CONTAMINATION OF SURFACE AND GROUND WATERS BY RUNOFF WATER FROM A CATTLE FARM AT FALENTY, POLAND

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ABSTRACT. – Contamination of surface and ground waters by runoff water from a cattle farm at Falenty, Poland. The paper presents the results of the analysis of runoff water from a cattle farm at Falenty near Warsaw, Poland. The water samples came from two wells collecting the outflow, the nearest draining ditch and the nearest stream. The sampling frequency was higher in the rain periods. The reaction, conductivity, COD, concentration of ammonia, nitrite, and nitrate nitrogen, as well as phosphates was determined. Additionally, the total quantity of psychrophilic and mesophilic bacteria, fungi, *Proteus* sp., sulphide reducing bacteria and the coliform index was also counted. Results showed an increased level of COD and higher concentration of phosphate ions in the rainwater in the area of the farmyard. Relatively high microbiological indexes were also observed. During periods with rain, the values of the biochemical demand for oxygen (COD) and concentration of phosphate ions exceeded the thresholds for flowing waters.

Keywords: water contamination, runoff water, cattle farm

1. INTRODUCTION

Inflow of pollutants from farmlands is one of the causes of the deterioration of surface waters. Sources of runoff pollutants commonly occur in rural settlements. Studies carried out by the Institute of Technology and Life Science in Falenty between 1999-2001 indicated a significant inflow of organic pollutants from villages where cattle was reared (Rossa, Sikorski 2006). Significant concentration of different sources of organic, biogenic and also toxic pollutants occurs in areas of cattle farms (Doruchowski, Hołownicki 2003; Sapek, Sapek, Pietrzak 2000). In various types of rearing farms, increased pollution of soil and groundwater was noted near livestock buildings and storage places of natural fertilizers (Rossa 2003; Sapek 2002).

The presented studies were focused on determining the actual concentrations of pollutants in rainwater runoff from two cattle farms differing in the size of cattle herds and its influence on the quality of surface and groundwater. The study included collecting samples and their analysis from wells and storm-water drainage collectors, from streams acting as runoff receivers and two piezometers.

2. MATERIALS AND METHODS

The studies were carried out on rainwater sewage samples from the experimental farm of the Institute of Technology and Life Science in Falenty.

The farm (Fig. 1) is located in the Mazovian voivodship, in the Pruszków county, Raszyn district. It lies within the Mazovian Lowland in the Raszynka drainage basin in the Utrata and Bzura catchment area. The surface of the area is flat, with the medium elevation at 112 m a.s.l. The groundwater level occurs at 1 to 3 m below surface level. Soils of the area are developed from loam and loamy sand and gravel. They are represented by podzols and combisols.

The study object was a 1100 m^2 fragment of the yard, adjacent to a shed with 10 tractors. To the south of the yard is located a cow-shed with 130 cows. The cow-shed does not have a manure settling tank. The manure is directed through a manure channel using a collecting well into a covered reservoir. After storage and fermentation in the basin, manure is transported by a waste removal truck onto pastures and occasionally also onto fields. The manure is removed every day from the cow-shed.

For experimental purposes, a system of farmyard drainage was constructed in 2009. Rainwater is directed on the surface to a 47-m long and $\varnothing$ 160 mm in diameter PVC collecting channel built underground along the communication route. The channel with a gradient of 1% and with inlets for rainwater, is connected with a measuring reservoir comprising two wells made of reinforced concrete, of a diameter 1.2 m each, distributed in series at the level of the well bottom. A depression was made in the bottom of the second well facilitating removal of the total volume of rainwater sewage from the measuring reservoir. In the case when volume of the inflowing rainwater exceeds the working volume of both wells, the water excess is directed through a $\varnothing$ 160 mm spillway into a retention-infiltration reservoir with a working volume of 8. 0 m^3, total depth of 1.20 m, working depth of 0.60 m, 3 x 10 m in size and embankment gradient at 1:1. From this reservoir the rainwater sewage is pumped out directly onto the neighbouring pastures.

