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IMPACT OF DAILY FLOW TO MID-SIZE WWTP BIOREACTOR ON ELECTRIC ENERGY CONSUMPTION

WPŁYW ZMIENNOŚCI OBCIĄŻENIA REAKTORA BIOLOGICZNEGO W ŚREDNIEJ OCZYSZCZALNI ŚCIEKÓW NA ZUŻYCIE ENERGII

A b s t r a c t

The paper analyses the share of single SBR in the total energy consumption of the studied wastewater treatment plant. The analysis is based on a two sets of data measurements, gathered by an automated measuring installation and data archived manually by the plant's operator. Energy consumption was also analyzed with reference to the archive data of daily flows. The paper is based on data collected from November of 2015 to January of 2016. This is a continuation of an ongoing research.

Keywords: energy consumption, wastewater treatment plant, SBR

S t r e s z c z e n i e

W artykule zestawiono zużycie energii elektrycznej pojedynczego reaktora typu SBR w odniesieniu do całkowitego zużycia energii przez badaną oczyszczalnię ścieków. Porównania dokonano w oparciu o dwa zestawy danych: pomiary, zarejestrowane przez automatyczną instalację pomiarową oraz dane eksploatacyjne archiwizowane przez operatora oczyszczalni. Analizę zużycia energii odniesiono również do zarejestrowanych przepływów dobowych przez oczyszczalnię. Analizowane dane pochodzą z okresu od listopada 2015 do stycznia 2016 i stanowią kontynuację wcześniejszych badań.

Słowa kluczowe: zużycie energii, oczyszczalnia ścieków, SBR

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1. Introduction

This paper presents the continuation of measurements launched in May of 2014. Its focus is on a 3-month cold period (late autumn to mid-winter), during which the average daily temperature oscillated around 0 degree Celsius [1]. During the studied period, the observed average daily flows were lower than usual.

2. Basic information

2.1. Plant's description

The studied plant is located near Kraków, in Southern Poland. The plant consists of two parallel treatment lines of a SBR (Sequencing Batch Reactor) type [2, 3, 4] and one sludge stabilization chamber each [5]. The plant's capacity is 1250 m^3/day and its PE (Population Equivalent) equals to 14 950. However, due to incomplete municipal sewerage, the real daily flows usually are below 700 m^3/day. Daily flows during tests were even lower, but the operator is not switching the plant into one-train only in order to prevent the installation against freezing. That is why all of the four reactors were rotationally activated according to the scheme: SBRs 3 and 4 were on line all the time and the SBRs 1 and 2 were activated alternately. Therefore, during the entire studied period, 3 of 4 reactors were constantly operational.

The plant's main device list (1.5 kW of power and above) [6]:

- sludge truck discharge station 3.5 kW
- vertical sieve 1.5 kW
- stage 1 pumping station 4.7 kW (1+1 in reserve, working interchangeably)
- grit & grease removal 4.0 kW
- retention tank blowers 5.5 kW (1+1 in reserve, working interchangeably)
- stage 2 pumping station 7.5 kW (1+1 in reserve, working interchangeably)
- 2x2 SBRs (no 1.2 – older tech-line, no 3, 4 – newer tech-line):
  - 2x3 blowers 30.0 kW each (2x2+1 in reserve, working interchangeably)
  - 2x2 excess sludge pumps 5.5 kW each (1 pump per reactor)
  - 2x2 internal turbines 11.0/7.5 kW (2 gears) (1 turbine per reactor)
- 2x1 sludge stabilization chamber (1 chamber per 2 reactors):
  - 2x1 blower 11.0 kW each (1 blower per chamber)
  - 2x1 internal turbines 5.5 kW (1 turbine per chamber)
- stabilized sludge pump 2.2 kW
- centrifuge (sludge dewatering) 17.2 kW
- dewatered sludge auger 1.5 kW.

During the studied period, WWTP operated flawlessly and easily met the administrative requirements [7, 8].

2.2. Measuring grid components

The measuring grid consists of (main elements only):
- 1 central unit (notebook) with specialized software
- 1 signal converter
- 5 automated energy counters.

Software installed on the central unit controls the work of the installation. The notebook functions also as a data archive. The signal converter translates data from meters to a form acceptable by the computer. Automated counters measured total energy used by selected devices in 5 minutes intervals (current settings). Counters are installed on following devices:
- Blowers (D4, D5, D6)
- SBR internal mixing-aerating turbine (Tr4)
- Excess sludge pump (P11).

To measure the energy usage of one reactor, installation of meters on all devices directly connected with this reactor is needed – SBR internal turbine Tr4, excess sludge pump P11, and oxygen source. Because of reliability reasons, all three blowers are connected into one oxygen supply system for both reactors [9]. During measurements, only blower D5 supplied SBR4 with oxygen.

3. Data

This paper contains data from two sources: automated measurements provided by a measuring grid and plant's journal of the exploitation provided by WWTP's operator.

