Effect of a Pig Farm on the Physical and Chemical Properties of a River and Groundwater[1)]

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Abstract

Research has been conducted to evaluate the effect of a large pig farm on the physical and chemical properties of river and groundwater within the close farm vicinity. A river "R" flows in 0.5-1 km distance of a farm border. River water was sampled at three following points: at farm border, sewage intake at decanter of a closed down treatment plant and outside the farm border. The groundwater samples were collected out of the observational network installed to examine physical and chemical properties of groundwater, that is 6 piezometers and a dug well. To do that, some geological bore-holes were made down to 5 m depth. The piezometric examinations showed a significant concentration of nitrogen compounds, phosphates and chlorides in groundwater. Well water showed the contents of ammonium and nitrate nitrogen to exceed the boundary values for drinking water tenfold and figured out at 5.52 mg/dm^3 and 100.72 mg/dm^3, respectively. The river water examined demonstrated a substantial concentration of ammonium nitrogen (mean 3.25 mg/dm^3), nitrite one (0.06 mg/dm^3) as well as total suspension (38.39 mg/dm^3). The parameters have greatly decreased the examined water purity grade and ranked it among purity grade **III.**

Keywords: pigs farm, pollution, groundwater, river waters

Introduction

Water quality depends on both its natural composition and introduced pollutants being mainly products of human operation. Serious sources of inland water pollution prove to be not only industry and municipal management, but also agriculture, especially trade oriented.

Nowadays in Poland the major sources of water pollution are made by: leakages out of livestock buildings as well as from manure, liquid manure and silage storage place. Manure is kept on the ground most often and hardly ever protected properly. Liquid manure flowing out of a heap percolates into the soil and sometimes it drifts to the nearest water-course. The water washes out great quantities of soluble organic substances out of a manure heap improperly protected or a defected manure tank [12]. Hence, the waters in close proximity to big breeding farms, where enormous amounts of organic matter is obtained and cumulated, have been seriously endangered to pollution.

Research has been taken up to evaluate the effect of big pig farms on the physical and chemical properties of river and groundwater within close farm vicinity.

Materials and Methods

Investigations were made in the close proximity of a pig breeding farm in "P" place, with 5,200 animal stock on average. The animals were kept in a bedding system on a shallow litter removed regularly every day. Manure was gathered near farm livestock buildings and taken away to fields.

The farm is situated in the southern part of Grzeda Sokolska. The southern part of the farm is a flat depress-

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ed area covered with permanent grassland, while its northern part is a plain, slightly rolling and sloping towards the south.

The geological constitution of this region shows the main contribution of loesses and silts reaching down to 15 m depth. The first water-bearing stage is made by marls; a water level appears at the depth of 10-15 m b.s.l.

A small river "R" flows in 0.5-1 km distance of the farm border. River water was sampled at the following three points: (Wl) - at farm border; (W2) - sewage intake at decanter of a closed down treatment plant; (W3) - outside farm border (Fig. 1).

The groundwater samples were collected out of the observational network installed to examine physical and chemical properties of groundwater, that is 6 piezometers and a dug well. To do that, some geological bore-holes were made down to 5 m depth.

The piezometers were produced from fully inactive material (PEHD), while the filters were additionally protected against silting up by a filter gauze. The piezometers were fitted at three different points at a distance of 100 to 500 m of farm boundary, yet only three were used for regular water sampling for physical-chemical analyses. No water rise in the piezometers resulted from hydrogeologic conditioning. A piezometer (PI) was located below a district of block of flats, (P2) outside the built up-area at the edge of the field making a line of morphological water - flow, (P3) located furthest of the farm close to buildings. The groundwater was also sampled from a dug well at 5.5 m depth (P4) used for over 30 years.

Samples of surface and groundwater for physical and chemical examination were collected in one-liter bottles flushed three times. The water from piezometers was taken out by means of an electrical pump until a piezometer was emptied completely.

In the water examined there was determined a content of ammonium nitrogen, nitrite and nitrate nitrogen, organic nitrogen, chlorides, phosphates, iron, manganese, copper, sulphides and sulphates, BOD_5, Oxidability (with $KMnO_4$) Oxidability (with K_2Cr_207) reaction, colour, total suspension, organic carbon and conductance of electrolytes.

