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Contaminant of rain waters from treatment system of motorway A4b – the section in Opole region

Introduction

Road investments are a very important aspect of the development of the infrastructure of our country. According Szkarowskiego [1], a sharp increase in the economic impact of human activities on different areas of the environment around us has already reached such a high level that it is no exaggeration to say that the very existence of humanity is being threatened. Thus, the development of effective methods for mitigating environmental problems requires careful evaluation and rigorous analysis of the existing situation. The national transport policy from 2006 to 2025 and the transportation system need to be reconstructed and improved with particular emphasis on reducing the negative impact on the environment. There is no question as to the need for Poland to build in the near future more than two thousand kilometers of motorways. This is especially true since Western European countries definitely surpass Poland in this area[2]. However, environmental warnings arise both in the implementation of these projects and in the use of transport networks. One disadvantage of the develop-

[1] A. Szkarowski, *Ocena współczesnych tendencji zanieczyszczenia środowiska naturalnego, in: Rocznik Ochrony Środowiska*, vol.1, 1999, p. 137-142.

[2] J. Potarzycki, K. Apolinarska, *Wpływ autostrady na tereny przyległe*, in: www.metropolitalnadlanas.pl/ page9.php.

ment of the automotive industry is the contamination of rainwater that as a result of runoff contains substances from the surface of the road, with the result that under the Regulations of the Water Low [3] it becomes the sewage. The extent of pollution depends on the intensity of precipitation, its duration, how long there was no rain preceding the precipitation, atmospheric pollution, the number of biologically active areas, the paved road surface area, the volume of pedestrian traffic, and many other factors that can significantly affect the degree of rainwater contamination [4,5]. However, the main sources of pollution are primarily solid waste, liquid oil spills (including fuel) and exploitation fluids which, as a result of surface runoff, leak into the ground, surface and deep water [5,6]. The high biological activity of the soil favors the ability to treat rainwater. Reconstitution and dilution processes take place in the aquifier. However, in the layers of the lingering above the water level there is intensive filtration, adsorption, absorption and biosorption. The top layer of soil with a thickness of about 30 cm is critical in the treatment of rainwater. The intensity of this process depends on the sodding, hydraulic load and exploitation [7]. Thus, as a result of washing deposited pollutants from hard surfaces by rainwater various kinds of chemicals enter the water. Wastes from road surfaces are transported to the final recipients, such as the ground environment, and to both flowing and stagnant water [8].

The aim of this study was to determine the effectiveness of the removal of selected transport pollutants by the wastewater treatment system of highway drainage found on highway A4b in the Opole province.

Characteristics of the study area

A significant section of the highway (western and central) is characterized by joining three aquifers: the quaternary, tertiary and upper cretaceous [9,10].

[3] Regulations of the Water Low: Journal of Law No 115,1229, 2001, as amended.

[4] M. Helman – Grubba: *Wody opadowe: jakość, regulacja, podczyszczanie*. Warszawa, 1999.

[5] A. Mc`Neil, S. Olley, *The effects of Motorway runoff on Water courses, in: Jurnal of the Chartered Institute of Arbitrators,* Vol. 12, 1988, p. 433-443.

[6] J. Merkisz, W. Piekarski, T. Słowik, *Motoryzacyjne zanieczyszczenie środowiska*, Warszawa, 2005.

[7] P. Błaszczyk., H. Sawicka – Siarkiewicz, *Urządzenia kanalizacyjne na terenach zurbnizowanych. Wymagania techniczne i ekologiczne*. Warszawa, 2007, p. 8-12.

[8] R. Edel, *Odwodnienie dróg, Wyd. Komunikacji i Łączności*, Warszawa, 2000, p 18-24.

[9] Z. Flaczyk, *Warunki przyrodnicze produkcji rolnej. IUNG*, Puławy, 1987, pp. 82.

[10] J. Kondracki, *Geografia regionalna Polski*, Wyd. PWN, Warszawa, 2002, pp.440.