A piezometer with a filter installed at the depth of 1. 70 m was located beyond the rainwater reservoir towards the groundwater runoff in order to collect groundwater samples.

Two effluent wells with a filter located above the groundwater level were installed in 2007 for study purposes in the farm at Falenty. The wells were intended to intake water from the aeration zone. The first was localized near the communication route and the second – beyond the dewatered area in a depression along the cattle route.

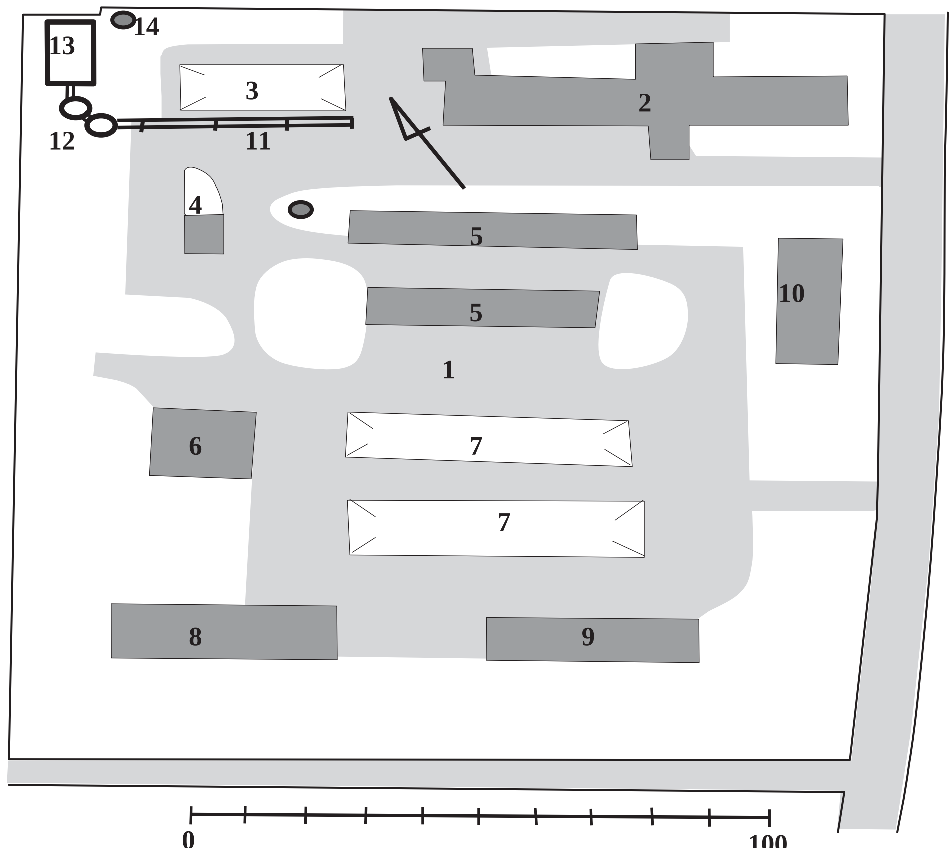

Fig. 1. ***Scheme of sampling sites in the Experimental Farm at Falenty 1 – hardened surface, 2 – cow-shed, 3 – umbrella roof for cattle, 4 – machine repair stand, 5 – garages, 6 – workshop, 7 – umbrella roof for agricultural machinery, 8 – calf shed, 9 – warehouse, 10 – office building, 11 – storm water channel, 12 – measurement wells, 13 – rainwater tank, 14 – piezometer, 15 – well with filter placed above groundwater level***

Samples for physical, chemical and bacteriological analysis were collected according to the requirements of polish norm PN-EN 25667-2 with increased frequency during the rain periods, as well as for comparison in the rainless periods from seven control points:

- effluent well located in the farmyard near the communication route,
- effluent well located in the depression near the cattle route,
- the nearest ditch that at heavy rainfall incidentally dewaters the area of the farm,
- an eastern stream flowing from Laszczki, capturing runoff water,
- well of the measuring point in 2009,
- piezometer located beyond the measuring point in 2009.

