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ORIGINAL ARTICLE

Surface Water Pollution by Untreated Municipal Wastewater Discharge Due to a Sewer Failure

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Abstract
The study is an attempt to assess the pollution impact on the aquatic ecosystem related with an emergency discharge of untreated municipal wastewater from the "Czajka" wastewater treatment plant (WWTP) in Warsaw. The present case study is based on the analysis of available monitoring data for chemical oxygen demand (COD), total nitrogen (TN), ammonia nitrogen (N-NH_4), and total phosphorus (TP) in the effluent mixing zone (MZ), the stretch of the river and before the discharge point. Data analysis was supported by a basic statistical analysis based on Pearson's correlation coefficient. The results proved the importance of efficient and reliable nutrient removal technologies used in modern WWTPs. A statistically significant correlation was achieved between the COD ($r = 0.567$) and TP ($r = 0.714$) discharged loads and their concentration in the MZ. However, no significant correlation has been identified with TN and N-NH_4. Furthermore, the dissolved oxygen (DO) deficits in the MZ were observed within 7 days of the discharge period resulting in an average DO concentration decrease from 8.4 to 7.1 mgO_2/L. The river stretch has not been affected by DO deficits while the average observed DO concentration 30 km behind the discharge point was 9.1 mgO_2/L. The analysis results present the pollutants assimilation capacity of a river ecosystem and its real reaction to sudden excessive nutrient loads discharge.

Keywords Untreated wastewater discharge · Water quality · Sewer failure · Nutrients · Eutrophication

Article Highlights
- Raw municipal wastewater is extremely dangerous to eutrophication-sensitive waters.
- The discharged COD, TN, N-NH_4 and TP loads were 1858, 232, 165 and 20.6 Mg, respectively.
- The sewer failure caused temporary water deterioration in the effluent mixing zone.
- Dissolved oxygen deficits were observed within 7 days of the discharge period.

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1 Introduction

Human activities can significantly affect the surface waters quality due to the growing pollutant loads of different origin introduced to waters (Pirsaheb et al. 2014). Among point sources, untreated municipal wastewater has been identified as the most hazardous to water ecosystems due to the large amounts of nutrients and organics content (Collins et al. 2018). Currently, in the developed countries municipal wastewater undergo advanced nutrient removal processes carried out in modern wastewater treatment plants (WWTPs), which are able to ensure effluent discharge limits concerning biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids, nitrogen (N) and phosphorus (P) loads set by legal regulations in almost every country (Rogowska et al. 2019). The effects of untreated wastewater discharge has been analyzed in many studies in terms of the impact assessment regarding metals and pesticides influence on agriculture and human health in India (Singh et al. 2004), active pharmaceutical ingredients dilution in freshwater systems in low and low-middle income countries (Bagnis et al. 2018, 2019) and the potential effect of developing municipal wastewater treatment infrastructure in China (Jackson et al. 2016). Moreover, experimental research were developed to assess the influence of raw wastewater mixed with river waters in an artificial cascade channel showing the "impact zone" assimilation capacity (Finnegan et al. 2009). Based on the literature review it was found that sudden and unforeseen untreated effluent discharges are very rare while modern WWTPs ensure high reliability (Kim et al. 2019).

However, one of the biggest and the most critical failures of wastewater infrastructure in the Baltic Sea catchment happened in August 2019 in Warsaw, Poland. According to the authorities of the Warsaw Waterworks and Sewage System operating company (MPWiK), the system of wastewater transport to the "Czajka" WWTP (2.1 million population equivalent) had broken down, which resulted in an emergency discharge of untreated municipal wastewater from the left-bank Warsaw directly to Vistula River. As a result, about 3.65 million m^3 of untreated municipal wastewater was discharged.

The Vistula River is the longest river in the Baltic Sea catchment and one of the largest contributors of nutrients and other pollutants to the Baltic Sea. Its total length is 1047 km and its drainage basin is 194,000 km^2. The Vistula is the major source of freshwater flow into the Gulf of Gdańsk (Lisimenka and Kubicki 2019) and supplies about 7% of the freshwater to the Baltic Sea (Majewski 2014). It is also one of the biggest sources of drinking water for Polish cities and is a part of the International Waterway E70 and E40. Due to its high natural values, practically the entire Lower Vistula has been qualified for conservation within the European ecological network Natura 2000 (Żelazo 2013). The river basin covers almost the entire eastern part of Poland and it is inhabited by nearly 21 million people, which is more than half of Poland's population. The main diffuse sources of water pollution are agriculture, scattered dwellings and atmospheric deposition. The main point source of water pollution are municipal WWTPs, industrial activities and mine drainages (HELCOM 2018a). Vistula River is the main source of waterborne pollutants, with a high share of nutrients introduced to the Baltic Sea (Kiedrzyńska et al. 2014). According to HELCOM assessments, Poland is responsible for over 22% of N load and 28% of P load discharged to the Baltic Sea, which makes it the main polluter among other nine Baltic countries (HELCOM 2011).