In the quaternary level, there are two sub-levels. One of them is associated with sandy - gravel river formation tracks and glacial river, while the other is a result of ice and interglacial intervals. The second sub-aquifer is formed by the underground water in the Żużela - Jaśkowice – Prądy – Przylesie area (MRGW 332) [11]. At the tertiary level, the presence of water is associated with interbeds of sand and gravel. A characteristic stretch of highway is located on the border of two sub-tertiary aquifers: south - west and south - east[12]. The cretaceous aquifer is associated with the occurrence of: sandstone, sand and carbonate sands works at a depth of 20 meters [13]. The Nogowczyce site is fed by many Main Reservoire Ground Water. Among them, the most important is reservoir MRGW No 333. From the studies of [14] and Pisarek and Głowacki [15] it was difficult to determine the impact of the highway on the reservoir. The researched sites on the A4 motorway belong to the catchment of the Oder River. The main rivers which intersect the highway are the Odra, Ścinawa Niemodlińska and Nysa Klodzka. Among the catchments distinguished on the basis of topography second-order aquifers sections, between Przylesie and Prądy, the longest stretch is found on the catchment Nysa Kłodzka[16].

The relief of the terrain in the western and central areas is characterized by low diversity. In the eastern part (upland) there is significant variety. The highest elevations are situated around Chełm (approximately 390 m a.s.l.), and the lowest areas are located in the valley of the Nysa Kłodzka and Odra (about 150 m a.s.l.)[17,18,19]. The researched area near the Prądy junction is more diverse geomorphologically compared to other areas of the region. From Prądy to Siedlisk the terrain rises to 182 meters above sea level. From there the mo-

[11] M. Głowacki, *Zanieczyszczenia zwykłych wód podziemnych,* Zagrożenie jakości wód na obszarze Głównego Zbiornika Wód Podziemnych nr 333 spowodowane działalnością rolniczą, OCEE, Opole 2003, p. 61 – 77.

[12] S. Dyjor, A. Sadowska, *Wody podziemne i geologia formacji wodonośnych Śląska Opolskiego,* Materiały i Studia Opolskie", vol. 52/53, 1984, p. 33 – 58.

[13] J. Kryza, *Wody podziemne i geologia formacji wodonośnych Śląska Opolskiego,* Materiały i Studia Opolskie", Uniwersytet Opolski, vol. 52/53, Opole 1988, p. 217 –233.

[14] M. Głowacki, *op cit.* p. 61 – 77.

[15] I. Pisarek, M. Głowack, *Soil and water humic substances in groundwater reservoir area no 333 in Opole district (Poland),* Roczniki Gleboznawcze, 60, no 2, 2009, p. 73-78.

[16] K. Badora, *Autostrada – środowisko przyrodnicze. Studium konfliktów przestrzennych na przykładzie opolskiego odcinka autostrady A4,* Studia i Monografie Uniwersytetu Opolskiego, 349, 2004, pp. 178.

[17] Ibid.

[18] Z. Flaczyk, *Warunki przyrodnicze produkcji rolnej. IUNG*, Puławy1987, pp. 82.

[19] J. Kondracki, *Geografia regionalna Polski*, Wyd. PWN, Warszawa 2002, pp.440.

torway runs along the glacial plateau of Bory Niemodlińskie (about 180 - 200 m a.s.l.). In addition to the forms of aeolian here are numerous river valleys and peat bogs formed in depressions without any outflow.

In the western section of the motorway from the Przylesie junction to the Nysa Kłodzka valley there are significant amounts of black soil, brown soil eutrophic and dystrophic brown. In the Nysa Kłodzka and Ścinawa Niemodlin valleys heavy alluvial soils dominate the river.

Sites and research methods

Rain water for chemical and physicochemical analyses was collected from two wastewater treatment sites located at the junctions of A Przylesie and B Prądy (Fig. 1). At each site three measurement points were set:

A 1-the position was a drainage ditch adjacent to the road (inlet). Water samples were taken at the height of the protective mesh.

A 2 – the position was a left-bank sedimentation basin (purifier). Water samples were taken at the outlet of the basin.