The following physical and chemical indexes were determined in the collected samples of rainfall sewage, surface and groundwater: conductivity, COD (Chemical Oxygen Demand), concentration of phosphates and ammonium, nitrite and nitrate nitrogen. The chemical analysis included also measurement of concentration of heavy metals, higher aromatic hydrocarbons and the sum of chloroorganic pesticides. Moreover, total number of psychrophilic and mesophilic bacteria, number of fungi, MPN(Most Probably Number) of sulphate reducing bacteria, number of representatives of genera *Proteus* sp. and Coli index were determined.

3. RESULTS AND DISCUSSION

The analysis comprised fourteen series of samples collected in 2009-2010. Table 1 shows the minimal, maximal and average values of the physical and chemical indexes determined in the rainwater runoff and in the surface and groundwater of the farm.

Table 1. ***Average, minimal and maximal values of conductivity ($\mu S \cdot cm^{-2}$), chemical oxygen demand (COD) ($mgO_2 \cdot dm^{-3}$) and concentrations of nitrate, ammonia, and nitrite nitrogen, and phosphorus in phosphates ($mg \cdot dm^{-3}$). Increased values are in the II class quality threshold according to polish Regulation of the Ministry of Environmental Protection from 2008.***

Measurement point		pH	Conductivity $\mu S \cdot cm^{-2}$	COD $mgO_2 \cdot dm^{-3}$	$N\text{-}NO_3$ $mgN\text{-}NO_3 \cdot dm^3$	$N\text{-}NH_4$ $mgN\text{-}NH_4 \cdot dm^3$	$N\text{-}NO_2$ $mgN\text{-}NO_2 \cdot dm^3$	PO_4 $mgPO_4 \cdot dm^3$
Well located in farmyard	Xmin	6.00	125.00	0.22	0.08	0.19	0.02	1.21
	Xmax	7.50	1287.00	339.27	26.70	2.69	0.75	16.60
	Xav	6.75	483.87	132.78	3.99	0.91	0.18	7.27
Well located near cattle route	Xmin	6.22	258.00	0.22	0.00	0.18	0.00	1.75
	Xmax	7.04	1960.00	228.55	4.70	5.25	0.44	18.60
	Xav	6.74	1043.38	80.05	2.04	1.18	0.10	6.48
Nearest draining channel	Xmin	6.00	125.00	0.20	0.00	0.20	0.00	1.80
	Xmax	7.46	1918.00	208.60	3.80	5.30	0.40	18.60
	Xav	6.96	775.47	80.59	1.72	1.61	0.08	6.93
Nearest stream	Xmin	6.50	226.00	0.22	0.00	0.16	0.01	2.45
	Xmax	7.88	1940.00	261.44	6.80	4.30	0.86	20.10
	Xav	6.99	915.24	87.12	2.07	1.73	0.11	8.98
Well on measuring point	Xmin	6.10	193.00	16.70	0.20	1.10	0.08	0.97
	Xmax	7.60	692.00	317.90	1.35	5.80	0.35	10.90
	Xav	6.90	373.00	135.77	0.81	2.40	0.18	5.88
Piezometer	Xmin	6.56	320.00	0.22	1.15	0.35	0.02	1.84
	Xmax	7.10	1454.00	194.15	8.10	0.64	0.24	3.90
	Xav	6.72	849.25	74.75	4.81	0.45	0.08	2.44

Most indexes reached the highest values in the water collected from the well located in the farmyard and from the well on the measuring point – i.e. in the rainwater runoff. Water from the ditch had the highest conductivity values, which points to the presence of mineral compounds, and water from the sewage well had the highest COD values, indicating organic pollution. Decrease of COD values in the ditch water may be linked with the influence of vegetation and soil.

The distribution of the concentrations of ammonia nitrogen and phosphates was different; the highest values were noted in surface waters.