The Baltic Sea due to its location, climate conditions, and closed character is one of the world's most polluted seas (Smol et al. 2020). According to HELCOM integrated status assessment for 2011–2016, the Baltic Sea is still threatened by eutrophication (HELCOM

2016). Over 97% of the Baltic Sea waters are still affected by eutrophication caused by previous and present excessive loads of N and P (Jetoo 2018). The total nutrient inflow decreased by 9% in total nitrogen (TN) and by 14% in total phosphorus (TP). By introducing nutrient removal measures, three countries achieved a downward trend for both nutrients (Denmark, Poland and Sweden), while two others increased their inflows for both nutrients (Latvia and Russia) (European Court of Auditors 2016). For the remaining countries, a downward trend was observed only for one nutrient. Moreover, Vistula River has the highest area specific TN (354 kg/km^2) and TP (44 kg/km^2) load among the seven largest rivers in the Baltic Sea catchment (HELCOM 2018b).

To mitigate anthropogenic eutrophication caused by excessive nutrients loads, in 2000–2015 over 15 billion Euro were spent by the Polish government at implementing the National Municipal Wastewater Treatment Program (NMWWTP) under which over 400 of new WWTPs were built and another 1500 were modernized (NWMH Polish Waters 2018). Unfortunately, according to the results of the assessment of surface water status in the same period, over 90% of rivers, 75% of lakes and 100% of coastal and transitional waters in Poland are still threatened by the risk of eutrophication (NWMH Polish Waters 2017).

Due to the implementation of the Council Directive 91/271/EEC concerning urban wastewater treatment (EC 1991) and its transposition with the current regulation of Ministry of Marine Economy and Inland Navigation (Ministry of Marine Economy and Inland Navigation 2019), municipal WWTPs effluents must meet high-quality requirements set for biogenic compounds content (Karydis and Kitsiou 2012). In case of any failures causing the limits to be exceeded, the WWTP operators are immediately controlled by the Regional Inspectorate for Environmental Protection which is the main Polish environmental control institution authorized to impose fines and enforce environmental laws.

However, unexpected failures at times occur in WWTPs or sewage systems, often forcing the emergency discharge of untreated wastewater directly to receiving waters (Ryu et al. 2014). The biggest threats to ecosystems are high amounts of N and P compounds in raw wastewater. It is well-known that these compounds have high eutrophication potential and are directly bioavailable for aquatic vegetation (Nakajima et al. 2006; Tu et al. 2019).

The current study presents an independent scientific analysis of the potential water pollution impact caused by the untreated municipal wastewater discharge from the city of Warsaw to Vistula River. The presented case study provides real information on how does the river ecosystem react when a sudden discharge of untreated municipal wastewater is introduced to its ecosystem from one of the biggest agglomerations in Central Europe. Moreover, the research novelty is demonstrated by the fact that no experimental or simulation-based research can provide so reliable information on how does WWTPs failures contribute to water environment deterioration due to large number of conditions and processes occurring in real water bodies which are difficult to be reflected in laboratory conditions or in the model settings (de Vera et al. 2017).

2 Methods

A range of methods has been used to assess the pollution impact on the surface water quality caused by the untreated wastewater discharge. The study was based on the monitoring data provided by the Regional Inspectorate for Environmental Protection which had four monitoring points:

a) Point 1: untreated wastewater discharge flow and pollutants concentration (located at the wastewater pipeline outlet to Vistula River)
b) Point 2: background water quality (located approx. 50 m before the discharge point)
c) Point 3: river water quality in the mixing zone (MZ) of discharged wastewater with the Vistula River waters (located 500 m downstream from the discharge point)
d) Point 4: the stretch of the river water quality (K_{30} monitoring point, located 30 km downstream from the discharge point)

The available data were processed and analyzed by using a basic statistical analysis including among others the Pearson's correlation coefficient and *p* value in order to investigate the relationships between the discharged pollutant loads on the water contamination during the discharge period.