Data archived by the plant's operator have daily intervals, except Saturdays, Sundays and statutory holidays. After consultation with WWTP operator concerning the average daily flows and total energy consumption, it became clear that extrapolation of missing data with simple arithmetic average will be sufficient. Extrapolated flows and energy consumption are a bit lower than the recorded ones; however, during weekends, no additional wastewater is delivered by sludge trucks, hence smaller results are plausible. Please note that these averages were based on data received from an effluent meter; therefore, the total flow in the studied period was not extrapolated. Only missing daily flows are the result of extrapolation. The exact same situation was with WWTPs total energy consumption [10]. All vital data used for analyzes are presented in Tables 1, 2 and 3.

Data recorded by the installation was registered in 5-minute intervals and the single series covers one month. It was the last three series recorded with a 5-minute time-step before the grid's extension and recalibration in February.

The presented results are free of a small software error, which caused sudden stops in data archiving on the 26th day of each month [10]. The error was caused by an improper configuration of the maximum volume of ANSI file in Windows 7. The error was finally corrected in September of 2015, and since then, interruptions in the measurements have been incidental and caused by sporadic power outages. It should be noted that the WWTP is equipped with a diesel electric generator. The installed meters are resilient to energy spikes during switches in power supply between the main grid and the generator.

Table 1

SBR4 energy consumption compared to WWTP's total energy usage in November of 2015

Date	D5 [kWh]	Tr4 [kWh]	P11 [kWh]	SBR4 [kWh]	TEC [kWh]	SBR4 % of TEC	Dailyflow [m^3/day]
2015-11-02	142.57	94.91	0.28	237.76	1320	18.01	305
2015-11-03	145.91	86.49	0.53	232.93	1320	17.65	431
2015-11-04	148.80	87.40	0.27	236.47	1560	15.16	344
2015-11-05	149.66	96.15	0.56	246.36	1440	17.11	436
2015-11-06	147.08	88.66	0.61	236.35	1080	21.88	243
2015-11-07	86.03	86.89	0.34	173.26	1080	16.04	243
2015-11-08	114.10	87.94	0.34	202.37	1080	18.74	243
2015-11-09	117.38	84.62	1.33	203.33	1200	16.94	517
2015-11-10	150.39	77.12	0.92	228.43	1140	20.04	222
2015-11-11	143.39	87.77	0.33	231.49	1140	20.31	222
2015-11-12	140.97	81.99	0.45	223.40	1200	18.62	370
2015-11-13	136.55	82.92	0.53	220.00	1140	19.30	297
2015-11-14	114.38	76.20	0.55	191.13	1140	16.77	297
2015-11-15	99.64	91.19	0.00	190.83	1140	16.74	297
2015-11-16	102.16	77.81	0.54	180.51	1200	15.04	534
2015-11-17	107.97	80.97	0.53	189.48	1200	15.79	378
2015-11-18	141.76	92.77	0.26	234.80	1200	19.57	373
2015-11-19	89.63	78.39	0.74	168.75	1200	14.06	364
2015-11-20	127.66	85.25	1.01	213.92	1020	20.97	390
2015-11-21	105.70	84.43	0.56	190.68	1020	18.69	390
2015-11-22	71.65	87.15	0.27	159.07	1020	15.59	390
2015-11-23	81.00	88.31	0.26	169.57	1260	13.46	555
2015-11-24	94.24	72.08	2.07	168.39	1260	13.36	385
2015-11-25	86.52	93.20	0.51	180.23	1260	14.30	420
2015-11-26	79.93	85.10	0.70	165.74	1380	12.01	376
2015-11-27	77.18	82.66	0.95	160.79	1080	14.89	286
2015-11-28	82.60	88.48	0.28	171.37	1080	15.87	286
2015-11-29	52.40	88.45	0.28	141.13	1080	13.07	286
2015-11-30	114.24	111.84	0.27	226.34	1140	19.85	577
TOTAL	3251.48	2507.12	16.27	5774.87	34380	–	10456
MIN	52.40	72.08	0.00	141.13	1020	12.01	222
MAX	150.39	111.84	2.07	246.36	1560	21.88	577
Average	112.12	86.45	0.56	199.13	1186	16.89	361

Table 2

SBR4 energy consumption compared to WWTP's total energy usage in December of 2015

