Chapter 10

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Identification of Pollution Hotspots and Their Effect on the Quality of Underground Waters of the 'Las Gdański' Water Intake in Bydgoszcz

1. Introduction

The drinking water intake for the city of Bydgoszcz is situated within the administrative borders of Bydgoszcz, in the districts of Las Gdański and Myślęcinek, in the northern part of the city. In the south the border of the water intake is marked by the Warszawa – Szczecin railway line, separating the water intake from the residential infrastructure, the western border is made up by the railway tracks of the Gdańsk – Katowice line, the eastern one – by the Jasiniecka Street, while the northern border – the Zamczysko Street at the foot of the Myślęcinek Slope. The collection of underground waters from the 'Las Gdański' intake is compliant with the water law permission (Decyzja Wojewody Kujawsko-Pomorskiego 2005). The water intake in Las Gdański is protected following the Decree of the Regional Director of the Water Management Board in Gdańsk (Rozporządzenie nr 2/2005). Despite the protective zones being defined, the isolation of underground waters from the ground, one shall identify and monitor the pollution hotspots which could affect the quality of underground waters. Kleczkowski breaks down the pollution hotspots into point, linear, small-area and large-area (Chełmicki 2002). Another division of pollution hotspots considers their location against the ground. The sources located in the atmosphere, on the ground and under it, however, above the aquifer are differentiated (Błaszyk, Górski 1993). An important source of underground waters degradation are unsecured wells, making the penetration of pollution to underground waters easier, in the non-sewered areas. A common cause of the deterioration of underground waters are leaky septic tanks and the application of plant protection agents, fertilisers, triggering changes in the composition of

underground waters. The area of the Las Gdański water intake has been thoroughly investigated in terms of hydrogeology (together with model studies), geology, geophysics; their results are provided in numerous papers (Dąbrowski 1993, Hercka 1994, Boroń, Woźniakowski 2008).

2. Material and methods

There have been determined types of threats which occur in the protected area or in its vicinity, such as railway lines of state importance, animal breeding stations, public and trunk roads, fertilisers application, and the composition of liquid waste from septic tanks. There were identified the zones of indirect protection, capture zone, locations of adjacent areas and the type of impact. Based on the analyses of the composition of wastewaters (authors analysis) from septic tanks from small septic units, there were calculated the loads of pollution from sewages introduced into the ground from the area of the allotment gardens during the holiday season (5 months), assuming the amounts of domestic wastewater per resident based on the report edited by Heidrich (2007). Drawing on the observations of the plant protection agents and fertilisers commercially available in the gardening centre, agrochemicals used by the garden-owners were defined. The area of the Las Gdański water intake was thoroughly investigated in terms of hydrogeology, geology, geophysics, and the results of those tests have been included in numerous papers (Dąbrowski 1993, Hercka 1994, Boroń, Konczal 2002, Boroń, Woźniakowski 2008).

In the vicinity of the water intake those best determined and used are 3 basic multiaquifer formations: quaternary (Pleistocene), tertiary (Miocene), and cretaceous multiaquifer formation (the Early Cretaceous – the Valanginian).

The quaternary multiaquifer formation (stratum I according to the hydrogeologic model of Bydgoszcz) is represented by a low thickness, from a few to a dozen or so meters of sands of the Late Pleistocene. The collection of waters with siphon wells (siphons I – III: wells 1 – 55), at present the water intakes of the Forest Part of Culture and Leisure and Family Allotment Gardens. The water table in the quaternary period is undisturbed in nature and it is supplied directly from precipitation, locally in the northern part of the area from watercourses. The stratum is most susceptible to pollution due to a lack of isolating deposit. Quaternary slabs are built by medium and course sands.

Tertiary multiaquifer formation (stratum II) is built from fine and silty Miocene sands, about 40 m thick, with interstratified brown coal in the roof, which makes the Main Reservoir of Underground Waters (GZWP) no 140 and it occurs almost all across the city of Bydgoszcz. The waters of that reservoir occur under the deposit of the insulating stratum of Pliocene clays reaching the thickness of about 30 m, with its total erosion in hydrogeologic windows. In the area of Las Gdański the Miocene level is not used, providing a buffer and a potential reserve under the further extension of the water intake. Only within the borders of the excavation valley of the **Early Pleistocene,** due to a favourable grain-size-composition of the aquifer, 6 wells are used. The valley runs in the NW – SE

direction, reaching the depth of about 60-80 m under the ground level and ensuring hydraulic contact of the Tertiary with the quaternary period. The formations of deeper quaternary period are built by medium and coarse sands with gravels.