A 3 – the position was a liquid treated discharge effluent. Water samples were taken below the point of discharge.

B1-the position was a drainage ditch adjacent to the highway. Water samples were taken at the point where waste water entered the treatment system.

B 2- the position was a sedimentation basin (purifier). Water samples were taken at the outlet of the basin.

B 3- the position was a water reservoir.

Water samples were taken at the inlet to the reservoir. Samples for physical - chemical and chemical analysis were collected on the following dates: 16.05.2011, 12.09.2011, 21.11.2011, 29.02.2012. Particular dates were chosen in order to have samples which would reflect changes occurring during the various seasons. Water temperature was recorded directly in °C. The temperature of wastewater taken for analysis changed according to the time of year at both research facilities. At particular times there were no changes of this parameter in the inlet - purifying treatment - outlet. Temperatures were within the average temperatures of the respective seasons.

Samples were analyzed as follows:

- Conductivity [µS/cm]: ISO 7888:1985/PN-EN 27888 (1999)
- pH: PN-EN ISO 10523 (2012)
- Chloride [mg Cl^-/dm^3]: ISO 9297 (1994)
- Chemical oxygen demand by dichromates (COD_{Cr}) [mgO_2/dm^3]: PN-74 / C - 04578/03
- The nitrogen content of nitrite [$mgNO_2^-/dm^3$]: PN-73/C-04576/06

- Compactness of nitrate [mgNO_3^-/dm^3]: PN-82/C-04576/08
- Kjeldahl nitrogen [mgN/dm^3] ISO 5663/DIN 38409H11 (1984)
- The total nitrogen content [mgN/dm^3]: was calculated as sum of: nitrate, nitrite, Kjeldahl nitrogen
- The content of orthophosphate [mgPO_4^{3-}/dm^3]: PN-ISO 6878 (2004)
- The content of total phosphorus [mgP/dm^3]: PN- ISO 6878 (2004)
- The content of extractable petroleum ether [mg/dm^3], including: benzene, toluene, ethylbenzene, m + p-xylene, o-xylene, styrene, cumene, n-propylbenzene, 1,2,3-tri – methylbenzene, tetrabutylobenzene, sec-butylbenzene, izopropylotoluene, butyltoluene, naphthalene (according GC method).

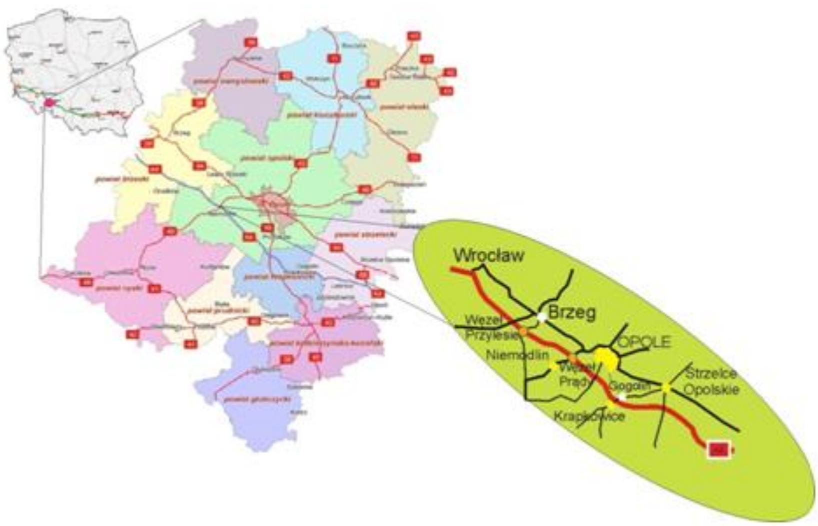

Figure 1. Localization of investigation area

Results and discussion

Rainwater deposited on the earth's surface and infiltrated with airborne pollution is contaminated with different kinds of chemical substances which become sewage. The pollution load of the sewage depends on many parameters, including: the kind of precipitation, the type of surface on which the rain falls, and many local factors. One of the primary sources of these pollutants is transportation [20].