Since the pollution source was municipal wastewater, the biggest concern was the possibility of enhancing eutrophication (Neverova-Dziopak and Preisner 2015), the main problem being the biogenic compounds (nutrients and organics) content in untreated wastewater: TN along with its inorganic form - ammonia nitrogen ($N\text{-}NH_4$) and TP. Moreover, chemical oxygen demand (COD) was analyzed to monitor the amount of organic matter in the outflow (Hanmin et al. 2009). As excessive concentrations of nutrients may lead to significant impact on the dissolved oxygen (DO) deficits (González et al. 2014) the DO level before and after the wastewater discharge was included.

3 Results

3.1 Untreated Wastewater Quality Parameters

Effluent content was monitored by the Regional Inspectorate for Environmental Protection from the first day of the emergency discharge (28th August 2019) and ended on 17th September 2019, thus 3 days after the discharge ceased. Concentrations of TN, $N\text{-}NH_4$, TP and COD were variable over the discharge period (Fig. 1a–c). The volume of discharged untreated wastewater peaked on 10th September and ended on 15th September (Fig. 1d).

The concentrations of biogenic compounds as N and P in untreated wastewater in the discharge period ranged from 37.3 mg/L (8-Sep) up to 82.6 mg/L (12-Sep) in terms of TN and from 2.11 mg/L (6-Sep) up to 9.49 mg/L (29-Aug) in terms of TP. Between 4th and 12th September, the average TP content was approx. 4–5 mg/L and reached 6.72 mg/L at the end of the discharge period. On the other hand, the TN content started to rise from 50 mg/L to over 75 mg/L (6-Sep), then it dropped to 37.3 mg/L (8-Sep) and stabilized at 50–60 mg/L till the end of the discharge period with a peak observed on 12th September when it reached 82.6 mg/L. Both TN and TP concentration peak values observed on 12th and 13th September respectively were less harmful due to the lower untreated wastewater flow resulting from the fact that the replacement pipeline was able to transport constantly more sewage (Fig. 1d). The COD concentration trends were similar to other pollutants in raw wastewater—a minimum COD content was 223 mg/L (1-Sep) and a maximum COD was 696 mg/L (29-Aug).

The discharged wastewater flow was stable from the beginning of the untreated wastewater discharge until 3rd September (approx. 260,000 m^3/day). From 4th September the flow began to decrease due to changing the regime of wastewater flow by diverting the influent to the grid chamber where in a temporary retention tank the influent was treated with ozone to eliminate

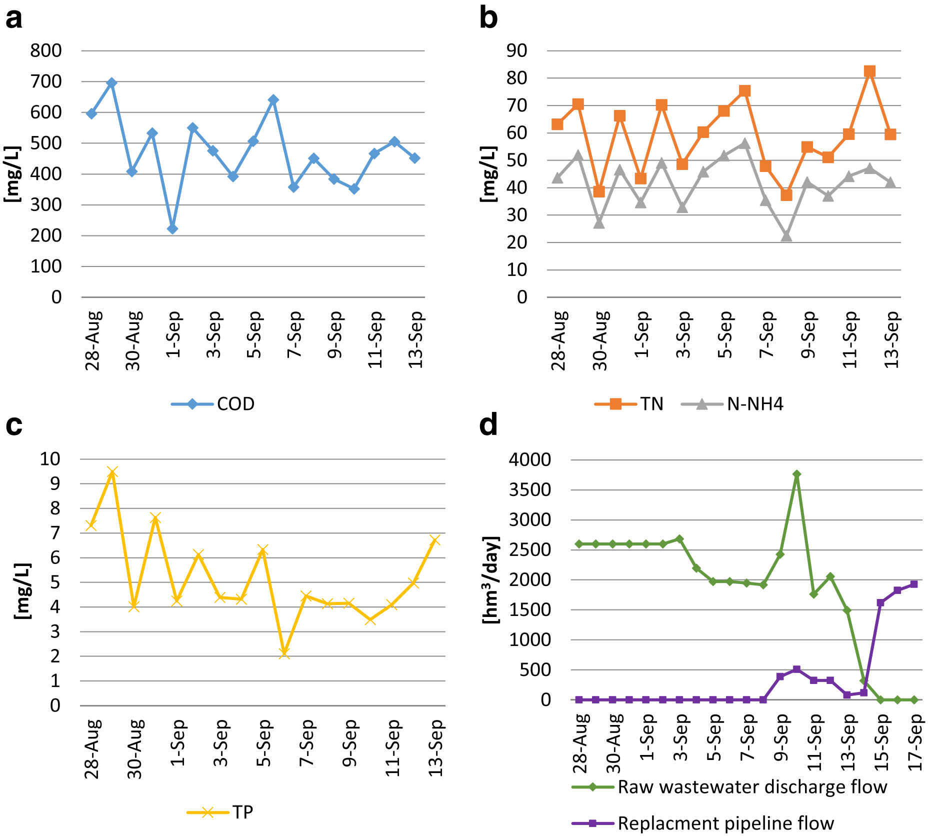

Fig. 1 Untreated wastewater discharge parameters: **a** COD content; **b** TN and N-NH_4 content; **c** TP content; **d** Raw wastewater flow

