Pol. J. Environ. Stud. Vol. 21, No. 2 (2012), 381-386

Original Research

Impact of Snowmelt Inflow on Temperature of Sewage Discharged to Treatment Plants

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Received: 14 June 2011
Accepted: 12 October 2011

Abstract

The objective of our research was to evaluate the impact of spring snowmelt inflow occurring in separate sewer systems on the temperature of raw sewage discharged into selected treatment plants supporting up to 2000 PE. The results were expected to indicate the range of sewage undercooling due to inflow of the melting water and to evaluate how long this state persists. The research was carried out from 1 January 2010 to 30 April 2010 in five selected sewer systems. The obtained results showed significant influence of snowmelt inflow on sewage temperature in the sewer system. Inflow, which during snowmelt constitutes from 43 to 70% of daily discharge into treatment plants, caused the decrease of average daily sewage temperature in the sewer system: in Gdów by 2.0ºC, in Kostrze by 2.2ºC, in Sidzina by 3.0ºC, in Skotniki by 2.5ºC, and in Wadów by 2.0ºC. The lowest values of hourly temperature of raw sewage during melt-water inflow to the sewer system reached the following values: 5.4ºC in Gdów, 5.0ºC in Kostrze, 4.6ºC in Sidzina, and 5.0ºC in Skotniki and Wadów. At such low average daily sewage temperatures, biological processes of nitrogen compound removal will be inhibited or even stopped. The research showed that the decreased sewage temperature lasted for 16 days. In this period, insufficiently treated sewage may be dangerous to collector water. The presented results provide another argument for increasing efforts to find out the reasons for inflow to the sewer system.

Keywords: infiltration/inflow, treatment plant, sewage temperature, sewer system

Introduction

The major purpose of the separate sewer system is to collect household, industrial, and processing sewage from the settling unit and discharge them [1]. Moreover, “extraneous water” that should not occur is discharged into the sewer system. Extraneous water consists of infiltration and inflow. Rainwater in separate sewer systems is discharged by a separate drainage system.

Inflow consists mainly of rainwater (after heavy rains) or meltwater (from snow melt), that enter sewage manholes through the technical or ventilation openings, or that are improperly discharged from the drain gutters and yard inlets to household sewage [2-6]. The research carried out by Pecher [7] in Rhineland-Westphalia showed that the amount of inflow in a sewer system is also influenced by illegal connections of drains from building drainage systems. Inflow also includes water intentionally or unintentionally directed into the sewer system from building industry, cleaning (flushing streets, washing vehicles), or repairs and cooling water [8-10].

Infiltration water mainly consists of groundwater flowing into the sewer system through damaged pipes, their connections, and leaks in walls and bottoms of the sewer manhole chambers [11-13]. Infiltration water in the sewer system occurs when the pipes are located in the ground below the groundwater table. Discharge of this water into

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Table 1. Basic parameters of the analyzed research objects.

Object location (town)	Material that the sewer system is built of	Length of the system (without discharges) (m)	Pipe diameters, (mm)	Type of mechanical -biological treatment plant reactor to which sewage is disposed	Hydraulic load of the treatment plant with average daily flow (%)	Average daily flow ($m^3 \cdot d^{-1}$)	Average daily flow in dry weather ($m^3 \cdot d^{-1}$)	Share of extraneous water in annual sewage inflow to the treatment plant (%)
Gdów	PVC	16,200	200-400	SBR reactor	68	406.4	268.1	28
Kostrze	Stoneware and PVC	8,970	250-300	A2O reactor	100	413.8	292.6	18
Sidzina	Stoneware	10,000	250-400	A2O reactor	100	435.9	274.4	32
Skotniki	Stoneware and PVC	22,000	250-300	A2O reactor	100	814.0	500.8	32
Wadów	Stoneware	15,200	200-300	A2O reactor	40	219.1	158.5	24

the sewage collectors increases after heavy rainfall events, and is the highest in early spring and late autumn due to high groundwater levels [5].

A large share of inflow and infiltration in the separate sewer system may cause a number of adverse effects in operation of the sewer system itself, as well as of the sewage treatment plant to which the sewage is discharged. During heavy rainfall, gravity sewer systems overflow with sewage, and inflow may periodically operate in pressure conditions, which causes unsealing of the pipe connections. Inflow and infiltration can have an adverse effect on the majority of the sewage treatment plant technological processes that are sensitive to changes of velocity, volume, and time of sewage retention. Operational efficiency of sand separators, primary and secondary settling tanks, and bioreactors is decreased. The presence of extraneous water causes significant dilution of raw sewage and has a negative impact on processes in activated sludge chambers. Extreme inflows after heavy rains can cause the removal of activated sludge from the chambers of biological reactor and secondary chambers, which in turn cause the threat of collector water pollution. Sewage flow, increased by the supply of extraneous water, increases operating costs related to energy consumption, sewage transport, and aeration [14].