[20] M. Helman – Grubba, *Wody opadowe: jakość, regulacja, podczyszczanie*, Warszawa, 1999.

Electrolytic conductivity indicates the presence of inorganic substances in the wastewater, both natural and anthropogenic. Other literature[21,22] and own research (and the value LSD_{term}) indicate that their concentrations are higher in spring and winter, which is associated with an increased presence of chlorides, wastewater rainfall during these periods. At the Prądy junction the value of this parameter ranged from 591 to 800 μS/cm (Table 1). At the Przylesie junction the highest value was recorded for the winter period (1966 μS/cm), high values occurred in spring and the lowest in summer and autumn (at least 546 μS/cm). The degree of electrolytic conductivity reduction through the inlet - purifier - outlet is insufficient, which is confirmed by the value of $LSD_{position}$.

Table 1 Physico-chemical and chemical properties of analyzed rainwater

Index	Term	Position					
		A 1	A 2	A 3	B 1	B 2	B 3
Conductivity [μS/cm]	29.02.11	597	591	592	1422	1966	455
	16.05.11	730	796	800	1232	1132	1094
	12.09.11	683	708	692	546	573	745
	21.11.11	636	645	643	684	720	773
LSD_{term} 698.7 $LSD_{position}$ 478.0							
pH	29.02.11	8.00	7.98	8.48	8.54	7.80	8.10
	16.05.11	8.04	8.02	8.01	8.37	8.31	8.61
	12.09.11	8.35	8.28	8.25	8.60	8.44	8.30
	21.11.11	7.36	7.32	7.26	7.35	7.40	7.40
LSD_{term} 0.93 $LSD_{position}$ 0.86							
Chloride [mgCl/dm^3]	29.02.11	82	88	115	157	160	161
	16.05.11	99	116	114	326	278	223
	12.09.11	107	98	96	105	115	157
	21.11.11	107	98	96	105	115	157
LSD_{term} 125.5 $LSD_{position}$ 116.3							
COD_{Cr} [mgO_2/dm^3]	29.02.11	58	67	55	31	56	62
	16.05.11	51	42	41	36	60	58
	12.09.11	34	29	11	44	46	6
	21.11.11	54	55	31	64	66	26
LSD_{term} 34.7 $LSD_{position}$ 32.2							
Nitrite [mgNO_2^-/dm^3]	29.02.11	3.03	2.03	2.79	5.72	5.22	2.83
	16.05.11	0.27	0.40	0.38	0.06	0.05	0.04
	12.09.11	0.19	0.18	0.22	0.16	0.25	0.06
	21.11.11	0.44	0.46	0.49	0.01	0.46	0.28
LSD_{term} 3.4 $LSD_{position}$ 3.2							
Nitrate [mgNO_3^-/dm^3]	29.02.11	30.5	31.8	39.6	33.4	43.3	8.4
	16.05.11	26.8	20.3	33.5	11.5	11.7	28.7
	12.09.11	20.1	28.0	16.0	31.1	21.2	33.1
	21.11.11	8.6	14.1	65.3	22.7	6.1	6.1
LSD_{term} 28.6 $LSD_{position}$ 26.5							

[21] I. Pisarek, M. Głowacki, *op cit.*, p. 73-78.

[22] I. Szczygiel, J. Kryza, A. Fic, *Aquitard conductivity calibration of the Triassic aquifer numerical model of the Strzelce Opolskie area*, Geologos 10, 2006, p. 272-283.