The cretaceous formation of confined water table (stratum II according to the hydrogeologic model of the city of Bydgoszcz (Dąbrowski 1993)) is bipartite. The lower stratum is connected with the sandstones and sands of the Valanginian – it is a basic stratum used on the water intake, and the upper one, connected with the sandy formations of the Barremian – or the well in operation in Fordon. There occur, among others, serious mudstone – sandy with clays and claystones of the Hauterivian resulting in a limited hydraulic communication between those strata. The Early Cretacenous level in the eastern part of the water intake is isolated with silts of the Oligocene, in the central and eastern part – with mudstone and claystones of the Hauterivian. The Vistula River was a natural base for the drainage of the waters of the Early Cretaceous. The measurement points within a given homogenous part of underground waters were well openings, the piezometers and other sources allowing for selective water collection from the aquifer investigated.

3. Results and discussion

Table 1 breaks down the types of threats posed to the underground waters intake of Las Gdański identified. Among numerous types of pollution which occur in the hotspots linear in nature (railway lines), one shall mention pesticides, herbicides, mineral oils, and lubricants. Throughout the operation of the allotment gardens and numerous private gardens agrochemicals are applied. The application of fertilisers containing easily soluble nitrogen compounds can be a concern. The fertiliser composition is given in Table 2.

Over 2008-2010 the State County's Sanitary Inspector in Bydgoszcz was performing audits of the sanitary condition of allotment gardens in the city of Bydgoszcz. It was found that uncontrolled and illegal wastewater discharge, even only throughout the summer season, triggers environmental degradation. Additionally the audit has identified the following irregularities:

- Despite the existing municipal sanitary sewer system, family allotment gardens are not connected to it (which is incompliant with the current law),
- Most allotment gardens have no possibilities of removing wastewater,
- Some allotment-gardeners have their own septic tanks, unfortunately the payment slips for empting the liquid waste containers are missing. There are no technical facilities (narrow access paths) and so 80% of allotment gardens cannot be reached by septic tanker trucks; the septic tanks are not emptied.

The irregularities identified breach the provisions provided for in the regulations (Rozporządzenie nr 2/2005) and in the following laws (Regulamin 2006, Rozporządzenie Ministra Zdrowia z dnia 20 kwietnia 2010, Rozporządzenie z dnia 9 listopada 2010, Ustawa z 8 lipca 2005, Ustawa z dnia 13 kwietnia 2007, Ustawa z dnia 13 września 1996, Ustawa z dnia 17 lipca 2007, Ustawa z dnia 27 kwietnia 2001, Ustawa z dnia 7 czerwca 2001, Załącznik do uchwały

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Table 1

Pollution hotspots and their impact on the quality of underground waters of the 'Las Gdański' water intake in Bydgoszcz

Item	Type of threat	Indirect protection zone:	Capture zone	Adjacent areas:	Impact:
1.	Railway lines of state importance	None	Routes: Warszawa – Gdańsk, Śląsk – Porty,	Routes Warszawa – Gdańsk, Śląsk – Porty,	Application of pesticides, herbicides, oils,
2.	Animal breeding	Animal Breeding and Insemination Station	Animal Breeding and Insemination Station, Fauna Garden, Stud Farm	None	Former wastewater discharge to the flow in Armii Krajowej Street
3.	Public and trunk roads	Road no 5, Gdańska Street, Zamczysko Street, Hipiczna Street,	Road no 5, Gdańska Street, Osiedle Leśne	Road no 5, the area of the city	Drainage of the road belt to the ditch
4.	Application of fertilisers	Family Allotment Gardens, agricultural areas	Family Allotment Gardens, agricultural areas	Family Allotment Gardens, agricultural areas	Composition of some agents is given in the text of this paper
5.	Introducing wastewater to waters and into the ground	Flow along Armii Krajowej Street, Family Allotment Gardens	Family Allotment Gardens	Family Allotment Gardens	Potential pollution are given in the text of this paper
6.	Underground water collection devices, with Q not lower than 10 m^3/h	Wells in the area of Family Allotment Gardens	Wells in the area of Family Allotment Gardens	Wells in the area of Family Allotment Gardens	Limiting the resources of underground waters by collection and pollution

Table 2

Content of fertiliser components in the fertilisers applied in the allotment gardens

Fertiliser type	Content of fertiliser components expressed as a percentage							
	N og.	NO_3	N_{NH4}	N_{NH2}	P_2O_5	K_2O	MgO	Microelements
Dobrovit	7.0	2.7	1.8	2.5	3.0	5.0	-	
Iglak	-	-	-	-	-	-	15.0	
Hortus	24.0	12.3	11.7	-	6.0	6.0	2.0	B, Cu, Fe, Mn, Mo, Zn.