The lowest values of the indexes were noted in the water from the piezometer. However, due to the average phosphate concentration, the water did not meet the thresholds of class II of groundwater according to the polish Regulation of the Ministry of Environmental Protection from 23.07.2008, Dz.U. 2008.143.896.

Exceeded values were noted for the average COD level and average concentrations of phosphates meeting the thresholds for class II of groundwater (Order MOŚ/143). The regulation does not state the threshold values for the remaining classes of surface water quality. Comparison with the threshold values stated for the last class of water with permissible quality in the previously valid regulation gives similar values (Order MOŚ/143).

The average COD values in rainwater sewage collected from the sewage well exceed the levels permissible for sewage discharged to water and soil (Order MOŚ/137).

A seasonal variability has been observed in the values of conductivity, COD and concentrations of nitrate and ammonia nitrogen. COD and ammonia nitrogen concentration values were higher in spring and autumn. The highest concentrations of nitrate nitrogen were noted in spring and summer.

The total pollution of water reflected in the conductivity values significantly increased during spring thaws.

Table 2 shows the minimal, maximal and average values of microbiological indexes determined in the studied samples of surface and groundwater in Falenty.

The highest content of mesophilic bacteria was noted in water from the effluent wells. In turn, rainwater sewage indicated the highest total content of fungi and the highest probable content of sulphate reducing bacteria and bacteria representing *Proteus* sp.

The average vales of the Coli index are maintained at the level of 10^{-2}-10^{-3}, but the highest values of the Coli index in water samples collected during several years from the dewatering ditches reached 10^{-4}. There was a significant dispersion of the results of microbiological indexes, but seasonal changes were not observed. The highest sanitary pollution of the studied water samples was observed during the rainless season, which can be explained by the lack of groundwater exchange and a low state of surface waters.

Table 2. ***Average, minimal and maximal values of the total number of psychrophilic bacteria in 1 cm^3, total number of mesophilic bacteria in 1 cm^3, total number of fungi in 1 cm^3, sulphate reducing bacteria (MPN), Proteus and Coli index.***

Measurement point		Total content of psychrophillic bacteria in 1 cm^3	Total content of meso-philic bacteria in 1 cm^3	Total content of fungi in 1 cm^3	MPN content of sulphate reducing bacteria	*Proteus* index	Coli index
Well located in farmyard	Xmin	3.00×10^4	0.00	0.00	0.00	1.00×10^{-4}	0.00
	Xmax	9.75×10^7	1.80×10^6	6.70×10^3	140.00	1.00×10^{-2}	1.00×10^{-2}
	Xav	1.02×10^7	7.51×10^5	1.79×10^3	56.67	1.00×10^{-3}	1.00×10^{-3}
Well located near cattle route	Xmin	6.00×10^4	5.00×10^5	2×10^2	25.00	1.00×10^{-4}	1.00×10^{-4}
	Xmax	6.70×10^5	1.76×10^6	1.60×10^3	140.00	1.00×10^{-3}	1.00×10^{-2}
	Xav	3.50×10^5	1.15×10^6	7.75×10^2	80.00	1.00×10^{-4}	1.00×10^{-3}
Nearest draining channel	Xmin	1.10×10^5	0.00	3.00×10^2	0.00	1.00×10^{-5}	1.00×10^{-3}
	Xmax	2.83×10^7	2.59×10^7	8.45×10^6	140.00	1.00×10^{-1}	1.00×10^{-2}
	Xav	2.99×10^6	2.96×10^6	7.69×10^5	61.25	1.00×10^{-2}	2.00×10^{-3}
Nearest stream	Xmin	1.00×10^4	8.00×10^5	0.00	0.00	0.00	0.00
	Xmax	7.50×10^5	6.90×10^6	1.90×10^4	110.00	1.00×10^{-2}	1.00×10^{-2}
	Xav	1.00×10^5	7.68×10^5	6.33×10^2	47.23	1.00×10^{-3}	1.00×10^{-3}
Well on measuring point		1.04×10^4	9.5×10^5	0.00	321	1.5×10^{-6}	1.00×10^{-3}
Piezometer		4.15×10^4	0.00	2.95×10^4		1.00×10^{-3}	0.00

The values of the analyzed microbiological indicators were also higher in water samples collected in autumn during continuous rainfall; particularly high was the total content of psychrophilic bacteria. Water samples from effluent wells in the farmyard of the Institute of Technology and Life Science in Falenty fulfil the sanitary conditions of sewage discharged to water and soil, because bacteria of the *Salmonella* group were not noted in them.