Kjeldahl nitrogen [mgN/dm3]	29.02.11	42	38	56	42	21	14
	16.05.11	29	27	63	25	64	34
	12.09.11	21	46	91	46	96	5
	21.11.11	39	56	77	35	87	28
LSD $_{term}$ 50.5 LSD $_{position}$ 46.8							
Nitrogen total [mgN/dm3]	29.02.11	50	47	67	53	34	17
	16.05.11	37	33	72	28	67	41
	12.09.11	26	54	95	54	102	14
	21.11.11	41	60	75	41	88	30
LSD $_{term}$ 48.7 LSD $_{position}$ 45.1							
Orthopho-sphate [mg-PO_4^{3-}/dm3]	29.02.11	2.36	2.35	2.17	0.57	0.65	0.27
	16.05.11	0.41	0.45	0.74	0.19	004	1.02
	12.09.11	1.61	1.32	1.86	9.17	11.74	5.06
	21.11.11	0.23	0.57	0.33	3.38	0.86	0.63
LSD $_{term}$ 5.9 LSD $_{position}$ 5.5							
Total pho-sphorus [mgP/dm3]	29.02.11	2.6	3.1	2.5	1.3	1.3	0.4
	16.05.11	0.9	0.7	0.7	0.3	0.5	1.5
	12.09.11	1.6	1.4	1.9	9.5	12.2	6.5
	21.11.11	0.8	2.0	0.3	15.3	2.7	2.1
LSD $_{term}$ 8.1 LSD $_{position}$ 7.5							

Thus, the treatment facility installed on the highway does not affect the reduction of inorganic contaminants in the analyzed water taken from the receivers.

In general, pH does not indicate contamination due to the large fluctuations in pH in natural waters, but rather, changes from the natural state. The pH of rainwater sewage on all test dates was alkaline and ranged from 7.32 to 8.61. According to the Regulation of the Minister of Environment of 24 July 2006[23] the acceptable pH of wastewater, which can be released into water or soil is 6.5 - 9.0. Therefore, in the analyzed period, there was no overstepping of the limits. The lowest pH value of water was in November (21.11.2011). It was found that the presence of the purification facilities does not affect important pH changes in the inlet - purifying device - receiver. At the same time significant differences in the value of this parameter was observed in September and November at all research sites. The average chloride concentration in the runoff water is within the range of 10 – 50 mg/dm^3. The Regulation of the Minister of Environment of 24 July 2006[24] allows the chloride content of the effluent which can be put into water or soil to be 1,000 mg cl/dm^3. As set forth in Item 627 Environmental Protection Law[25] the environment must not be impaired as a result of the introduction of wastewater. Therefore, the amount of chloride should not exceed 300 mgCl/dm^3. At the Przylesie junction the value of this parameter ranged from 82 to 116 mgCl/dm^3 and showed

[23] Regulation of the Minister of Environment: Journal of Law No. 212, 1799, 2006.

[24] Ibid.

[25] Regulation of the Minister of Environment: Journal of Law No. 62, 627, 2001

no significant differences between both the collection date and the location of the inlet - purifier – outlet. A different relation was recorded at the Prądy junction. The highest values (more than 300 mg/dm^3) were found in samples taken in May 2011. These values showed significant differences in the amounts of chloride in comparison to other collection dates (LSD_{term}), which indicates local anthropogenic pollution along this section of the motorway. The maximum value[26] of COD_{Cr} in wastewater, which can be released into water or soil is 125 mgO_2/dm^3. This index indicates the presence of organic impurities [27]. This value was not exceeded in the analyzed runoff water. Therefore, rain water collected from selected positions (sites) does not require purifying. The values of chemical oxygen demand were the highest in the samples: IV (29.02.2012) and I (16.05.2011). Higher values of COD_{Cr} were found in samples from the inlet (incoming sewage, untreated) and were significantly lower at the outlet, which proves the efficiency of the sewage treatment of organic pollutants. At the same time, there was a significant reduction ($LSD_{position}$) in the content of organic compounds in water samples collected 12.09.2011. This was probably associated with high microbial activity during the summer. Transformation of nitrogen in runoff water, especially contaminated anthropogenically has a very high dynamics rate.