Extraneous water in a sewer system may cause yet another negative effect that is rarely mentioned in Polish scientific and technical literature, namely sewage undercooling in the spring snowmelt season. This problem has been pointed out by Kroiss and Prendl [11], Michalska and Pecher [15], and Franz [16]. According to their research, sewage temperature may be decreased even by 6ºC by spring snowmelt inflow to sewer systems. The temperature of sewage is an important factor influencing the effectiveness of sewage biological treatment [17-19]. This is related to the range of temperature optimum for bacteria that take an active part in disposal of contaminants. The temperature that increases biochemical processes for nitrification and denitrification ranges from 10 to 22ºC [20]. Arnold, Bohm, and Wilderem in their research [21] indicated that decreasing sewage temperature by 10ºC may cause a decrease of nitrifying activity by even 70%. At low sewage temperatures the process of organic acid formation is weakened, which has a negative impact on the removal of biological phosphorus.

Sewage temperature gradually decreases during flow through the sewer system. This is affected by many factors, but most importantly by the length of collectors, intensity and velocity of sewage flow, depth of the gradeline, number of manholes and pumping stations, and by intensity of infiltration and inflow. According to Szpindor [8], as a result of the mentioned factors the final sewage temperature by the inlet to the treatment plant should be in the range of 11.2-12.2ºC.

Research Procedures

The objective of our research was to define the impact of spring snowmelt inflow to separate sewer systems on the temperature of raw sewage discharged into the selected treatment plants. The results were expected to indicate the range of sewage undercooling due to melting water inflow and to evaluate how long this state persists. The research was carried out from 1 January 2010 to 30 April 2010. An intensive snowmelt period was observed from 19 February 2010 to 1 March 2010.

Five separate sewer systems located in Lesser Poland voivodeship were selected for research. They discharge sewage to treatment plants that support up to 2,000 PE (population equivalent). It needs to be stressed that small sewer systems, characterized by small pipe diameters and small range, are more sensitive to extraneous water than big collective systems.

The analyzed sewer systems are located in krakowski (4 objects) and wielicki Poviats (1 object). The general characteristics of the analyzed sewer systems and treatment plants are presented in Table 1.

Observations of daily sewage flow, performed in the analyzed sewer systems since 2005, indicated inflows (mainly during heavy rainfall events) as well as infiltrations (increased in spring and after heavy rainfall events). On the basis of a comparison of daily sewage flow during dry weather (rainless) with other flows during the year, it was calculated that, depending on the object, inflow and infiltration constitute from 18 to 32% of annual sewage supply to the treatment plant (Table 1). The daily share of inflow and infiltration (extraneous water) in the sewage in the treatment plant was calculated on the basis of the following equation [7, 22]:

$$UWO = \frac{Q_d - Q_{bd}}{Q_d} \cdot 100\ [\%] \qquad (1)$$

...where:

Q_d – daily sewage discharge to the treatment plant [$m^3 \cdot d^{-1}$]

Q_{bd} – average daily sewage discharge to the treatment plant in dry weather [$m^3 \cdot d^{-1}$]

A detailed method of calculation of infiltration and inflow share in the sewer system has been presented by Pecher [7], Ellis and Bertrand-Krajewski [13], Franz et al. [16].

The temperature of raw sewage was measured with Nautilus 85 ACR electronic sensors with an accuracy of 0.1ºC. The sensor with a data recorder (placed in a stainless steel jacket) enabled constant measurement of sewage temperature at a given time interval. The sensors were placed directly in inspection chamber base units of sewage manholes located before the treatment plants.

To evaluate the impact of the temperature of sewage flowing out of the sewer system on the temperature of sewage in a biological sewage treatment system, the temperature of sewage in the biological rector was additionally measured using the Nautilus 85 sensors.

The temperature of raw sewage discharged into the treatment plant was measured constantly in 1h intervals (24 measurements daily). Moreover, constant measurement of atmospheric air temperature was carried out with an electronic sensor with a Smart Button ACR recorder (accuracy of 0.5ºC). The temperature of raw sewage and atmospheric air were measured individually for each object. Daily sewage flow was measured in the area of each treatment plant using an ultrasound probe for the level over a triangular spillway. The measurements were carried out from 1 January 2010 to 30 April 2010. The snowmelt period (from 19 February 2010 to 1 March 2010) was defined on the basis of atmospheric air temperature measurement and field observations.

