lack of water for about 22 thousands inhabitants of Pleszew and surrounding villages for almost one and half months.

These examples clearly show the importance of recognizing LRDS as a potential groundwater pollution source. First and foremost it is indispensable to catalogue these systems (particularly old unrecognised systems). This should be completed during the selection of new well-field localisation or during documentation of groundwater protection zones. It is particularly important in case of the Tursko well-field because LRDS are also located in a region where the well-field is currently being extended.

2. Hazard of groundwater contamination caused by land reclamation drainage systems

The negative influence of the LRDS on groundwater quality can appear in the following cases:

- incorrect design of these systems (when conditions of groundwater protection are not taken into consideration),
- damage of drainage system elements,
- changes of groundwater regime on the drainage area.

The first case take places when the LRDS is wrongly constructed and its influence is manifested by infiltration of drainage water to deeper groundwater flow systems. This situation can appear when part of the drains is located in the vadose zone of an aquifer and the water table is located below drains. In this case drainage water (soil water and shallow groundwater) collected from an area of shallow water table occurrence moves to drains located in the vadose zone of an aquifer where its infiltration is facilitated by a high permeability of rocks. The infiltration of drainage water can take place also through the bottom of settler wells or pipeline transported drainage water from drains to surface water or a drainage ditches. These elements of drainage systems are usually poorly constructed and are subject to leaks. The contamination of groundwater can also appear if the exits of drains or pipelines are located in position which enable the penetration of surface contaminated water to drains in periods of high surface water level occurrence.

The second case is connected with situation, when during building works, digging works or the excavation of rocks leads to uncontrolled damage of drainage systems. In this case drainage water does not move to surface water but infiltrates through leaks (usually uncontrolled) to groundwater.

The third case occurs when a properly designed and built drainage system is located within a well-field cone of depression (especially in case of an unconfined aquifer). In this environment the drains (or its part) can bring drainage water into groundwater circulation.

The article presents two cases of groundwater contamination resulting mainly from the damage of pipelines which move drainage waters from drains to surface water. In the case of Tursko well-field contamination of groundwater can also be connected with improperly construction of the drainage system. Part of the drainage net is probably located in the area where the highly permeable sands and gravels occur below the ground surface. These sands and gravels form a vadous zone of water supply unconfined aquifer.

3. The influence of land reclamation drainage systems on groundwater quality deterioration

3.1. Wilkowyja well-field example

The Wilkowyja well-field is located within the area of the zerkowsko-rydzynska ice-marginal valley. The wells are located in a line barrier parallel to the Lutynia River, close to a moraine upland area boundary (Fig. 1). The thickness of the unconfined aquifer is about 20 m. The anthropogenic contamination of groundwater was documented during period of well-field construction in 1988 (nitrate concentration - 3,5-6,0 mgN-NO_3/l, nitrite concentration - 0,29-0,59 mgN-NO_2/l). During well-field exploitation continuous deterioration of groundwater quality was documented. Due to this fact in 1994 hydrochemical research was performed [4]. A net of piezometers was installed and samples of groundwater were taken in the well-field recharge area. The result of this research showed that the main reason of groundwater quality deterioration was the influence of water from the upland area. These waters are characterized by high concentrations of nitrite (9,0 mgN-NO_2/l) and nitrate (20 mgN-NO_3/l) and a relatively low concentration of chloride (34,0 mg/l), sulphate (48,0 mg/l) and Total Dissolved Solids (TDS – 311,0 mg/l) - the concentrations typical for drainage water. These waters move from an upland area characterized by agricultural land use. Groundwater occurring in the aquifer in the area outside the drainage water plume were characterized by low concentration of nitrate (1,2 mgN-NO_3/l) and nitrite (0,012 mgN-NO_2/l).

The explanation of the reason of the appearance of drainage water in the well-field recharge area was enabled by an old drainage system map which was recovered. The insightful analysis of these maps indicated that on the moraine upland area the LRDS was built in 1912. This system was composed of a drains net which collected soil water and shallow groundwater. These waters were moved to a collective settler well located within the area of the ice marginal valley from where drainage water was moved by pipeline to the river (Fig. 1). It was turned out during field work that elements of this drainage system had been damaged during the construction of a housing estates. This caused infiltration of drainage water to deeper groundwater and its movement to the pumped wells.