Drawing on the composition of liquid waste from septic tanks from small septic units, broken down in Table 3, there were calculated the loads of pollution from domestic waste introduced into the ground in the area of the allotment gardens during the holiday season (5 months), assuming that septic tanks are not pumped out. The results, broken down in Table 4, show considerable masses of pollution discharged with domestic waste to the ground, e.g. total nitrogen 18.8 Mg, ammonia nitrogen 12.6 Mg, total phosphorus over 11 Mg. One shall note introducing almost 3 Mg of zinc, about 0.5 Mg of chromium, 5.7 Mg of sulphates and 3 Mg of chlorides into the ground.

Table 3

Composition of liquid waste from septic tanks from small septic units

Parameter	Unit	Composition of liquid waste from septic tanks	
		Range of variation	Mean value
BOD_5	$gO_2{*}m^{-3}$	6284-11720	8879
COD	$gO_2{*}m^{-3}$	11526-19620	15741
Total suspensions	$g{*}m^{-3}$	2866-6427	4263
Total dry residue	$g{*}m^{-3}$	11342-20110	15694
Ammonia nitrogen	$gN_{NH4}{*}\ m^{-3}$	132-310	210
Total nitrogen	$gN{*}\ m^{-3}$	205-632	314
Total phosphorus	$gP{*}\ m^{-3}$	110-242	185
Total iron	$gFe{*}\ m^{-3}$	178-310	234
Lead	$gPb{*}\ m^{-3}$	-	7.3
Zinc	$gZn{*}\ m^{-3}$	-	48.5
Copper	$gCu{*}\ m^{-3}$	-	5.3
Chromium	$gCr{*}\ m^{-3}$	-	9.1
Nickel	$gNi{*}\ m^{-3}$	-	3.6
Cadmium	$gCd{*}\ m^{-3}$	-	0.5
Chlorides	$g{*}\ m^{-3}$	38-71	51
Sulphates	$g{*}\ m^{-3}$	66-182	95
Detergents	$g{*}\ m^{-3}$	21-38	28
Ether extract	$g{*}\ m^{-3}$	49-81	64

Table 4

Estimated pollution loads from domestic waste introduced into the ground from the area of the allotment gardens /season (5months)

Parameter	Loads of pollution in kg
Ammonia nitrogen ($N_{NH4)}$	12 600
Total nitrogen (N)	18 840
Total phosphorus (P)	11 100
Total iron (Fe)	14 040
Lead (Pb)	438
Zinc (Zn)	2910
Copper (Cu)	318
Chromium (Cr)	546
Nickel (Ni)	216
Cadmium (Cd)	30
Chlorides ($Cl^{-)}$	3060
Sulphates (SO^{-}_{4})	5700
Detergents	1680
Ether extract	3840

Another important element which can have a negative effect on the quality of underground water of Las Gdański is the application of plant protection agents and fertilisers. The gardening centres, located in the vicinity of allotment gardens, offer many plant protection and weed control agents. Below there are a few easily available products used by allotment-gardeners:

– Cheminova A/S agent: Glyfos 360 SL – a weed killer: the control of *Elytrigia* and other monocotyledonous and dicotyledonous weeds. The content of glyphosate (compound of aminophosphonates group) – 360 g/l in a form of isopropylamine salt **N**-(phosphonomethyl)glycine), has a toxic effect on aqueous organisms, it can cause long-lasting unfavourable changes in the water environment.

– Dow AgroSciences agent Starane 250 EC – herbicide – a weed killer in a form of concentrate to prepare water emulsion, applied as a foliar fertiliser, used for post-emergence control of onerous dicotyledonous weeds on agricultural land, lawns, orchards of pome and stone fruit trees. The content of bioactive substance: fluroxypyr in a form of 1-methylheptyl ester (compound from a group of derivatives of pyridinecarboxylic acid) – 250 g/l (it is forbidden to use the agent in the direct protection zone of the water intake and in the area of spa towns, the buffer zones of national parks and nature reserves. One shall not allow the agent to penetrate to water reservoirs and watercourses.