Date	D5 [kWh]	Tr4 [kWh]	P11 [kWh]	SBR4 [kWh]	TEC [kWh]	SBR4 % of TEC	Dailyflow [m^3/day]
2015-12-02	117.93	101.56	0.46	219.95	1200	18.33	396
2015-12-03	73.40	87.24	0.74	161.39	1260	12.81	388
2015-12-04	70.99	97.48	0.61	169.08	1040	16.26	299
2015-12-05	90.28	101.20	0.27	191.75	1040	18.44	299
2015-12-06	112.60	100.47	0.27	213.34	1040	20.51	299
2015-12-07	88.10	97.13	0.24	185.47	1020	18.18	502
2015-12-08	113.78	82.35	0.51	196.63	1020	19.28	409
2015-12-09	91.02	84.17	0.86	176.05	1440	12.23	506
2015-12-10	93.73	83.38	0.37	177.48	1320	13.45	423
2015-12-11	130.90	92.93	0.39	224.22	1240	18.08	274
2015-12-12	102.42	89.85	0.28	192.55	1240	15.53	274
2015-12-13	71.14	89.15	0.27	160.56	1240	12.95	274
2015-12-14	100.12	92.39	0.27	192.77	1500	12.85	481
2015-12-15	135.34	81.70	0.55	217.59	1320	16.48	355
2015-12-16	111.09	83.62	0.72	195.43	1260	15.51	504
2015-12-17	148.77	96.06	0.52	245.35	1380	17.78	502
2015-12-18	134.50	86.13	0.52	221.15	1320	16.75	329
2015-12-19	129.91	99.85	0.27	230.02	1320	17.43	329
2015-12-20	117.14	97.61	0.26	215.01	1320	16.29	329
2015-12-21	117.53	111.45	0.28	229.25	1320	17.37	504
2015-12-22	129.89	91.82	0.52	222.22	1260	17.64	493
2015-12-23	122.81	93.85	1.31	217.97	1296	16.82	262
2015-12-24	137.98	103.17	0.27	241.42	1296	18.63	262
2015-12-25	89.93	96.52	0.28	186.73	1296	14.41	262
2015-12-26	75.56	107.92	0.00	183.48	1296	14.16	262
2015-12-27	74.60	103.31	0.27	178.18	1296	13.75	262
2015-12-28	91.51	103.84	0.71	196.07	1200	16.34	330
2015-12-29	70.43	97.27	0.37	168.08	1260	13.34	395
2015-12-30	91.05	95.34	0.88	187.26	1260	14.86	335
2015-12-31	135.21	107.36	0.28	242.86	1275	19.05	243
TOTAL	3169.62	2856.12	13.54	6039.27	37575	–	10781
MIN	70.43	81.70	0.00	160.56	1020	12.23	243
MAX	148.77	111.45	1.31	245.35	1500	20.51	506
AV	105.65	95.20	0.45	201.31	1253	16.18	359

Table 3

SBR4 energy consumption compared to WWTP's total energy usage in January of 2016

Date	D5 [kWh]	Tr4 [kWh]	P11 [kWh]	SBR4 [kWh]	TEC [kWh]	SBR4 % of TEC	Dailyflow [m^3/day]
2016-01-01	73.87	104.41	0.27	178.54	1275	14.00	243
2016-01-02	48.40	105.74	0.00	154.15	1275	12.09	243
2016-01-03	38.11	104.25	0.00	142.36	1275	11.17	243
2016-01-04	78.17	103.31	0.27	181.75	2400	7.57	391
2016-01-05	111.26	106.71	1.15	219.12	1800	12.17	243
2016-01-06	48.07	93.01	0.39	141.47	1800	7.86	243
2016-01-07	104.57	101.35	0.41	206.32	1860	11.09	481
2016-01-08	130.03	92.47	0.80	223.29	1680	13.29	274
2016-01-09	88.00	97.70	0.40	186.10	1680	11.08	274
2016-01-10	95.02	99.99	0.40	195.41	1680	11.63	274
2016-01-11	109.16	108.00	0.39	217.54	1740	12.50	461
2016-01-12	141.73	96.07	0.81	238.62	1680	14.20	467
2016-01-13	103.04	71.47	0.41	174.91	1500	11.66	351
2016-01-14	100.95	84.36	2.08	187.39	1440	13.01	459
2016-01-15	94.11	90.28	0.85	185.25	1400	13.23	243
2016-01-16	95.07	91.27	0.47	186.80	1400	13.34	243
2016-01-17	97.35	91.72	0.47	189.54	1400	13.54	243
2016-01-18	71.22	87.89	0.47	159.58	1680	9.50	375
2016-01-19	108.06	79.77	0.95	188.78	1860	10.15	363
2016-01-20	51.97	86.86	0.48	139.31	1800	7.74	314
2016-01-21	92.17	83.27	0.94	176.38	1800	9.80	364
2016-01-22	33.18	89.60	0.87	123.66	1560	7.93	199
2016-01-23	62.64	90.12	0.46	153.22	1560	9.82	199
2016-01-24	42.32	87.17	0.47	129.96	1560	8.33	199
2016-01-25	84.00	95.66	0.56	180.22	1920	9.39	461
2016-01-26	95.36	83.01	0.91	179.29	1380	12.99	372
2016-01-27	77.03	79.78	1.30	158.11	1380	11.46	468
2016-01-28	60.71	86.61	0.46	147.78	1380	10.71	344
TOTAL	2335.53	2591.88	17.44	4944.85	45165	–	9032
MIN	33.18	71.47	0.00	123.66	1275	7.57	199
MAX	141.73	108.00	2.08	238.62	2400	14.20	481
AV	83.41	92.57	0.62	176.60	1613	11.12	323

The time of power source change for WWTP is far shorter than the grid's central unit battery life. Since the beginning of the measurements, only a handful Random Missing Records (RMR) was observed. The amount of RMR was so small that it could be considered negligible.