Nitrites are unstable, do not undergo interchangeable and chemical sorption in soils and are easily washed away with water. According to Szczygiel et al.[28], their concentration in water is variable and highly dependent on the microbial activity of the environment. According to the permissible regulation [29]the levels of nitrite in the effluent rainwater should not exceed 1 mg NO_2^-/ dm^3. This level was exceeded in all sample sites in February 2011 The increased concentrations of nitrite in winter indicate the presence of additional sources of water pollution from nitrogen compounds. Most likely, the substances are concentrated in the snowfall, and are of anthropogenic origin related to transportation (e.g. nitrate addition to the brine), agricultural or municipal - household usage. At the same time the LSD, do not indicate sufficient wastewater treatment efficiency of rainwater. As a result, the biochemical conversion of nitrogen compounds dissolved in waters of nitrates, nitrites and ammonium nitrogen have the ability

[26] Regulation of the Minister of Environment: Journal of Law No. 212, 1799, 2006.

[27] K. Banaś, K. Goś, *Effect of peat-bog reclamation on the phisico-chemical characterization of the ground water in peat. Polish Journal of Ecology* 52/1, 2004, p. 69-74.

[28] I. Szczygiel, J. Kryza, A. Fic, *Aquitard conductivity calibration of the Triassic aquifer numerical model of the Strzelce Opolskie area. Geologos* 10, 2006, p. 272-283.

[29] Regulation of the Minister of Environment: Journal of Law No. 212, 1799, 2006.

to move from one to the other form. In assessing the degree of pollution by nitrogen compounds their qualitative and quantitative presence are considered[30].

Table 2. The content of extractable petroleum ether [μg/dm^3]

Index	Term	Position					
		A 1	A 2	A 3	B 1	B 2	B 3
benzene	29.02.11	0.21	0.21	0.01	0.02	0.05	0.24
	16.05.11	0.62	0.33	0.24	1.26	0.16	0.98
	12.09.11	1.99	0.98	0.95	1.09	1.65	1.40
	21.11.11	2.09	0.98	0.90	1.09	1.73	1.62
LSD $_{term}$ 1.4 LSD $_{position}$ 1.3							
toluen	29.02.11	0.03	0.08	0.05	0.06	0.02	0.06
	16.05.11	82.97	7.99	16.62	51.45	20.86	44.83
	12.09.11	0.20	0.19	0.66	0.54	0.23	0.20
	21.11.11	0.20	0.18	0.76	0.53	0.25	0.23
LSD $_{term}$ 43.4 LSD $_{position}$ 40.2							
etylobenzen	29.02.11	2.09	0.12	1.58	0.6	0.19	0.05
	16.05.11	0.66	0.37	0.77	3.66	0.69	0.12
	12.09.11	0.07	n.o.	0.05	0.15	0.15	0.10
	21.11.11	0.07	n.o.	0.05	0.24	0.22	0.15
m+p xylene	29.02.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	16.05.11	0.28	n.o.	0.65	0.18	n.o.	0.18
	12.09.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	21.11.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
o – xylene	29.02.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	16.05.11	0.08	n.o.	n.o.	0.04	n.o.	0.04
	12.09.11	0.05	n.o.	n.o.	n.o.	n.o.	n.o.
	21.11.11	0.05	n.o.	n.o.	n.o.	n.o.	n.o.
styene	29.02.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	16.05.11	0.05	n.o.	n.o.	0.05	n.o.	0.04
	12.09.11	0.05	n.o.	n.o.	n.o.	n.o.	n.o.
	21.11.11	0.05	n.o.	n.o.	n.o.	n.o.	n.o.
cumene	29.02.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	16.05.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	12.09.11	0.07	n.o.	n.o.	n.o.	n.o.	n.o.
	21.11.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
n – propyloben-zene	29.02.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	16.05.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	12.09.11	0.29	n.o.	0.08	n.o.	0.04	n.o.
	21.11.11	0.25	n.o.	0.08	n.o.	n.o.	n.o.
123- tri - mety-lobenzene	29.02.11	n.o.	0.10	0.06	0.08	0.09	0.06
	16.05.11	0.12	n.o.	n.o.	0.06	n.o.	0.05
	12.09.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	21.11.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
tetrbutyloben-zene,	29.02.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	16.05.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	12.09.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	21.11.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
sec – butylobenzene	29.02.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	16.05.11	0.03	n.o.	n.o.	n.o.		