An ammonium nitrogen content was established by a method of direct nesslerisation (PN-C-04576-4), a nitrite nitrogen content by colorimetric method with sulfanilic acid and L-naphtylamine (PN-73-C-04576/06), while nitrate nitrogen content with sodium salicylate (PN-82 C-04576/08). A content of organic nitrogen and organic carbon was determined in accordance to the Polish Norms PN-73 C-4576/11 and PN-C-04633-3. A phosphate level in the water was fixed by a colorimetric molybdate method with stannic chloride as reducer (PN-89 C-04537/02), while the chlorides by Mohr titration method according to PN-ISO 9297. A sulphide content was determined by methylene blue (method 8131), while a sulphate one according to gravimetric method PN-74-C-04566/09. A manganese level in the water was examined with PAN indicator (method 8149), whereas total iron by colorimetric method with 1.10 phenothroline (PN-73 C-04586/03). The determination of specific conductance of electrolytes, total suspension and pH was performed after the Polish Norms as following: PN-77 C-045542, PN-72 C-04559/02 and PN-90 C-04540/01. Oxidability was fixed with two methods: a dichromate method with 1007 Digester set use and permanganate method acc. to PN-85 C-04578/02. The organoleptic methods were applied to evaluate water colour and flavour (PN-74-C-04558 and PN-72 C-04557).

River and groundwater was sampled at two seasons: autumn-winter (from Oct. to March) and spring-summer time (from April to Sept.) over the two-year period. There were 52 samples of the river water and 20 of the groundwater gathered altogether (5 series from each piezometer).

The findings obtained were subjected to statistical analysis. All the determination results were characterized by a number of samples collected (N), median value (Me), arithmetic mean (M) and standard deviation (SD), mean error of aritmetic mean (SE) and variability coefficient (V%). The relation between sampling points and results of ground water physical and chemical determination was checked by Anov Friedman test (mean rank).

The relation between sampling and results of river water physical and chemical determination was checked by t-Student test - P(t) and madian test - P(Me) [10].

Results and Discussion

The results of examination on physical and chemical properties of groundwater are presented in Table 1.

The groundwater from different piezometers demonstrated great variability of physical and chemical indicators examined. Only a content of phosphates, manganese and total suspension was not conditioned by water origin (In the table lack of significant statistical differences are marked with the same letter). The other indicators showed some significant differences in regard to location of piezometer installation.

A natural sloping of area caused substantial cumulation of organic matter in the meadow groundwater below the farm (PI). At this spot a high concentration of ammonium, nitrite and nitrate nitrogen, as well as an increase in phosphate and chloride concentration was stated.

Lomotowski [9] holds that chloride increase in farming sewage amounts to mean 50 gCl/m^3. Chloride concentrations in clean groundwater at the first water-bearing stage in Poland range from 10 up to 30 gCl/m^3. If chloride concentrations are higher than 30 gCl/m^3 it is highly possible that shallow deposition of groundwater is affected by anthropogenic pollutants. In case of the farm monitored the ground water contained from 57.2 $mgCl/dm^3$ up (P2) to 1021.6 $mgCl/dm^3$ (P3) and that proved a considerable influence of a farm on this water quality.

According to Hermanowicz [6] nitrite nitrogen concentration in groundwater did not exceed 0.01 mg/dm^3 level, yet in groundwater the level was a lot higher and ranged from 0.31 mg/dm^3 up to 3.14 mg/dm^3. A raised content of ammonium and nitrite nitrogen together with nitrite presence could rise from permanent infiltration of animal droppings to groundwater.

The geological constitution of the farm, i.e. fine fraction of eroded loess material (semipermeable material), brought about a slow water flow that could be conducive to self-purification processes. Biernacka and Pajnowska [2] draw attention to the sorptive capacity of the soil areation layer, which is able to decompose most pollutants and neutralize over the self-purification process.

High concentrations of analyzed indices in groundwater could prove a steady and intensive pollutants supply from a farm used for over 25 years and, moreover, exceeding sorptive capacity of areation layer as well as breaking protective barrier and ability of the environment to self-purify.

Table 1. Physical - chemical properties of groundwater.