The acronym "TEC" used in all tables below stands for Total Energy Consumption.

The average flow in November was roughly 30% of the designed flow. Underflow conditions had no negative impact on effluent quality. However, in terms of energy efficiency, it is a very undesirable situation. On average, to process 1 m^3 of sewage, 3.28 kilowatt-hours (kWh) of energy was needed. It is more than it should be for flow above 100 m^3/day [11]. SBR4 had, on average, a 16.89% share in the Total Energy Consumption with the maximum value of almost 22%, which is about half of the share registered in May of 2015 [10]. A similar situation can also be observed in December and January.

Similar to November, in December, the average daily flow was also roughly 30% of the designed flow. The SBR4 share in TEC in December was also very similar to the previous month and was 16.18% with a maximum also below 22%. It can be said that, despite not operating in the designed conditions, the plant operated steadily.

The last data set was registered in January of 2016. Average daily flow was little lower than during the previous 2 months, and reached about 26% of the designed flow. In addition, the SBR4 share in TEC was a bit lower and was on average 11,12%, never reaching more than 14.20%. It is a result of putting more pressure onto the rest of the reactors by the plant's operator, which is clearly visible in the D5 column. A lower amount of sewage resulted in a lower amount of processed BOD, nitrogen and phosphorus compounds, thus a lower amount of air had to be supplied to the SBR4.As a result, in January, blower D5 used only 2335 kilowatt-hours. This is 919 kilowatt-hours less than in December and 916 kilowatt-hours less than in November. Since the D5 is one of the 2 main contributors of the SBR4 share in TEC, the lower share in January is not a surprise.

Table 4

SBR4 energy consumption compared to WWTP's total energy usage 3 moths summary

3 months:	D5 [kWh]	Tr4 [kWh]	P11 [kWh]	SBR4 [kWh]	TEC [kWh]	SBR4 [%] of TEC	Dailyflow [m^3/day]
TOTAL	8756.63	7955.11	47.25	16758.98	117120	–	30269
MIN	33.18	71.47	0.00	123.66	1020	7.57	199
MAX	150.39	111.84	2.08	246.36	2400	21.88	577
AV	100.65	91.44	0.54	192.63	1346	14.79	348

As can be seen in Table 4, the average daily flow for a three-month period was 348 m^3/day, which is as low as 28% of designed average flow. This resulted in an average of 3.87 kWh being needed for treatment of 1 cubic meter of wastewater. For all 3 months, the average energy usage for 1 m^3 of treated sewage was higher than expected based on design calculations. Such a situation appears to be unavoidable, even with highly efficient equipment installed. Design power shall match the designed flow; therefore, if the flow is lower than designed, the energy efficiency of the whole plant will be lower than expected. Countermeasures to improve energy efficiency during underflow conditions are limited.

One of the methods are Variable-Frequency Drives (VFDs) thanks to which it is possible to greatly reduces the amount of energy needed by a device by adjusting it with VFD to current operating conditions, but at least for now, most of the devices operating at WWTPs are not equipped with such drives due to their high cost. Usually, blowers or other high-energy units are powered by VFDs. The studied plant is one of such examples, with blowers equipped with VFDs. The rest of the devices are powered directly or with few operating modes and the inflexibility of these devices results in higher than normal energy usage per 1 m^3 of treated wastewater. Another solution in situations like the ones described is turning off a part of the treatment plant; usually it is one or more of few technological lines. This method is a drastic step because a complete shutdown of a technological line takes time; restarting a tech-line is even more problematic and it takes weeks before a bio-reactor can reach optimal operating parameters (active sludge composition, effluent quality etc.) [12, 13]; therefore, this solution is uncommon. The best solution to problem of WWTPs operating not efficiently due to too low daily flows is avoiding its occurrence with good coordination of the construction of the sewerage network and sewage treatment plants. This, however, is a hard goal to achieve. However, the energy efficiency of the plant will rise after the sewerage system is complete.

The two main contributors of SBR4 energy usage are blowers and the internal turbine. The amount of energy used by the sludge pump is almost negligible.

The average share of SBR4 in TEC was around15%, which may seem low, but there were also 2 more active reactors during the studied period. That means the SBR section of Wołowice WWTP is responsible of about 50% of the plant's TEC. SBR4 share in each month and as a 3-month average was shown in Fig. 1. The share varies in time, but only data collected across a few months can show how big this variation can get.