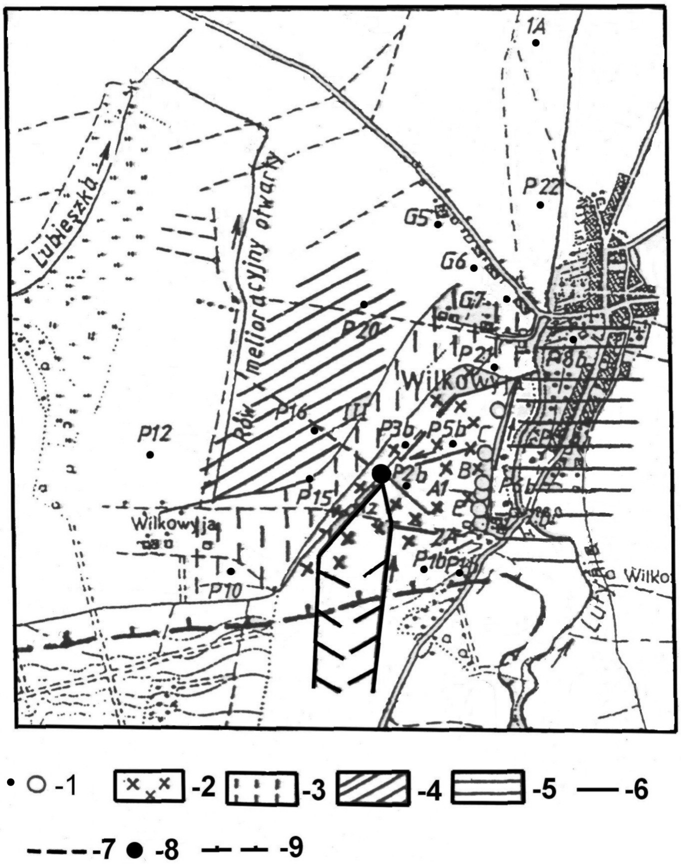

Fig. 1. Wilkowyja well-field location map. 1 – piezometers and wells sampled for chemical analyses; 2 –the area contaminated by nitrate at high level (>10 mg-NO_3/l) originating from land reclamation drainage system; 3 – the area contaminated by nitrate at high level (<10 mgN-NO_3/l); 4 – the area contaminated by nitrate at low level influenced by arable lands; 5 – the area contaminated by ammonia, chloride and sulphate influenced by the rural area of Wilkowyja village; 6 – drainages; 7 – pipeline moving drainage water; 8 – collective well; 9 – the valley boundary

3.2. Tursko A well-field example

During the spring of 2007 intensive bacterial contamination was detected within the water supply system in Pleszew. As it turned out the reason for this condition was the bacterial contamination of the Tursko A well-field – the main well-field supplying water for Pleszew town. As a consequence the exploitation of the well-field was stopped and this lead to a lack of water for about 22 thousand inhabitants of Pleszew and surrounding villages for one and half months (period of time between March 15 and April 30). The bacterial and chemical contamination was detected in two wells screened in an unconfined aquifer in the Prosna River valley region [2].

3.2.1. Well-field characterization

Tursko A well-field has been functioning since 1986 and it is composed of two wells (43,0 and 44,0 m deep). These wells tapping groundwater from unconfined Quaternary aquifer which is composed mainly of gravels and coarse sands [1]. It should be underlined that also the approximately 10 m thick vadose water zone is composed of highly permeable sands and gravels. These conditions create high vulnerability to pollution.