	Indicator		P1	P2	P3	P4
1.	Ammonium nitrogen	M	6.79	3.15	61.94	5.52
		Me	7.5	3.0	75.0	6.3
	(mg N / dm^3)	mean rank	2.8 b	1.2 a	4.0 c	2.0 ab
2.	Nitrate nitrogen	M	23.98	2.96	121.4	100.72
		Me	24.2	2.22	103.0	62.0
	(mg N / dm^3)	mean rank	1.8 a	1.2 a	3.6 b	3.4 b
3.	Nitrite nitrogen	M	0.77	0.31	3.14	0.38
		Me	1.15	0.2	2.5	0.4
	(mg N / dm^3)	mean rank	2.6 ab	1.40 a	3.8 b	2.2 a
4.	Organic nitrogen	M	7.1	7.38	93.4	43.8
		Me	6.8	7.8	95.0	23.0
	(mg N/dm^3)	mean rank	1.2 a	1.8 a	3.8 b	3.2 b
5.	Phosphates	M	0.55	0.96	2.58	0.93
		Me	0.4	0.8	2.8	0.94
	(mg PO_4/dm^3)	mean rank	1.4 a	2.4 a	3.4 a	2.8 a
6.	Iron	M	0.08	1.83	0.94	0.0
		Me	0.1	2.3	1.2	0.0
	(mg Fe/dm^3)	mean rank	2.2 b	4.0 c	2.5 b	1.3 a
7.	Manganese	M	0.1	0.11	0.08	0.1
		Me	0.1	0.1	0.1	0.1
	(mg Mn/dm^3)	mean rank	2.5 a	2.9 a	2.1 a	2.5 a
8.	Chlorides	M	107.0	57.2	1021.6	135.0
		Me	98.0	30.0	1010.0	135.0
	(mg Cl/dm^3)	mean rank	1.7 a	1.4 a	4.0 c	2.9 b
9.	Sulphates	M	260.2	44.0	806.8	76.2
		Me	247.0	45.0	814.0	78.0
	(mg SO_4/dm^3)	mean rank	3.0 c	1.0 a	4.0 d	2.0 b
10.	Oxidability (with $KMnO_4$)	M	51.4	108.6	174.0	277.0
		Me	48.0	125.0	188.0	277.0
	(mg O_2/dm^3)	mean rank	1.2 a	1.8 a	3.0 b	4.0 c
11.	Oxidability (with $K_2Cr_2O_7$)	M	194.0	378.0	552.0	512.0
		Me	190.0	430.0	500.0	512.0
	(mg O_2/dm^3)	mean rank	1.2 a	1.8 a	3.0 b	4.0 b
12.	Reaction	M	6.8	7.28	7.04	7.50
		Me	6.8	7.2	7.1	7.5
	pH	mean rank	1.5 a	3.0 b	1.6 a	3.9 b
13.	Conductance of electrolytes	M	1605.8	722.2	5776.0	1732.0
		Me	1700.0	706.0	5900.0	1800.0
	(μS/cm)	mean rank	2.2 b	1.0 a	4.0 c	2.8 b
14.	Colour	M	14.0	24.0	28.0	20.0
		Me	10.0	20.0	30.0	20.0
	(mg Pt/dm^3)	mean rank	1.2 a	3.0 bc	3.6 c	2.2 b
15.	Total suspension	M	25.8	37.2	59.6	54.8
		Me	20.0	38.0	60.0	55.0
	(mg/dm^3)	mean rank	1.4 a	2.4 a	3.3 a	2.9 a
16.	Organic carbon	M	80.6	89.8	268.0	77.0
		Me	82.0	92.0	250.0	77.0
	(ppm)	Mean rank	1.8 ab	2.8 b	4.0 c	1.4 a

Table 2. Physical - chemical properties of river water.

	Determination	Units	n	min.	max.	Me	M	SD	SE	V%
1.	Ammonium nitrogen	mg N-NH_4/dm^3	52	0.02	16.6	0.63	**3.25**	4.79	0.66	147.3
2.	Nitrate nitrogen	mg N-NO_3/dm^3	52	0	4.3	0.89	**0.9**	0.89	0.12	99.6
3.	Nitrite nitrogen	mg N-NO_2/dm^3	52	0	0.66	0.01	**0.06**	0.13	0.01	213.6
4.	Organic nitrogen	mg N/dm^3	52	1.2	3.2	2.1	**2.05**	0.53	0.07	26.0
5.	Chlorides	mg Cl/dm^3	52	6.5	46	19	**22.42**	10.64	1.48	47.4
6.	Phosphates	mg PO_4/dm^3	52	0	0.98	0.13	**0.19**	0.19	0.02	103.1
7.	Iron	mg Fe/dm^3	52	0	0.76	0.20	**0.29**	0.21	0.02	71.1
8.	Manganese	mg Mn/dm^3	52	0	0.05	0.03	**0.02**	0.01	0.003	77.5
9.	Sulphides	mg S/dm^3	52	0	0	–	**0**	–	–	–
10.	Sulphates	mg SO_4/dm^3	52	7	24	15	**15.5**	3.96	0.55	25.5
11.	BOD_5	mg O_2/dm^3	21	3	4.9	4.3	**3.93**	0.7	0.15	17.9
12.	Oxidability (with $KMnO_4$)	mg O_2/dm^3	52	2.3	28	7.4	**9.37**	6.74	0.94	72.0
13.	Oxidability (with $K_2Cr_2O_7$)	mg O_2/dm^3	32	20	82	50	**46.38**	18.1	3.2	39.0
14.	pH		52	6.8	7.9	7.7	**7.53**	0.3	0.04	4.0
15.	Colour	mg Pt/dm^3	52	10	45	20	**21.44**	8.35	1.16	38.9
16.	Total suspension	mg/dm^3	49	7	59	38	**38.39**	11.93	1.7	31.1
17.	Organic carbon	ppm	46	2.15	8.8	3.05	**4.37**	2.42	0.36	55.4
18.	Conductance of electrolyt.	µS/cm	28	597	1924	880	**897.4**	267.3	50.5	29.8