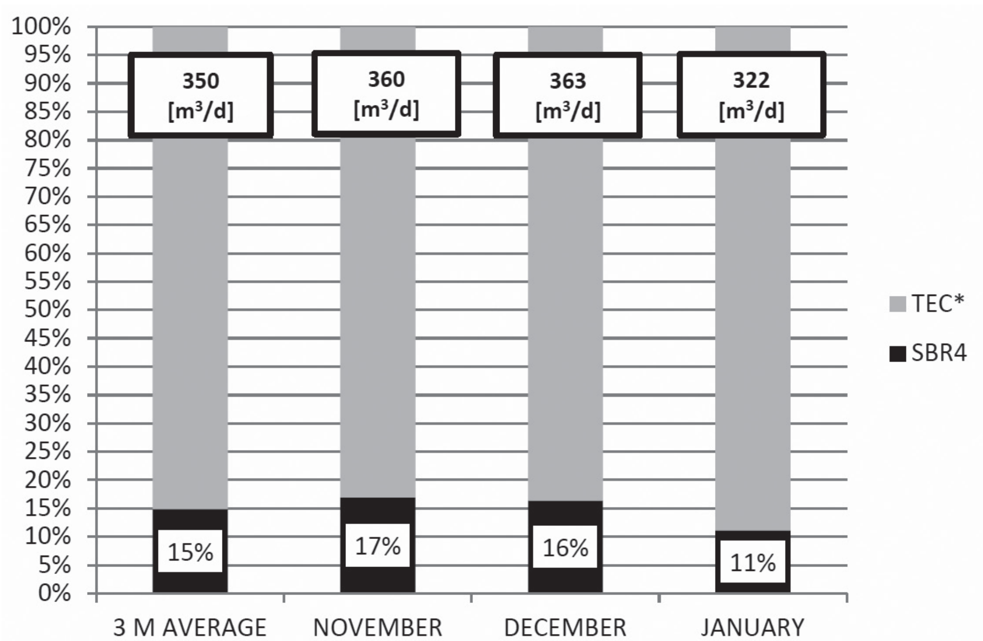

Fig. 1. SBR4 share in the Total Energy Consumption during the studied period

For example, there is a significant difference between May of 2015 (~30% of TEC) [9, 10] and any of the 3 discussed months ~15% of TEC). This difference may be caused by several factors. It could be caused by overall seasonal changes in WWTP performance or due to more sewage being directed to the rest of the reactors; also, the composition of wastewater affects the energy consumption. The factors that have the biggest influence on the variation of the SBR4 share in the plant's energy consumption are a subject of further research.

The collected data indicates weaker than expected correlation between DF and EC, especially in the case of individual reactors. This is a result of stronger than expected impact of varying Hydraulic Retention Times. The HRTs usually range from 0 to 30 hours in the case of the Wołowice plant. The exact influence of HRT on the correlation between DF and EC is hard to determine due to dynamic changes of HRT values; however, the mathematical description of it is under development.

4. Analysis

4.1. Correlation between the Total Energy Consumption and the daily flow

The best way to determine the influence of the Daily Flow (DF) on the energy consumption of the plant is calculating the correlation coefficient. In theory, the relation between DF and the energy usage seems to be directly proportional. A higher daily flow causes more wastewater to be treated, which leads to a longer work-time of the plant devices and therefore higher energy consumption.

The previous statement is definitely true for pumps and other devices involved in transporting and mixing of the wastewater. The situation is more complex for the blowers – higher flow may carry lower concentration of pollutants; therefore, the demand for oxygen can be lower during higher flow, which leads to a lower energy consumption by the blowers. Since the blowers are the main contributor to the TEC [14, 15], a higher flow with lower pollutant concentration may result in the same or even lower TEC than for smaller flows, but with higher concentration of BOD, N and P.

WWTPs, similar to the Wołowice plant, with retention tanks and based on the SBR technology, have one more significant factor influencing the relationship between the daily flow and the energy consumption – the retention time and/or the sewage distribution between reactors. It may take anywhere from a few hours to over a day for the portion of wastewater to reach the reactor(s). This means that the registered energy consumption for a given day never fully corresponds with the measured inflow from that day. It affects the TEC-DF correlation, but it affects the correlation between single SBR EC and the daily flow even more. The Wołowice plant does not have flow meters installed on each individual reactor. With 3–4 active reactors, it is hard to determine how much wastewater and from which days it is being processed on a given day by a given reactor. A method to determine the exact amount of sewage distributed between SBRs is currently being developed. Due to the presence of the retention tank, which normalizes the composition of wastewater, the developed method will not have to take into account the differences between the pollutant concentrations in different reactors. It can be safely assumed that differences in the sewage composition within a few-day period in different SBRs are minimal.

In Table 5, the calculations of the correlation coefficient between the energy consumption and the daily flow on a given day are shown. The results in Table 5 illustrate that the relationship between energy use and the daily flow in WWTP with retention tank and SBR is not straightforward.

Table 5

Correlation between the daily flow (DF) and SBR4 or WWTP-TEC energy consumption

	NOV 2015		DEC 2015		JAN 2016	
	SBR4-DF	TEC-DF	SBR4-DF	TEC-DF	SBR4-DF	TEC-DF
Correlation Coefficient	–0.04	0.29	–0.01	0.19	0.42	0.34

In November and December of 2015, there was no correlation between SBR4 energy usage and the daily flow. Some correlation can be observed globally, which indicates that, in fact, there is a relationship between the plant's total energy usage and the daily flow, but the influence of the daily flow variation seems to be insignificant. In January, however, the influence of daily flow is quite significant from the global point of view, but the most drastic change occurred for SBR4-DF. CC jumped from 0 to 0.42. The preliminary analyses of the sewage distribution between SBRs indicate that the causes of such a drastic change are retention times. In November and December, wastewater was kept longer in the retention tank before being transported to the reactors. In January, the retention times were lower than for the two previous months and this is reflected by the higher correlation between the energy consumption and the daily flow for both SBR4 and the entire plant. These results will be verified after the method for calculating sewage distribution between reactors will reach desired accuracy.