The first series of determinations of toxic and hazardous substances was carried out; the results are presented in Table 3.

The content of higher aromatic hydrocarbons and oil-derived substances in rainfall sewage from the farmyard in Falenty was shown to exceed the permissible norms. Likewise were noted exceeded concentrations of zinc in the stream capturing the runoff in Falenty.

A higher pollution of samples of rainfall sewage collected from systems of the storm-water drainage was noted in relation to the samples collected from the streams. At present, polish legal acts supply norms for only two parameters of rainfall sewage: suspension up to 100 mg·dm^{-3} and oil-derived substances up to 15 mg·dm^{-3}.The remaining parameters were therefore compared with the requirements for purified communal sewage, which, however, does not reflect the actual pollution of rainfall sewage.

The results of the first series of analysis of toxic and hazardous substances may suggest exceeded pollution of the runoff from the Falenty farms. The values of concentrations of some higher aromatic hydrocarbons exceed ten times the norms permissible for surface waters (Order MOŚ/162).

Table 3. ***Concentration of chlorine-organic pesticides (μg·dm^3), heavy metals (μg·dm^3), oil-derived substances (mg·dm^3) and higher aromatic hydrocarbons in water samples collected from the farm.***

Measurement point	Well on measuring point in Falenty	Stream from Laszczki in Falenty
1	2	3
Sum of chlorine-organic pesticides	<0.01	<0.01
Oil-derived substances	0.6	0.5
Mercury Hg	<0.01	<0.01
Lead Pb	0.06	<0.02
Cadmium Cd	<0.001	<0.001
Nickel Ni	<0.02	<0.02
Zinc Zn	0.32	0.02
Copper Cu	0.05	<0.005
Chromium Cr	<0.02	<0.02
Fluorene	0.0319	0.0146
Fenantrene	0.2996	0.0308
Antracene	0.0695	0.0025
Fluoroantene	0.8007	0.0233
Pirene	0.6409	0.0182
Benzo(a)antracene	0.2548	0.0048
chryzene	0.0620	0.0010
Benzo(b)fluorontene	0.4979	0.0085
Benzo(k)fluorontene	0.2294	0.0037
Benzo(a)pirene	0.4861	0.0082
Dibenzo(a,h)antracene	0.1707	<0.0004
Benzo(g,h,i)perylene	0.3184	0.0052
Indeno(1,2,3cd)pirene	0.3778	0.0078
Sum	4.2397	0.1286

4. CONCLUSIONS

Analysis of the studies carried out in 2007-2009 allows formulating the following conclusions:

- Rainwater from the farmyards of the cattle farms in Falenty discharges large quantities of organic compounds, nitrate nitrogen and phosphates. However, the average concentrations of these compounds and COD values do not exceed the values permissible for sewage discharged to water and soil, but are higher than the recently determined threshold values for the quality classes of flowing water.
- COD values and phosphate concentrations in the ditch and stream receiving rainwater runoff from the area of the Institute of Technology and Life Science in Falenty exceed the recently determined threshold values for the quality classes of flowing water.

- Chemical pollution of groundwater from the first aquifer horizon does not exceed the permissible norms.
- Increased values of some microbiological indexes may suggest sanitary hazard posed on the water environment by the inflow of rainfall sewage due to the presence of pathogenic microorganisms.

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The paper was supported by grant nr NN 305036934 KBN (Committee of Scientific Research)