[30] I. Pisarek, M. Głowacki, *op cit.*, p. 73-78.

	12.09.11	0.17	n.o.	n.o.	n.o.	0.88	0.33
	21.11.11	0.17	n.o.	n.o.	n.o.	0.88	n.o.
izopropylotoluen	29.02.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	16.05.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	12.09.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	21.11.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
butyltoluene	29.02.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	16.05.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	12.09.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	21.11.11	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
naphthalene	29.02.11	0.05	0.10	0.23	0.13	0.10	0.18
	16.05.11	0.07	n.o.	n.o.	n.o.	n.o.	n.o.
	12.09.11	0.25	n.o.	0.56	0.93	n.o.	0.02
	21.11.11	0.25	0.27	0.56	0.93	n.o.	0.04

n.o. – not presence

According to Szczygiel et al. [31] the presence of nitrate ions alone testifies to pollution in the distant past. Nitric nitrogen enters the water with municipal wastewater, from fields fertilized with nitrate fertilizers and manure, and also from the oxidation of organic compounds. In the analyzed wastewater rain an increase in this ratio in the basins was observed. Exceptions occurred in wastewater samples collected on: 21.11.2011 and 29.02.2012 in Prądy.

The total nitrogen contents in the analyzed wastewater were high. They exceeded 30 mg N/dm^3 which is the total nitrogen content permissible in wastewater that can be released into water or land[32]. The highest average content of total nitrogen in the effluent was recorded in summer and autumn, the lowest was in the winter (Table 1). Seasonally, statistically significant (LSD_{term}) changes in the content of nitrogen compounds are associated with agricultural pollution, especially intense during the growing season as well as biochemical changes of nitrogen compounds in the environment. Wastewater collected from Przylesie had a lower nitrogen content than in Prądy. At the same time the content of nitrogen in the basins were much higher than the concentrations carried by the water to the purifying system at Przylesie, which may reflect an improper design of the purification facilities. This situation was not found in Prądy. The orthophosphate content in the water samples showed high variability (Table 1). Phosphorus compounds in natural waters are subject to intense microbial and chemical transformations. During the optimal development of micro-organisms there is a process of intensive assimilation of phosphates. This is associated with a significant reduction in the concentration of these ions in the water (summer). However, in the winter there is an increase in phosphates

[31] I. Szczygiel, J. Kryza, A. Fic, *Aquitard conductivity calibration of the Triassic aquifer numerical model of the Strzelce Opolskie area*, Geologos 10, 2006, p. 272-283.

[32] Regulation of the Minister of Environment: Journal of Law No. 212, 1799, 2006.

due to the dying of micro-organisms. This was not observed in the analyzed waters. The highest values of this index were recorded in Prądy in the summer. This could be related to agricultural pollution and reduced microbial phosphorus uptake due to the accumulation of other pollutants. Furthermore, the reduction of the orthophosphate content was not sufficient through the inlet – purifying facility - outlet. The mean content of phosphorus in the effluent ranged from 0.5 to 3 mgP/dm^3.[33] The permissable value should not exceed 3 mgP/dm^3. The highest concentration of this biogenic substances was observed in the analyzed wastewater during the summer and fall. It was much lower in the spring. The reason for this phenomenon could be the strong evaporation from the surface of the wastewater and runoff from the surrounding fields. An important source of phosphorus during this period can also be particulate matter. Fields are subject to wind erosion and porous particulate matter fall in the vicinity of technical barriers (linear objects, rivers, roads and water bodies).