Discussion of Results

Before the snowmelt, snow depth in the research area ranged from 350 to 380 mm. In 2010 an intensive snowmelt began on 19 February (Fig. 1). That day the average air temperature reached 1.4ºC and positive temperature remained for 24 hours per day. On 18 February 2010 the average daily temperature of sewage reached the following values: 8.0ºC in Gdów, 7.6ºC in Kostrze, 7.8ºC in Sidzina, 8.0ºC in Skotniki, and 8.1ºC in Wadów. Positive air temperature lasted until 21 February, – when the average air temperature decreased to -0.23ºC, but still remained above zero for 11 hours. In the first two days of snowmelt, the average daily sewage temperature decreased in each sewer system from 0.3ºC in Gdów to 0.7ºC in Sidzina. From 23 February to 3 March the average daily air temperature remained above zero. These days positive air temperature remained from 11 to 24 hours per day. Fig. 2 graphically presents the percentage of inflow and infiltration in sewage flow in each treatment plant.

The highest discharge of extraneous water occurred from 27th February to 2nd March, reaching from 42.6% in Kostrze to 70.0% in Skotniki. It may be assumed that the majority of extraneous water percentage consisted of snowmelt inflow, but infiltration water discharge is also expected, because in spring and in late autumn the level of groundwater is the highest [5].

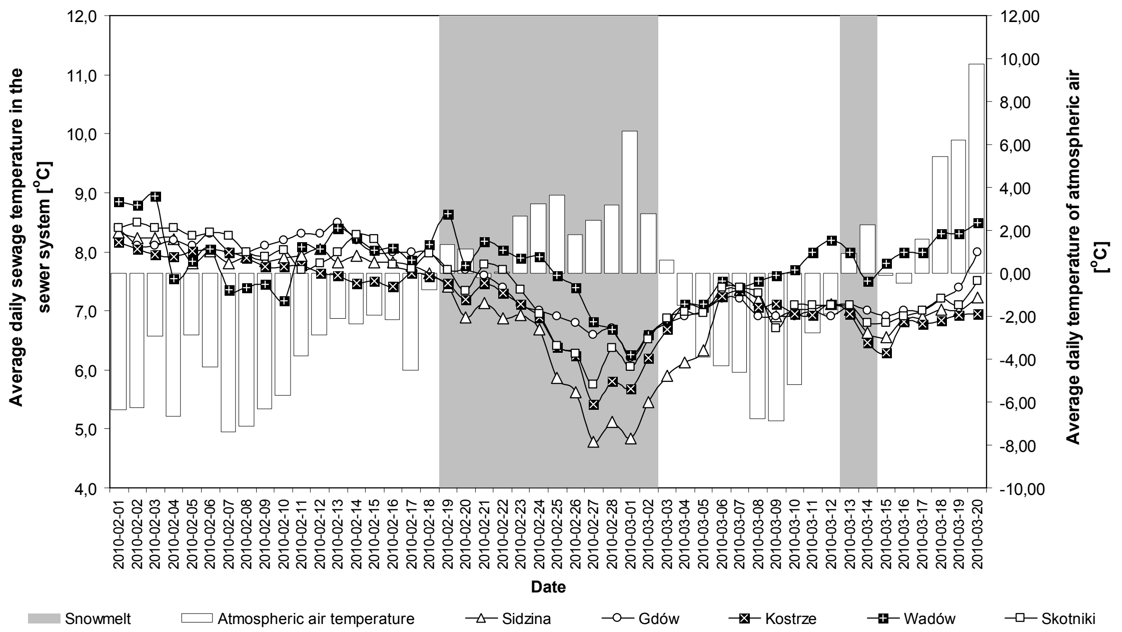

Fig. 1. Impact of snowmelt inflow on the decrease of sewage temperature in the sewer system.