Table 3. Physical - chemical properties of surface water in respect to a season.

	Indicator	Units	S (spring-summer)			W (autumn-winter)			p		Conclusion
			n	M	SD	n	M	SD	P(t)	P(Me)	
1.	Ammonium nitrogen	mg N-NH_4/dm^3	21	0.618	0.379	31	**5.037**	5.546	< 0.001	≈ 0.008	W>>S
2.	Nitrate nitrogen	mg N-NO_3/dm^3	21	1.327	1.186	31	**0.605**	0.447	< 0.01	< 0.05	S >W
3.	Nitrite nitrogen	mg N-NO_2/dm^3	21	0.073	0.099	31	**0.054**	0.151	> 0.59	> 0.15	IS
4.	Organic nitrogen	mg N/dm^3	21	2.060	0.515	31	**2.046**	0.552	> 0.93	> 0.60	IS
5.	Chlorides	mg Cl/dm^3	21	16.050	7.64	31	**26.74**	10.29	< 0.001	< 0.04	W>>S
6.	Phosphates	mg PO_4/dm^3	21	0.230	0.285	31	**0.167**	0.105	> 0.26	> 0.53	IS
7.	Iron	mg Fe/dm^3	21	0.287	0.177	31	**0.303**	0.233	> 0.78	> 0.60	IS
8.	Manganese	mg Mn/dm^3	21	0.018	0.017	31	**0.029**	0.018	0.03	< 0.03	W>S
9.	Sulphides	Mg S/dm^3	21	0	–	31	**0**	–	–	–	–
10.	Sulphates	mg SO_4/dm^3	21	16.29	5.58	31	**14.97**	2.26	> 0.24	> 0.86	IS
11.	BOD_5	mg O_2/dm^3	9	4.09	0.76	12	**3.81**	0.66	> 0.37	> 0.13	IS
12.	Oxidability (with $KMnO_4$)	mg O_2/dm^3	21	8.26	7.01	31	**10.13**	6.57	> 0.33	> 0.95	IS
13.	Oxidability (with $K_2Cr_2O_7$)	mg O_2/dm^3	13	42.85	23.76	19	**48.78**	13.14	> 0.37	< 0.04	W>S
14.	pH		21	7.50	0.34	31	**7.54**	0.28	> 0.60	> 0.50	IS
15.	Colour	mg Pt/dm^3	21	19.29	9.75	31	**22.90**	7.04	> 0.2	> 0.22	IS
16.	Total suspension	mg/dm^3	18	34.67	15.65	31	**40.55**	8.72	≈ 0.10	> 0.78	IS
17.	Organic carbon	ppm	15	3.44	1.36	31	**4.82**	2.70	≈ 0.07	> 0.75	IS
18.	Conductance of electrolyt.	µS/ cm	9	807	423	19	**940**	147	> 0.22	< 0.01	W>S

W>S – differences significant statistically
IS – differences insignificant statistically

A few times higher concentrations of the indices studied were found in the groundwater close to an individual farm (P3). The high pollution of groundwater resulting from improper water-sewage disposal and lack of sewerage in this farm correlated to a very low quality of well water (P4). The norm of ammonium nitrogen content in drinking water and for farming needs is 0.5 mg/dm^3, were as nitrate nitrogen - 10 mg/dm^3 [11]. The water sampled in well showed the exceeding these values for ten times and figured out at 5.52 mg/dm^3 and 100.72 mg/dm^3, respectively. This creates an enormous hazard for people and animals consuming this water. Increased content of nitrate nitrogen may be a reason for mathemoglobinemia and cyanosis and, in extreme cases, death due to oxygen deficiency of organism. A high content of nitrite (0.38 mg/dm^3 in the well water examined) is evidence of organic matter penetration. Still, it is a serious hazard for consumers. The international organisation FAO/WHO defined allowable consumption of nitrate and nitrite ions by man i.e. level 220 and 8 mg a day [13]. Giving the water from this well to animals to their needs would surpass the values many times.