bacteria and viruses activity. On 8th September, the replacement pipeline was launched to take over the wastewater flow and transfer it to the WWTP located on the other river bank. Due to the rainfall observed on 8-10th September the discharged wastewater flow was increased and reached its peak on 10th September (376,133 m^3/day). Finally, from 14th September, the replacement pipeline was able to transfer the total untreated effluent to the WWTP.

For further analysis, the loads of TN, N-NH_4, TP and COD were calculated (Fig. 2).

The loadings of TN, N-NH_4, TP, and COD were also variable (Fig. 2) and showed that an exceptional quantity of nutrients was introduced into the Vistula River ecosystem. The total mass of COD, TN, N-NH_4 and TP were 1858, 232, 165 and 20.6 Mg, respectively, during 17 days of discharging untreated municipal wastewater. The highest discharged COD (180.96 Mg/day) and TP (2.47 Mg/day) loads were observed on the second day of the sewer failure (29-Aug). It might have been caused by the discharge flow which probably dislodged sediments deposited on the inner surface of the pipes, resulting in additional pollutant loads.

The maximum loads of TN (19.22 Mg/day) and N-NH_4 (13.92 Mg/day) were observed after the rainfall on 10th September which can be related to atmospheric deposition of nitrogen oxides originating from air pollution caused by city traffic (Rzeszutek et al. 2019).

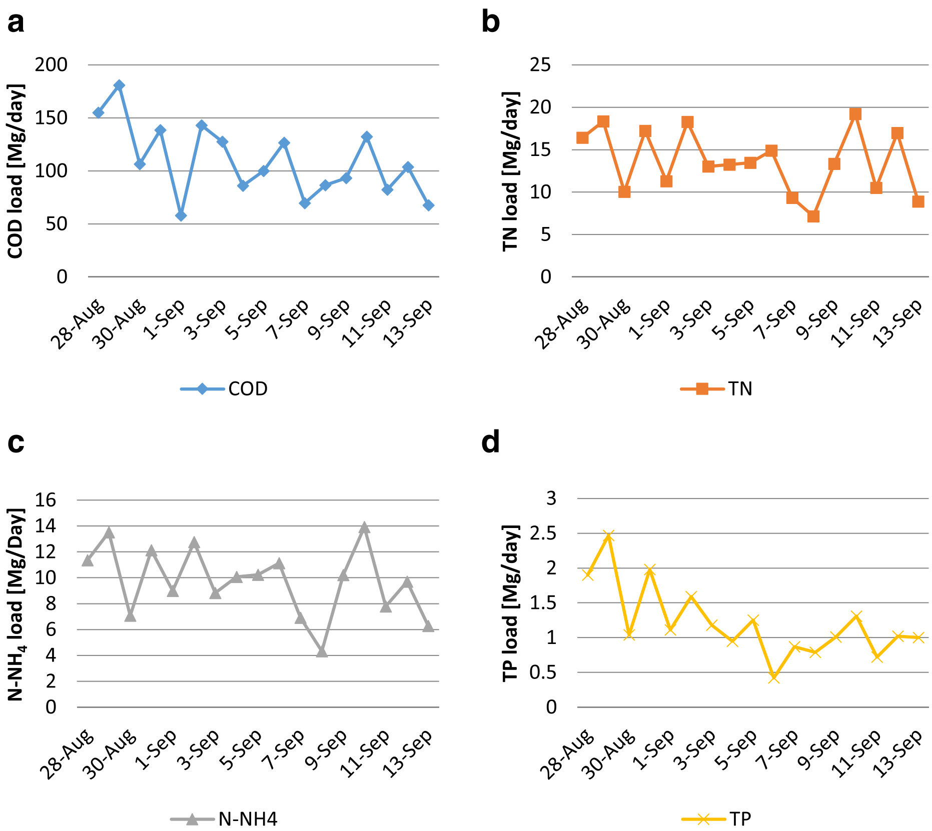

Fig. 2 Loads of discharged COD, TN, N-NH_4, TP

3.2 Background Monitoring Parameters

The background monitoring data were used to assess the potential impact of actual water quality before the discharge of untreated wastewater. The background monitoring point was set by the Regional Inspectorate for Environmental Protection approx. 50 m before the discharge point. The monitored parameters for the analysis of the pollution impact on the wastewater receiver water quality were narrowed to COD, TP, TN, N-NH_4, and DO (Table 1). DO is one of the most important abiotic factors determining the growth and survival of fish and other aquatic organisms (Diaz and Rosenberg 2008).