The relationship between the energy consumption and the flow can be observed in Fig. 2–7. It is rather consistent with the results of correlation coefficient calculations. Although, from Figures 2–7, it seems that the relationship is stronger than that expected from the values of correlation coefficient. The line for the TEC follows pattern of the daily flow, sometimes at once, sometimes with visible delay. Of course, there are periods when TEC seems to be completely unaffected by the DF. This supports the statement that the relationship between the energy consumption and the daily flow may be heavily influenced by the operating mode of the WWTP, with a significant role of the sewage retention time. The exact nature of this relationship will be closely investigated after more data is obtained.

4.2. Relationship between SBR4, or the Plant energy consumption, and the daily flow

Based on the obtained data, 2 diagrams for each month were created – one for changes in the Total Energy Consumption and the Daily Flow during the studied month; the second very similar, but with SBR4 energy consumption instead of the plant's total energy usage.

In both November and December of 2015, TEC and DF drew similar lines. Changes in TEC generally corresponded with changes in DF, at the same time or with some delay. Fig. 2 and 4 are consistent with CC values; however, a similarity between both lines indicates

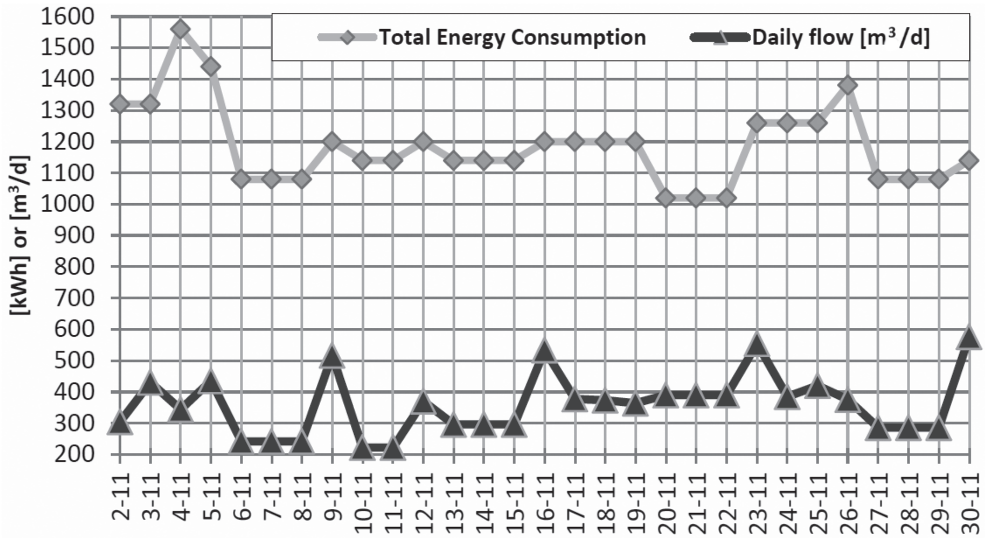

Fig. 2. Dependency between the Total Energy Consumption and the daily flow in November of 2015

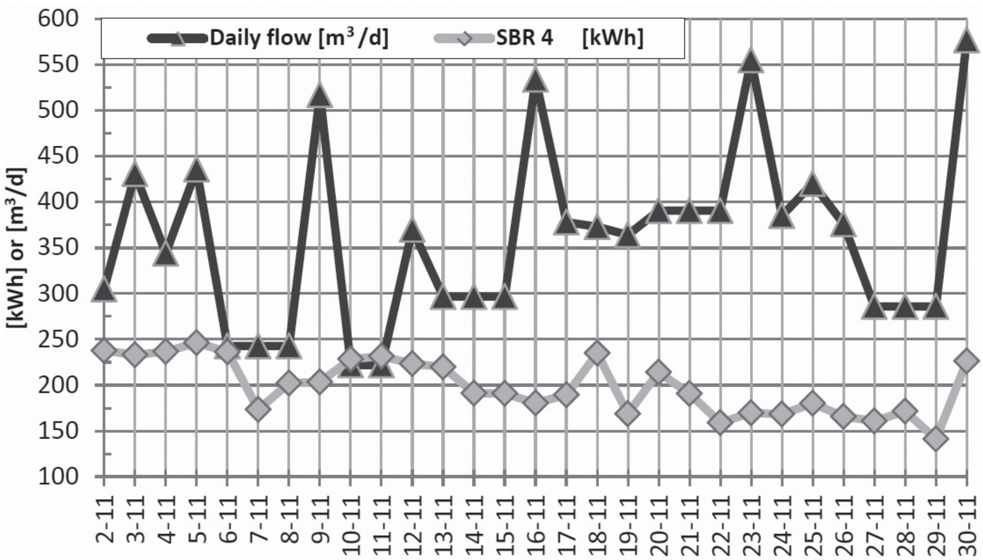

Fig. 3. Dependency between SBR4 Energy Consumption and the daily flow in November of 2015

a higher correlation between TEC and DF than the one presented in Table 5. Verification of the influence of the retention time on CC will be the next step in this area of research.