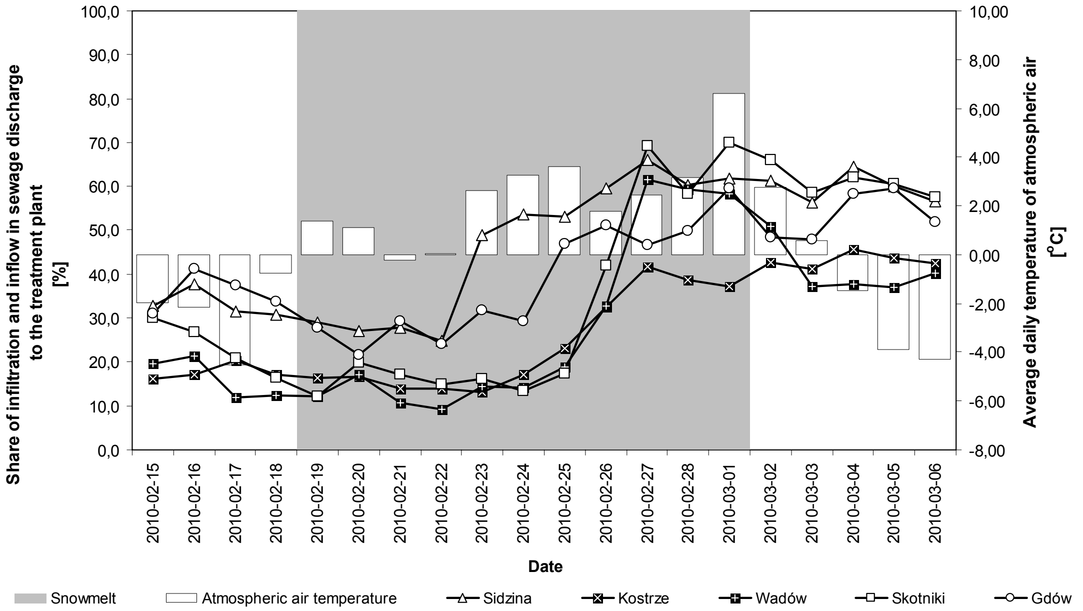

Fig. 2. The share of inflow and infiltration in the treatment plant sewage flow in the spring snowmelt season.

Extraneous water discharge to the sewer system during snowmelt caused gradual decrease of the sewage temperature. The lowest values of the average daily sewage temperature in each sewer system reached: 6.2ºC in Gdów, 5.4ºC in Kostrze, 4.8ºC in Sidzina, 5.8ºC in Skotniki, and 6.3ºC in Wadów. Thus, snowmelt inflow to the sewer system caused a decrease of average daily sewage temperature in comparison to the period before the snowmelt season: by 2.0ºC in Gdów, 2.2ºC in Kostrze, 3.0ºC in Sidzina, 2.5ºC in Skotniki, and 2.0ºC in Wadów.

The lowest values of hourly raw sewage temperature during snowmelt water inflow to the sewer system reached the following values: 5.4ºC in Gdów, 5.0ºC in Kostrze, 4.6ºC in Sidzina, and 5.0ºC in Skotniki and Wadów.

Fig. 3 shows the impact of low temperature of sewage flowing into the Sidzina treatment plant on the decrease of the sewage temperature in the bioreactor during the spring snowmelt season. The research indicated that the temperature of sewage in bioreactors of each sewage treatment plant was only from 0.2 to 0.4ºC higher than the temperature of sewage flowing into the analyzed objects.

At such low sewage temperatures the majority of biological processes of biogenic compound removal is inhibited or even stopped.

Only after 16 days did the sewage temperature in the sewer system reach a value comparable to the period before snowmelt. A high percentage of extraneous water in the sewage outflow from the sewer system lasted even two