The background parameters analysis revealed that according to the current legal requirements for second water quality class in Poland (Ministry of Environment 2016), the limit values for COD and DO were exceeded during 6 days in terms of COD and 2 days in terms of DO.

3.3 River Pollution Monitoring in the Mixing Zone

The biggest risk of ecosystem degradation and eutrophication development occurs in the nearest area to the discharge point (Rankinen et al. 2019). Therefore, the water quality in the mixing zone (MZ) of wastewater and river waters was constantly monitored by Regional

Table 1 Background parameters from the monitoring point 50 m before the discharge point

Date	COD [mg/L]	TN [mg/L]	$N\text{-}NH_4$ [mg/L]	TP [mg/L]	DO [mg/L]
28-Aug	32.10	2.00	<1.00	0.16	10.80
29-Aug	29.90	1.61	<1.00	0.13	10.10
30-Aug	32.00	1.38	<0.078	0.08	7.76
31-Aug	26.20	1.31	<1.00	0.17	7.70
1-Sep	25.60	0.90	<1.00	0.12	6.20
2-Sep	29.30	1.31	<0.078	0.07	8.50
3-Sep	15.10	1.42	<0.078	0.06	6.20
4-Sep	32.70	1.57	<0.078	0.15	8.00
5-Sep	25.80	1.33	<0.078	0.07	8.70
6-Sep	49.90	1.34	<0.078	0.04	9.00
7-Sep	27.60	1.47	0.06	0.09	8.00
8-Sep	29.10	1.50	<0.078	0.10	7.40
9-Sep	23.60	1.55	<0.078	0.06	8.50
10-Sep	26.60	3.03	<0.078	0.05	8.70
11-Sep	23.40	1.89	<0.078	0.04	8.70
12-Sep	27.30	1.65	<0.078	0.04	9.60
13-Sep	32.50	1.95	<0.05	0.12	8.90
Limit (2nd class)	≤30.00	≤4.00	≤0.843	≤0.30	≥7.40

Inspectorate for Environmental Protection (Table 2). The untreated wastewater discharge influenced water quality in the MZ, which was approximately 500 m from the discharge point.

From the river pollution monitoring data, it can be assumed that the untreated wastewater discharge had a high influence on the water quality in the MZ whose length was estimated approx. 500 m behind the discharge point. All analyzed parameters, besides DO exceeded the limits for second water quality class almost every day from the beginning of the discharge to its end. The highest impact on the water quality occurred during the first 9 days of the wastewater discharge until 5th September.

Table 2 Water quality parameters in the MZ

Date	COD [mg/L]	TN [mg/L]	$N\text{-}NH_4$ [mg/L]	TP [mg/L]	DO [mg/L]
28-Aug	292.00	40.30	29.50	3.32	7.87
29-Aug	134.00	15.00	10.10	1.76	7.80
30-Aug	149.00	12.50	5.99	1.21	5.80
31-Aug	139.00	16.60	11.40	1.64	5.30
1-Sep	60.10	8.07	4.97	0.68	4.60
2-Sep	200.00	20.10	13.00	1.44	5.70
3-Sep	42.90	6.44	3.63	0.45	5.90
4-Sep	56.90	6.96	3.98	0.53	7.20
5-Sep	184.00	28.50	20.10	2.25	5.10
6-Sep	50.20	3.71	1.23	0.05	7.90
7-Sep	46.20	5.12	2.70	0.47	8.10
8-Sep	86.90	7.16	3.20	0.75	6.40
9-Sep	53.40	5.29	2.84	0.30	8.30
10-Sep	69.30	6.23	2.37	0.31	8.40
11-Sep	47.80	5.03	2.30	0.23	8.80
12-Sep	41.20	5.84	3.02	0.31	9.00
13-Sep	50.20	5.10	1.90	0.36	9.10
Limit (2nd class)	≤30.00	≤4.00	≤0.843	≤0.30	≥7.40

3.4 Stretch of the River Pollution

To assess more distant effects of the emergency discharge, data from a monitoring point located in Kazuń, 30 km distance from the discharge point (K_{30}), were analyzed (Table 3).