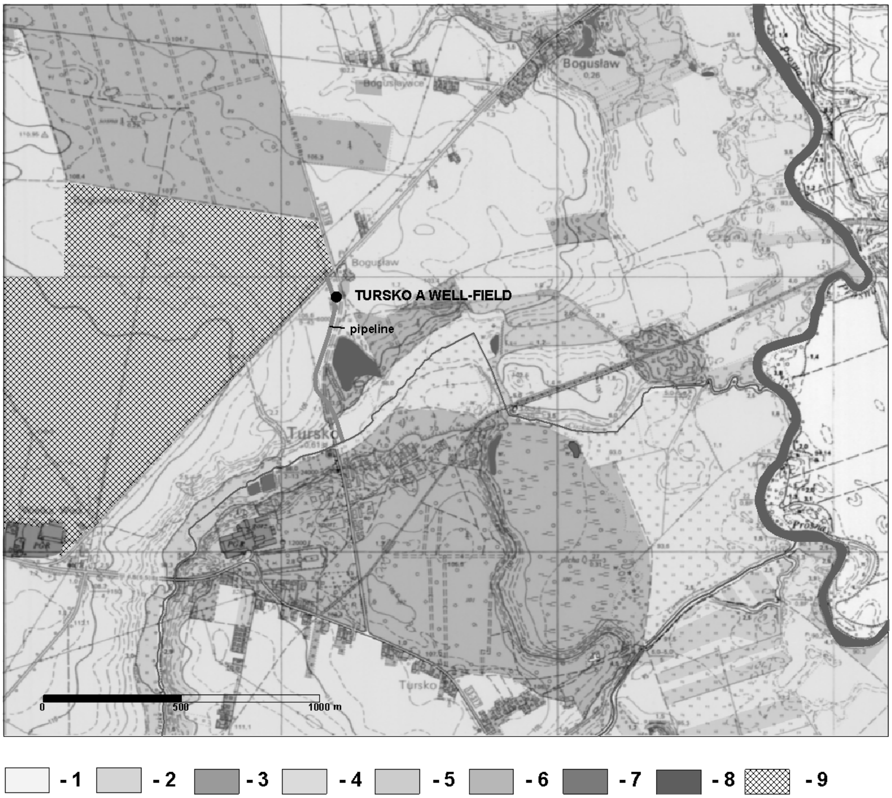

Fig. 2. Map of the land use (surrounding of the Tursko A well-field). 1 – arable lands; 2 – meadows and pastures; 3 – forests; 4 – orchards; 5 – wastelands; 6 – households buildings; 7 – animal farms (cattle and pigs); 8 – surface water; 9 – area of the land reclamation drainage system

The well-field surrounding the area is dominated by agricultural lands. On these lands both organic and artificial fertilizers are used but organic fertilizers prevail (livestock manure). In Tursko village a distillery factory is located from where waste products are spread onto the fields (also fields directly adhering to the well-field).

A serious source of pollution is the LRDS which functions in the surroundings of the well-field. This system is composed of a drainage net located north and north-west of the well-field (Fig. 2 and 3). Approximately 100 m north of the well-field the collective well is located from where drainage waters are moved to the Giszka stream. This pipeline is composed of cement pipes which are linked by leaking connections (unsealed). The pipeline directly crossed the well-field protection zone and is located 2 m away from well no 1a. Moreover, the pipeline is equipped with settle wells with poorly sealed leaking bottoms. One of the settle well is located 20 m away from the well-field. Such faulty construction of the pipeline causes infiltration of drainage water directly to the ground within the wells cone of depression. Drainage water originating from agricultural cultivated fields where organic and mineral fertilizers (and also waste products from a distillery factory) are used are invariably strongly contaminated (particularly by nutrients). Moreover, these settle wells are open and not protected. As a consequence it is easy to spill sewage or manure into them.

3.2.2. The reasons of groundwater quality deterioration

Groundwater tapping from Tursko A well-field was contaminated by both: bacterial and chemical constituents [3].

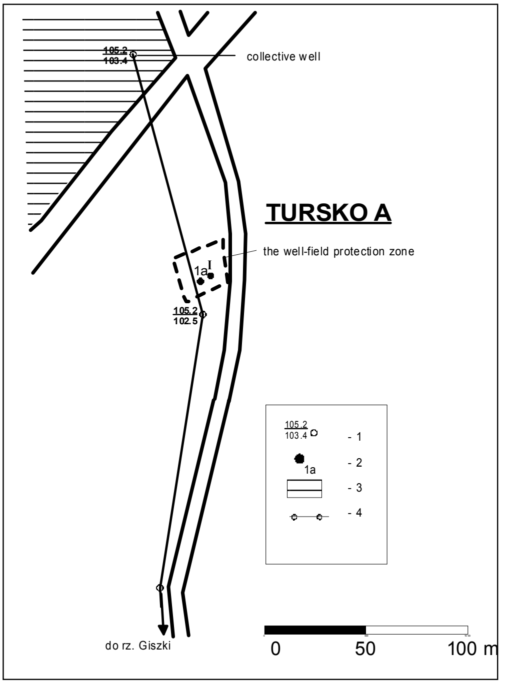

Fig. 3. Location of the components of land reclamation drainage system nearby Tursko A well-field. 1 – settler wells; 2 – wells of the Tursko A well-field; 3 - area of the land reclamation drainage system; 4 – pipeline