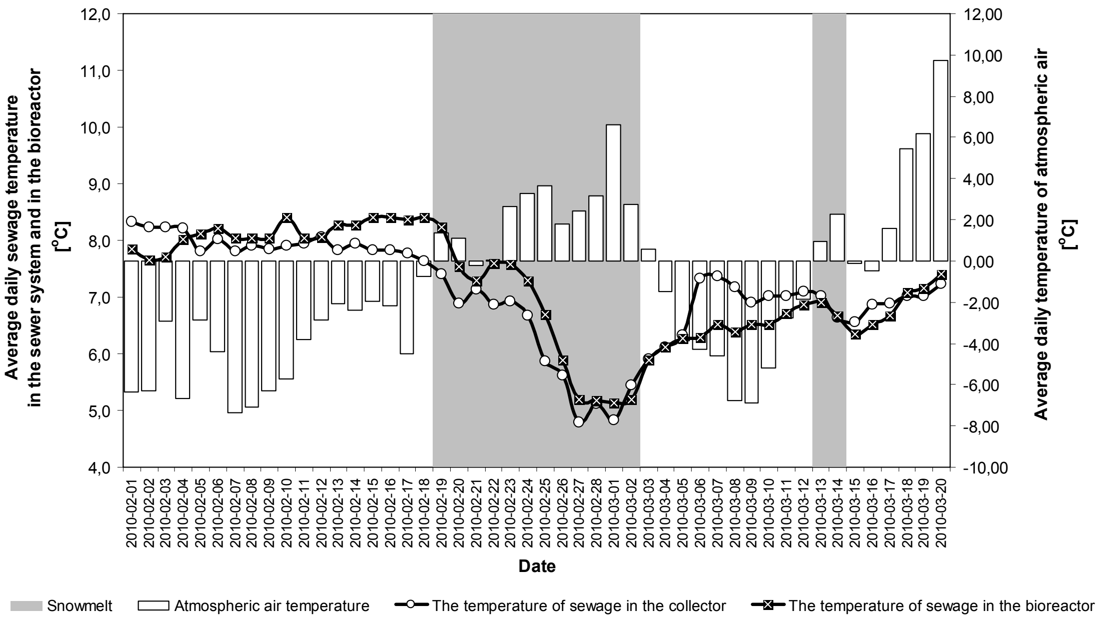

Fig. 3. Impact of the temperature of sewage flowing into the Sidzina treatment plant on the temperature of sewage in the bioreactor.

more weeks after the snowmelt. It was caused by groundwater infiltration to the sewer system. The last part of the snowmelt – the period from 13 to 14 March, is marked in Fig. 1. Moreover, the decrease of the average daily sewage temperature occurred these days, but it was small, reaching from 0.2ºC in Gdów to 0.5ºC in Kostrze and Wadów.

Conclusions

The performed studies indicate a significant impact of snowmelt inflow on sewage temperature in the sewer system. Inflow, which during snowmelt period constitutes from 43 to 70% of the daily discharge to the treatment plants, caused a decrease in average daily sewage temperature by 2-3ºC, depending on the object. At relatively low average daily temperature of sewage, reaching from 7.6 to 8.0ºC in winter, an additional temperature decrease due to inflow caused sewage undercooling in the sewer system to 6.2ºC in Gdów, 5.4ºC in Kostrze, 4.8ºC in Sidzina, 5.8ºC in Skotniki, and 6.3ºC in Wadów. These days, the sewage temperature in bioreactors was not more than 0.5ºC higher. At such low average daily sewage temperatures biological processes of nitrogen compound removal will be inhibited or even stopped. The dephosphatation process is less sensitive to low sewage temperatures, but the effectiveness of phosphorus fixation decreases significantly at sewage temperatures lower than 10ºC.

Our research showed that the decreased sewage temperature lasted for 16 days. In this period insufficiently treated sewage may be dangerous to collector water. As a result of raw sewage dilution, the values of pollution indexes in the treated sewage may still not transgress the conditions of water-law permission (especially in treatment plants that belong to the group supporting under 2000 PE). However, it needs to be remembered that much higher pollutant loads will be discharged these days due to increased sewage flows [6, 23].

The presented results provide another argument for increasing the intensity of actions in order to find out the reasons of inflow to the sewer system. First, illegal connections of the drain gutters and yard inlets to the sanitary sewer system in the estate areas need to be located and removed. Sewer manhole openings located below roadways or pavements are the second most common source of inflow. Rainwater or meltwater that runs down the ground area is collected in the cavity, and then it gets into the manhole chamber by the airholes or technical holes [4], and also by the connections of the manhole cover with the well crown. It has been estimated that in Germany 18 to 56% of inflow enters sewage collectors through manholes [10, 16].

Sealing the sewer systems should be encouraged by cost analysis. Sewage flows increased by extraneous water cause a increase of exploitation costs related to energy consumption for transport and aeration of sewage [14]. The research carried out in 1990 in Thuringia showed that more than 60% of sewer systems' and treatment plants' supervisory institutions admitted that infiltration water and inflow constitute the majority of discharge. Over 40% of the entire surveyed group assessed the effects of extraneous water to be significant. Decreasing the discharge of this water to the sewer system has been estimated to reduce annual operating costs by 30% [22].

In summary, the presented results contribute to the current state-of-the-art in the field of sewage cooling caused by snowmelt infiltration. The results indicate that the sewage temperature in small sewer systems may drop even below 5ºC. Sewage undercooling due to long-term snowmelt may last more than 2 weeks (16 days). Biological processes during this period are completely inhibited. All these factors suggest an urgent need to seal sewer systems and to protect sewer manhole openings from snowmelt inflow from streets and sidewalks.

Publication and dissemination of the obtained results is intended to provide further arguments for discussion on improving the technical condition of the sewer system in Poland and other countries.

Acknowledgements

The results of research project No. N N305 073236 financed by scientific resources and realized in 2009-12 were used for this paper.

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