The monitoring results from the K_{30} point did not show exceedence of TN, $N\text{-}NH_4$ and TP limit concentrations. The exceeded parameters were DO, with two values not meeting the requirements (7.10 and 7.20 mg/L on 1st September and 3rd September, respectively) and COD which varied in the monitoring period from 23.6–46.8 mg/L.

3.5 Impact Assessment of the Discharged Wastewater on the Water Quality

A statistical analysis was conducted using Pearson's correlation coefficient (r) and alpha p value between discharged pollutant loads, and the MZ and K_{30} monitoring points (Table 4; Fig. 3).

A statistically significant correlation was observed between the COD ($r = 0.567$) and TP ($r = 0.714$) discharged loads and their concentration in the MZ. There was no statistically significant correlation with TN and $N\text{-}NH_4$ values. Furthermore, no statistically significant correlation has been identified regarding parameters from the K_{30} monitoring point that suggest full assimilation of the introduced pollutants by the river ecosystem.

Within the impact assessment of discharged wastewater on receiver water quality, the DO concentration was analyzed in the MZ and K_{30} monitoring point and compared with the background DO concentrations (Fig. 4).

4 Discussion

Regarding the above results, it is evident that the aquatic ecosystem in the MZ during untreated municipal wastewater discharge was exposed to excessive amounts of nutrients and organic

Table 3 Water quality parameters in K_{30} monitoring point

Date	COD [mg/L]	TN [mg/L]	$N\text{-}NH_4$ [mg/L]	TP [mg/L]	DO [mg/L]
28-Aug	n/d	n/d	n/d	n/d	n/d
29-Aug	n/d	n/d	n/d	n/d	n/d
30-Aug	37.40	2.14	0.05	0.14	8.00
31-Aug	42.40	1.69	0.05	0.12	8.20
1-Sep	28.90	1.64	0.05	0.12	7.20
2-Sep	28.80	1.58	0.05	0.13	7.60
3-Sep	26.40	1.60	0.11	0.13	7.10
4-Sep	46.80	1.62	0.07	0.14	8.60
5-Sep	34.80	1.56	0.10	0.16	9.10
6-Sep	36.30	1.51	0.05	0.13	9.00
7-Sep	32.80	1.57	0.05	0.11	8.80
8-Sep	32.50	1.55	0.05	0.11	8.50
9-Sep	23.60	1.55	0.01	0.06	7.80
10-Sep	29.10	1.94	0.06	0.13	9.90
11-Sep	33.10	1.91	0.05	0.12	10.50
12-Sep	30.20	1.82	0.06	0.15	11.00
13-Sep	35.60	1.66	0.06	0.13	10.80
Limit (2nd class)	≤30.00	≤4.00	≤0.843	≤0.30	≥7.40

n/d no data

Table 4 Pearson correlation coefficient (r) with *p* value (p) between discharged pollutants loads and their content in the receiver at the MZ and K_{30} monitoring points

Parameter	MZ		K_{30}	
	r	p	r	p
COD	**0.567**	**0.018**	0.025	0.931
TN	0.357	0.159	0.066	0.814
$N\text{-}NH_4$	0.368	0.146	0.014	0.960
TP	**0.714**	**0.001**	0.100	0.722

Statistically significant r at 5% significant level in bold

matter. Those findings correspond with the results of different experimental studies followed by simulations tests carried out in order to evaluate the so-called "impact zone" assimilation capacity in freshwater systems (Finnegan et al. 2009). According to the above study changes in many pollutants content including COD, $N\text{-}NH_4$, TN, orthophosphates ($P\text{-}PO_4$), TP and DO in water are dependent mainly on the distance from the wastewater discharge point; however, the kinetics and microbial activity in the analysed artificial channels also played a key role in the