It was discovered that commercial breeding of animals can also be considered a main source of river pollution with biogenic compounds. Unitary out-flow of nitrogen and phosphorus out of such basins is 2-3 times larger as from other basins of this type i.e. including only field culture [14].

Currently surface water eutrophication is one of the most vital problems of water management. Nutrient content growth in water stimulates biomass gain, which affects water quality unfavourably, especially at the decomposition time of organic substance formed [1, 3].

The hydrogeological structure of soils within the farm implies that water-bearing layer of area adjacent to the farm used to be in permanent contact with a river valley and that proved groundwater drainage by river-bed. Besides, morphological sloping of the area where the farm is situated, a slightly permeable loess layer found on the top soil caused that all the pollutants gathered at the farm and those introduced into the soil outside it flew as surface or underground runoff towards the river. At some points there were also introduced municipal and farming sewage into the river, coming from farm workers buildings or the farm itself. The impurities used to be disposed of by a working treatment plant, nowadays they are directed in a raw state right to the river. This fact was reflected in the findings.

The physical and chemical properties of river water are shown in Table 2.

The river water studied showed a considerable concentration of ammonium nitrogen (mean 3.25 mg/dm^3), nitrite nitrogen (0.06 mg/dm^3) and total suspension (38.39 mg/dm^3). These parameters have decreased the examined water purity grade significantly and ranked it among purity grade III. Over the spring-summer period there was recorded a substantial growth of nitrite nitrogen content (Table 3). Nitrite nitrogen concentration at 0.073 mg/dm^3 level, according to the norms established for inland waters, disqualifies river water in respect to purity.

Ammonium nitrogen presence in river waters is a result of many factors, the most important being ammonia inflow from point and area sources, water plant development, oxygen conditions, and temperature. Ammonium nitrogen content shows significant fluctuation throughout the year. Dojlido [5] maintains that concentrations of nitrogen are quite low at summer at higher temperatures, whereas when biological life disappears and the nitrification process is inhibited ammonium nitrogen concentrations reach fairly high values up to a few mg/dm^3. The present examinations showed that ammonium compounds content was substantially higher just at winter period (5.037 mg/dm^3) when the soil was deprived of its plant cover. At this period there was also observed an increase of chloride. That may testify that great amounts of organic matter washed out of fields fertilized organically in autumn penetrated to the water. At the time of spring snow thawing intensive field runoff caused an increase in total suspension content. Mineral compounds leached out of soil have also resulted in increase on conductance of electrolytes in water (940 µg/m^3).

Throughout the experimental period phosphate presence was rather imperceptible. At spring-summer time there was observable a considerable inflow of these compounds to surface waters. A high concentration of phosphates - 0.23 mg/dm^3 was recorded and that ranked the water among purity grade II.

The presented results agreed with other works [4, 7, 8, 15] where the authors indicate a strong influence of livestock breeding on the sanitary state of surface waters and in particular biogenic components cumulation.

Due to agriculture intensification enormous quantities of organic and inorganic matter in form of impurities is found in the natural environment. The pollutants are distributed unevenly and cumulated on a small area, thus leading to every ecosystem degradation, including water. The examinations carried out have proven once more that animal breeding has a significant effect on this problem.

Conclusions

1. The piezometric examinations showed a significant concentration of nitrogen compounds, phosphates and chlorides in groundwater. The groundwater contained from 57.2 mg/dm^3 up to 1021.6 mg/dm^3 of chlorides; 3.15 mg/dm^3 - 61.94 mg/dm^3 of ammonium nitrogen; 2.96 mg/dm^3 - 121.4 mg/dm^3 of nitrate nitrogen; 0.31 mg/dm^3 - 3.14 mg/dm^3 of nitrite nitrogen and 0.55 mg/dm^3 - 2.58 mg/dm^3 of phosphates.
2. Well water showed the contents of ammonium and nitrate nitrogen to exceed the boundary values for drinking water tenfold and figured out at 5.52 mg/dm^3 and 100.72 mg/dm^3, respectively.
3. The river water examined demonstrated a substantial concentration of ammonium nitrogen (mean 3.25 mg/dm^3), nitrite one (0.06 mg/dm^3) as well as total suspension (38.39 mg/dm^3). The parameters have de creased much the examined water purity grade and ranked it among purity grade III. At spring-summer time there was observed a significant growth in nitrite nitrogen content up to level of 0.073 mg/dm^3 and that, according to the norms for inland waters, disqualified the river water in respect to purity.

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