Ideally, a method of including dynamic retention times into calculations of TEC-DF correlation will be developed and will improve the accuracy of results.

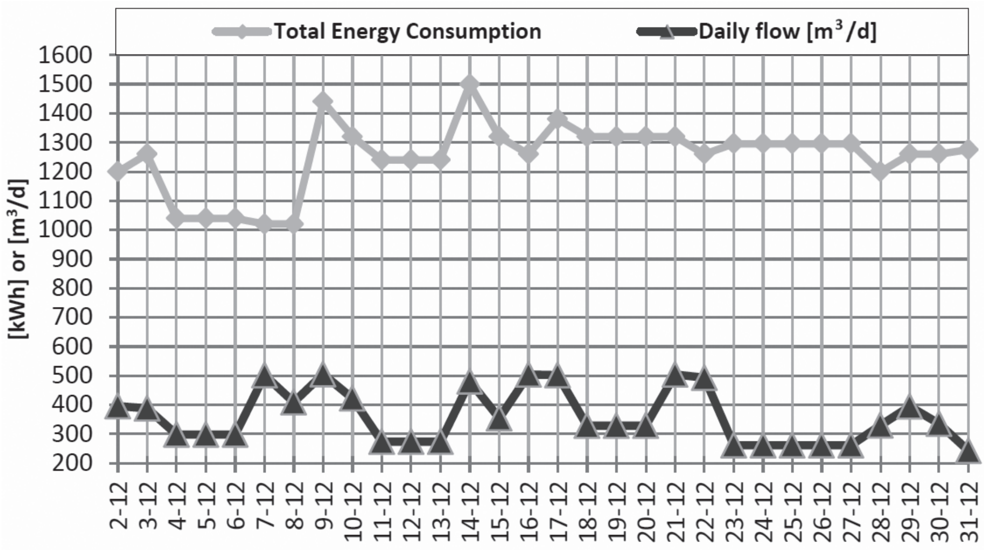

Fig. 4. Dependency between the Total Energy Consumption and the daily flow in December of 2015

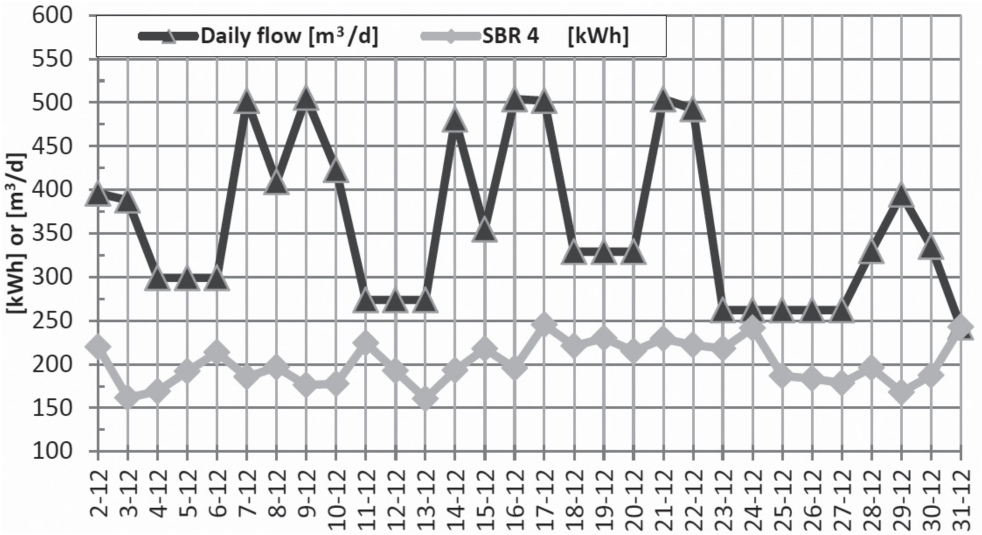

Fig. 5. Dependency between SBR4energy consumption and the daily flow in December of 2015

The diagrams for SBR4 energy usage in November and December of 2015 are consistent with the calculated correlations. This confirms that the retention times and sewage distribution between reactors had a significantly larger impact on the single reactor energy usage than the WWTP's daily flow.