Among the substances extractable with petroleum ether are: benzene, toluene, ethylbenzene, and naphthalene were found in the largest concentrations in the analyzed water (Table 2). Other substances were present in minor or trace amounts[34],[35]. These substances are commonly found in the environment. This is due both to their numerous usages, and their presence in gasoline and automotive engine exhaust. Benzene in the analyzed wastewater rainfall occurs constantly in low concentrations (the lowest was found on 29.02.2012 - 0.01 mg/dm^3) The highest concentrations were recorded for toluene, especially during the spring. The highest concentrations of benzene were recorded in the autumn - winter. Purifiers in Przylesiu were more efficient in their water treatment with organic compounds in comparison to Prądy. At the same time, in accordance with regulations [36] the reported organic pollutants pose no threat to the environment and human health. A sustainable developmental strategy should create social, and economic conditions which threaten the environment and human health as little as possible. In doing this, economic growth cannot be lowered, including the development of the transport infrastructure [37]. Therefore, the evaluation of the effectiveness and efficiency of removing selected pollu-

[33] I. Szczygiel, J. Kryza, A. Fic, *op cit.*, p. 272-283.

[34] J. Piekutin, *Zanieczyszczenie wód produktami naftowymi*, Rocznik Ochrony Środowiska, 13, 2011, p. 1905.

[35] K. Ramus, T. Ciesielczuk, *Evaluating the efficiency of selected extraction methodsfor PAHs on the example of compost from urban waste,* Ecological Chemistry and Engineering A vol. 17 (2) 2010, p. 1655-1661.

[36] Regulation of the Minister of Environment: Journal of Law No. 212, 1799, 2006.

[37] A. Pawłowski, *Globalizacja a rozwój zrównoważony*, Problemy Ekorozwoju/Problems of Sustainable Development, vol.8, no 2, 2013, p.5-16.

tants by transport wastewater treatment along highways seems to be an important part of this process.

Conclusions

1. The effectiveness of rainwater sewage treatment plants located on the Opole stretch of highway A4 in the inlet system – purifying facility - outlet can be evaluated as being insufficient.
2. Increased nitrogen and phosphorus in wastewater precipitation, including purified water may indicate their potentially negative impact on the environment and the threat of eutrophication receivers.
3. The content of extractable petroleum ether was low and is allowable for safe release of rain water into the environment.

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SKUTECZNOŚĆ FUNKCJONOWANIA SYSTEMU OCZYSZCZANIA WÓD OPADOWYCH ZBIERANYCH Z AUTOSTRADY A4b – ODCINKA NA OBSZARZE WOJEWÓDZTWA OPOLSKIEGO

Streszczenie

W pracy przedstawiono skuteczność oczyszczania wód opadowych spływających z autostrady A4b odcinka zlokalizowanego na terenie Opolszczyzny. Zgodnie z Ustawą Prawo Ochrony Środowiska (Dz. U. nr 25 poz. 150) oraz Prawem Wodnym (Dz. U. Nr 115, poz. 1229, z późniejszymi zmianami) analizowane wody opadowe uważane są za ścieki, zatem wymagają one oczyszczenia przed wprowadzeniem ich do środowiska.

W celu zbadania efektywności działania urządzeń zlokalizowanych na odcinku Przylesie – Prądy dokonano poboru prób na drodze wlot – urządzenie oczyszczające – wylot. W pobranych próbach ścieków wykonano analizy fizykochemiczne i chemiczne: przewodność, odczyn, $ChZT_{Cr}$, zawartość chlorków, azotu azotynowego, azotu azotanowego, azotu Kjeldahla, azotu ogólnego, ortofosforanów, fosforu ogólnego, substancji ekstrahujących się eterem naftowym. Stwierdzono, iż skuteczność oczyszczania jest niedostateczna w zakresie analizowanych wskaźników. Ścieki charakteryzuje zasadowy odczyn oraz bardzo wysokie stężenie biogenów. Stwierdzono także, iż analizowane wody ściekowe nie wykazują zanieczyszczenia substancjami ropopochodnymi. Wykazano istotne zmienności pomiędzy wartością niektórych wskaźników w wodach ściekowych a zmiennością pór roku w obiekcie Prądy. Podobnej zależności nie stwierdzono w wodach ściekowych w obiekcie Przylesie. Zależność ta mogła być związana z lokalnym, punktowym antropogenicznym zanieczyszczeniem.