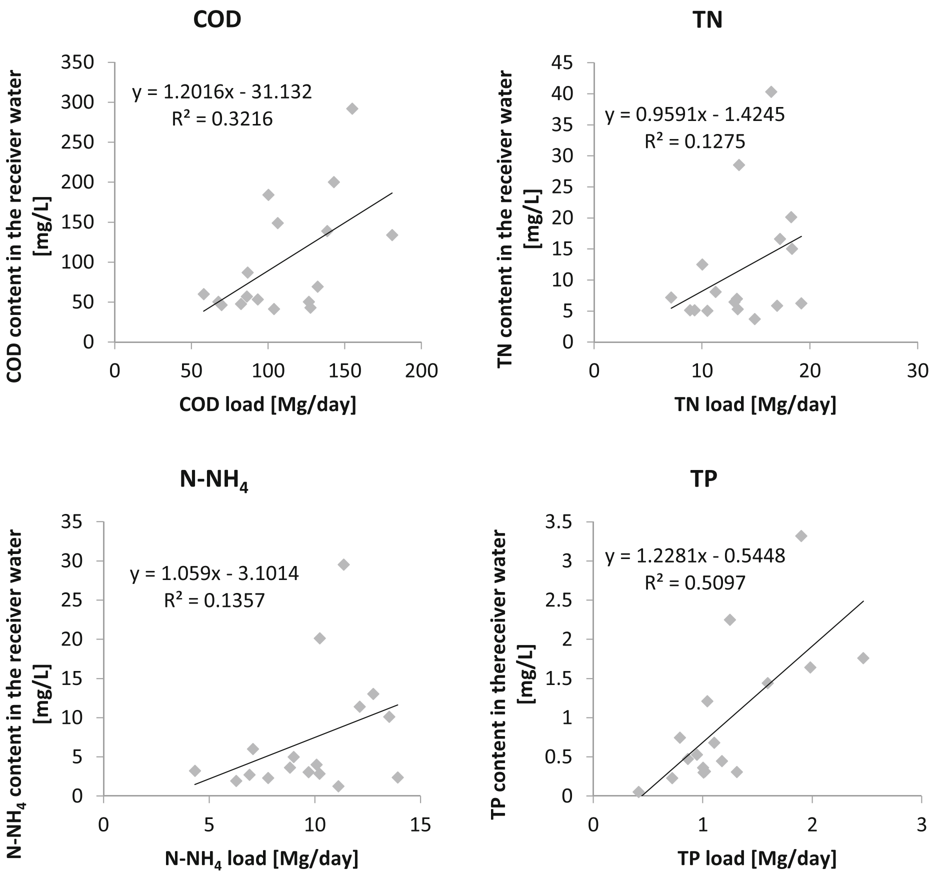

Fig. 3 Scatter plots of the relationships between the content of COD, TN, $N\text{-}NH_4$ and TP in the receiver and their discharged loads

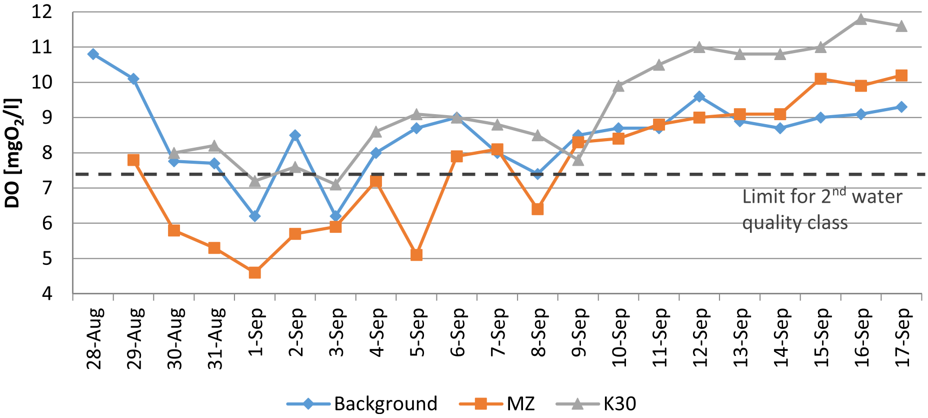

Fig. 4 DO concentration in the background waters, mixing zone (MZ), behind the fully mixed zone (K_{30})

impact zone length. This proves that assessing the implications of a sudden untreated wastewater discharge is a complicated and complex task and requires a wide knowledge of the individual water body properties (Howarth and Marino 2006).

In a different study, a real impact of untreated wastewater discharge was evaluated in Serbia (König et al. 2017). The impact of raw effluents from the city of Novi Sad to the Danube River resulted in severe water pollution in approximately 7 km downstream from the wastewater discharge point. Furthermore, the river stretch between Novi Sad and Belgrade was identified as one of the hot spots for fecal pollution which is an ongoing problem in the Danube River due to incompletely treated or untreated wastewater discharges in many river sections (Kirschner et al. 2009).