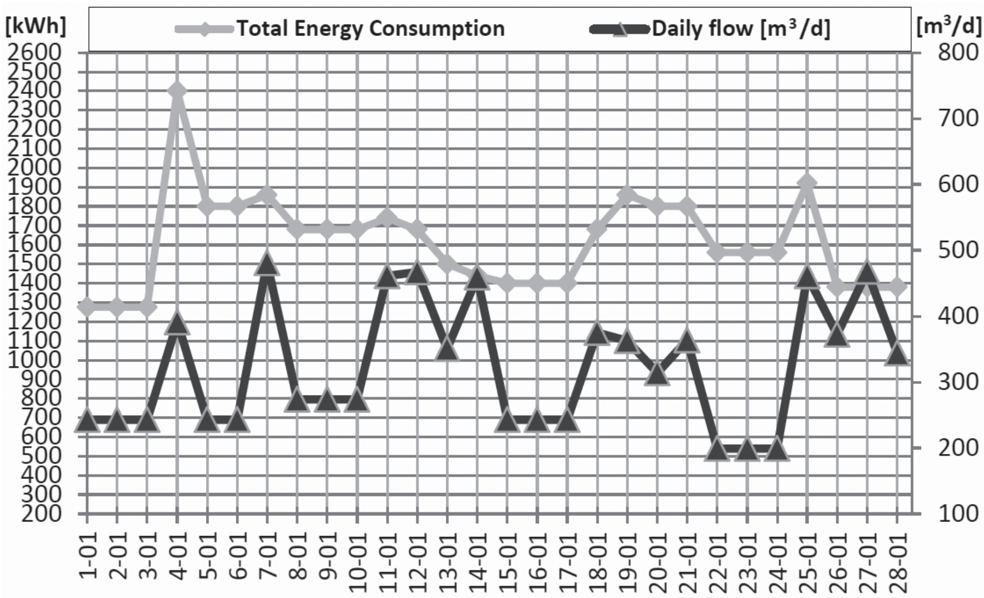

Fig. 6. Dependency between the Total Energy Consumption and the daily flow in January of 2016

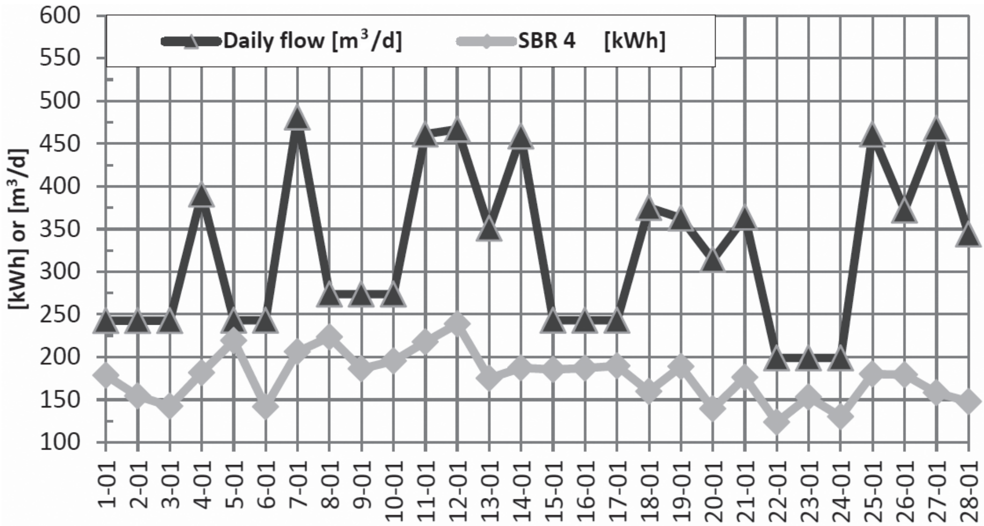

Fig. 7. Dependency between SBR4 Energy Consumption and the daily flow in January of 2016

The situation in January was different compared to the two previous months. The retention times of raw sewage were smaller. This is reflected by a higher correlation coefficient for the WWTP, but also for the SBR4, even despite the unequal distribution of the inflow between reactors.

All of the gathered data and observations that were made will be used in subsequent studies and will help in the determination of the exact nature of the relationship between the daily flow and the energy consumption at the Wołowice plant.

5. Conclusions

The impact of daily flows on WWTP's total energy consumptions had been observed and was consistent with previous measurements.

The impact of daily flows on single SBR energy consumptions had been observed during one of the three months of observation. This dependency will be monitored in future to determine the exact nature of this relationship.

Initial observations showed that a HRT impacts a plant's daily TEC. It is difficult to find a mathematical relationship between a HRT and a daily TEC, especially at longer HRTs. In such a case (e.g. when a HRT is longer than 15 hours), a wastewater flow value is 'counted' on the day of its discharge to the WWTP, while higher TEC is 'counted' on the next day. The relation is even harder to describe mathematically in the case of a single reactor due to the unequal sewage distribution between SBRs. This problem will be investigated more comprehensively in further steps of investigations.

The collected data had a reasonable quality, but there is still room for improvement. A tighter cooperation with plant's crew and plant cooperators (f. e. electricity supplier) in collecting data should result in even further improvement of the quality of gathered data.

The 5-minute interval for on-line energy consumption measurements is barely enough for more detailed analyses, thus it will be lowered to 1 minute.

The SBR4 average share in the total energy consumption stayed almost the same during the studied period. It is consistent with previous measurements. However, seasonal change (between May of 2015 and Nov'15-Jan'16) had been observed.

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