Chemical contamination was observed as early as 1975, when the first well was constructed. In this period increased concentrations of nitrates, chloride and sulphate were observed (13,2; 46,0 and 100,0 mg/L - respectively). Over succeeding years the contamination level increased to 30,8; 70,0 and 195,0 mg/L (respectively) in 2007. In the spring of 2007 a high bacterial content of *Eschericha Coli* was discovered: in well no I 28000 (jtk/100 ml) and in well 1a 130000 (jtk/100 ml). Groundwater pumped from well no I was characterised by a specific odour of manure (z2S; g2S). In the water a high oxygen consumption ($ChZT_{Mn}$ 6,6 mgO_2/L), a high content of ammonia (0,44 mg/l) and nitrite (0,68 $mgN\text{-}NO_2/l$) was also detected. Moreover, increased concentrations of organic nitrogen (0,51-0,7 mgN/l) and phosphates (0,2-0,3 mg/l) occurred there.

The most probable reason for bacterial contamination was infiltration of drainage water from the transmit pipeline directly crossing the well-field protection zone, which moves water from drainage net to the Giszka stream (Fig. 4). The transmit pipe is located 2 m away from the well no 1a. The direct reason of contamination almost certainly was damage of the transmit pipeline, that took place in January 2007, when digging work was carried out to unblock the movement of water in the pipe. This reason was documented by the differentiation of groundwater quality in two wells with identical construction, during simultaneous pumping of these two wells. The higher level of contamination in well no 1a located near to the pipeline (2 m away) than in well no I more distant from the pipeline (8 m) was observed. This is also supported by the fact that bacterial contamination appeared in 2007, while the pipeline has existed from the beginning of the well-field exploitation.

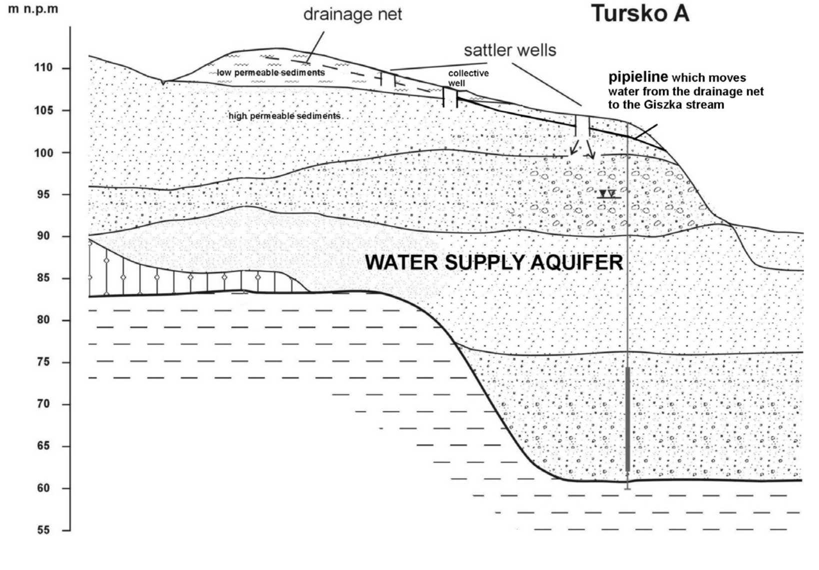

Fig. 4. The schematic hydrogeological cross-section

It should be added that the appearance of contamination in March 2007 to some extent could be connected with hydrologic-meteorological conditions. In the late autumn of 2006 and winter of 2007 intensive precipitation was noted. This can activate effective infiltration of meteoric water after a long period of hydrologic drought, which had existed in the Wielkopolska region from 2003. This precipitation also activated the flow of water in the LRDS and its infiltration to the ground.

4. Conclusions

The presented examples of groundwater quality degradation point out to the necessity of becoming aware of the LRDS as potential sources of groundwater contamination.

The detailed cataloguing of the LRDS is indispensable, particularly in the case of the recharge area of well-field. Also the assessment of drainage systems hazards on groundwater quality is important. For this assessment cataloguing of technical characteristics of these systems is necessary and assessment of their technical efficiency (particularly recognition of drainage system damage).

Based on the collected information about the LRDS and based on the research of hydrogeological conditions the assessment of groundwater hazards should be performed taking into consideration the natural groundwater regime and changed by exploitation. It is particularly important in case of new well-fields construction because liquidation of negative influences of the LRDS on groundwater quality requires costly works of its reconstruction and rebuilding.

On the other hand it should be underlined that the LRDS should be constructed taking into consideration conditions of groundwater quality protection. It is indispensable to consider in the construction process not only the agricultural criterions but also the hydrogeological conditions.

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