Moreover, modeling-based predictions of effluent quality resulting from wastewater treatment processes application or modernization were analysed in numerous studies including developed (Druart et al. 2016; Vialkova et al. 2020) and developing countries (Heddam et al. 2016; Karnib 2014). Within main threats to the aquatic ecosystems mainly inorganic nutrient compounds such as N-NH_4, nitrates (N-NO_3), nitrites (N-NO_2) and P-PO_4 were identified as the most hazardous to aquatic vegetation due to the eutrophication process acceleration causing an ecosystem imbalance (Kemp et al. 2005; Wang and Wang 2009).

In the present study, especially high N values were observed, which in the river MZ ranged from 6.44 to 28.50 mg/L in terms of TN and from 3.63 to 20.10 mg/L in terms of N-NH_4. Inorganic N forms such as highly bioavailable N-NH_4 are usually efficiently removed by the wastewater treatment processes (Farazaki and Gikas 2019; Kowalewski et al. 2016; Smol et al. 2018) since it causes oxygen deficiency in the wastewater receiver due to high oxygen demand for its oxidation (Fuhrmeister et al. 2015). A study from China on urban river N pollution (Zhang et al. 2015) confirms a sharp decrease in DO concentration with the increase of N-NH_4 concentration. Thus, it reduces the water self-purifying ability and deteriorates the living conditions of aquatic organisms, contributing to water eutrophication (Selman and Greenhalgh 2010). Moreover, a high N-NH_4 concentration also results in the presence of free ammonia (NH_3), which can be toxic to fish and slows down the biological nitrification (Mąkinia and Zaborowska 2020).

The P content as a key eutrophication factor (Correll 1998; Kobayashi et al. 2008) was also multiple times exceeded in the MZ in the first 9-days of the discharge period (0.45–2.25 mg/

L). Unfortunately, the pollution monitoring has not included the share of mineral P compounds as orthophosphates which are considered as the most bioavailable nutrient form (Jiang et al. 2004; Wang and Wang 2009). Diazotrophic cyanobacteria, unlike most phytoplankton which require both high N and P conditions, only require high P concentrations and they can produce their own ammonia by assimilating gaseous nitrogen N_2 from the atmosphere (Granéli et al. 1990; Lim and Lee 2017).

The COD concentrations in the MZ were over the limit in the whole discharge period and remain high even after the wastewater discharge was over. Comparing COD value with the background monitoring parameters suggest that COD concentration might not be the direct effect of the wastewater discharge from Warsaw sewer but the general poor water quality in terms of organic pollutants.

The high concentrations of the above factors caused a minor DO deficit. However, the legal limits were not achieved in the MZ only in exactly 7 days (30-Aug to 5-Sep) and ranged from 4.6 to 7.2 mg/L. Even this short period of poor oxic conditions can affect fish population since DO is one of the most important abiotic factors determining growth and survival of fish (Abobi and Wolff 2019; Taylor and Miller 2001) and one of the most commonly used indicators of a river ecosystem health assessment (González et al. 2014; Ouyang et al. 2018). Because of this phenomenon, it is recommended to keep DO level over 6 mg/L (Piper 1982) especially during the late summer months when fish require more oxygen due to higher metabolism (McDaniel et al. 2005). If the levels of DO drops below 4 or 5 mg/L, the number of aquatic species is reduced (Kampschreur et al. 2009). A minimum concentration of 2 mgO_2/L is required to maintain higher life forms (Nazari Alavi et al. 2007).

5 Conclusions

This study provides a real information on how a river ecosystem reacts when a sudden discharge of untreated municipal wastewater is introduced to its ecosystem. An analysis of the untreated wastewater emergency discharge adds value to an efficient and reliable WWTPs with enhanced nutrient removal technologies. However, the effects of WWTPs failures can result in severe environmental, economic and social problems. The results of the present study confirm that the receiving water body quality was highly impaired by discharged pollutants. In a longer perspective, continued discharge of untreated wastewater would contribute to major eutrophication of the Vistula River and the Baltic Sea. Fortunately, the river stretch has not been affected by oxygen deficits while the average observed DO concentration 30 km behind the discharge point was not lower than before the wastewater introduction, showing that due to self-purifying abilities the river ecosystem was able to handle the pollution without significant and permanent degradation. Nevertheless, this study revealed the ineffectiveness of the national water quality monitoring system in the event of an emergency discharge of raw wastewater. It would work better if a larger amount of monitoring points were established especially in the nearest effluent mixing zone. Moreover, parameters such as orthophosphates, nitrites and nitrates should be included in the monitoring system while their share might be significant for eutrophication process intensification.

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