– Syngenta Crop Protection Sp. z o.o. – agent Bravo 500 S.C. fungicide, with a contact effect, as a preventive agent to protect agricultural, vegetable crops and ornamental plants from fungal diseases. The content of active substance:

chlorotalonil (tertrachloroizoftalonitrile: compound of the group of phthalates) has a toxic effect on aqueous organisms, it can trigger long-lasting unfavourable changes in the water environment.

– SumiAgro (UK) Ltd.: agent Ślimakol 06 GB, a slug-killing agent, with a gastric and contact effect, in a form of granulated bait. To control snails e.g. in lettuce, ornamental plants grown in the field and under shields. The content of bioactive substance: metaldehyde – 6% (it is forbidden to use the agent in the zone of direct protection of the water intakes as well as in the area of spa towns, the buffer zones of national parks and nature reserves. One shall not allow for the agent to penetrate to water reservoirs and watercourses).

– Dow AgroSciences Polska Sp. z o.o. agent Magus 200SC, a spider-mite-killing agent in a form of concentrate of concentrated suspension to be diluted with water. It controls all the development stages of spider-mites, especially the European red mite and red spider mite. The plants: apple, pear, plum, cherry, sweet-cherry trees, raspberry, blackberry, white currant, ornamental plants in the ground and under shields. The content of bioactive substance: fenazaquin (compound of the quinazoline class).

4. Discussion

Considering the effect of pollution hotspots on the underground waters of the 'Las Gdański' water intake, the hydrogeologic conditions are the key element; mostly the depth of the underground water table and the degree of its insulation from the ground surface. The underground water movement in porous formations is slow: from the fractions of millimetres a day to tens of meters. In the case of rocks strongly insulated and karst rocks, the underground water movement is fast, even up to a few hundred meters a day. The fast movement is accompanied by poor filtration or no filtration at all (Dąbrowski 1993). The degree of potential threat was determined based on the time of the penetration of pollution from the ground to the reservoir (Dąbrowski 1993). According to that criterion, considering the fact that for most underground water reservoirs, a lack of insulating cover in the aquifers roof, more than 90% of the underground waters in the province have been classified as group AB. Those are threatened waters, with the time of migration of pollution from the ground to waters up to 25 years.

The results of research of nitrates in underground waters in 17 European countries (EEA 1999) according to the report of the European Agency of Environmental Protection of June 1999 showed that in about 25% of the underground waters investigated the concentration of 25 mg $NO_3 \cdot dm^{-3}$ was exceeded. In the 96 areas of underground waters in Europe analysed, only in 20 there were found no exceeded concentrations of nitrates. In Poland about 62% of water to be supplied to people is collected from underground water intakes. The degree of degradation of those waters depends on the amount of pollution discharged and the geological structure of the areas of the occurrence of aquifer deposits. The amount of pollution reaching the underground waters gets

considerably decreased due to the pattern of natural purification processes. An important factor affecting the degree of degradation of underground waters is soil permeability over the aquifer. Shallow quaternary waters most often are not covered by the non-permeable stratum and so they are threatened with a direct effect of pollution from the surface. The type of nitrogen compounds which occur in underground waters is an indicator of their pollution. A high concentration of ammonia nitrogen with the absence of nitrates and nitrites demonstrates a fresh pollution with wastewater. The occurrence of all inorganic forms of nitrogen points to permanent pollution, while the domination of nitrate nitrogen – to pollution distant in time (Kleczkowski 1990, Chełmicki 2002).

From the information on the results of the audit of conditions for the adequate operation of family allotment gardens (Heidrich 2007), presented by the Department of the Environment, Agriculture and Spatial Management of the Supreme Chamber of Control in September 2010 shows that an inadequate use of the infrastructure of family allotment gardens, against the family allotment gardens law and the law on keeping the communes clean and orderly, poses a threat to the environment.

5. Conclusions

1. The types of threats posed to the 'Las Gdański' underground water intake were identified. Among numerous pollution which occurs in the hotspots linear in nature, one shall mention pesticides, herbicides, mineral oils, and lubricants. In the allotment gardens, and in numerous private gardens situated in the region under protection, the protected zone principles are violated.
2. Uncontrolled and illegal discharge of domestic waste to the ground in the area of the allotment gardens results in introducing tens of tones of various kinds of pollution.
3. The first stage of protective measures must involve getting rid of septic tanks and connecting the areas of the allotment gardens to the municipal sanitary sewer system.

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