CIVIL AND ENVIRONMENTAL ENGINEERING REPORTS

No. 10 2013

DETERMINATION OF RELIABLE CONCENTRATIONS OF POLLUTANTS IN RAW WASTEWATER BASED ON DIFFERENT SAMPLING METHODS

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The aim of this study was to check the extent to which the sampling method and the volume of sewage (size of the wastewater treatment plant) influence the determined daily average concentrations of pollution components. Within three days of dry weather, the composition of two raw sewage wastewater treatment plants was continuously monitored. The WWTPs were designed for the flow of 820 m^3/d and 51000 m^3/d, respectively. The concentrations of pollutants were measured in samples taken both in time-proportional and flow-proportional ways. The obtained values show the possibility of taking the samples mixed at equal time intervals and in proportion to the flow as reliable sources for design values of concentrations. The size of WWTP, i.e. the amount of investigated raw sewage, was of no significant importance to the obtained results regarding concentrations of pollutants.

Keywords: sampling, raw sewage, pollution loads, desing of wastewater treatment plant

1. INTRODUCTION

Amendments and adaptation of legal regulations to the EU requirements forces operators of sewage treatment plants to carry out precise measurements of quantity and analysis of physical-chemical composition of sewage. Technical progress and abundant offer of devices allows to meet these requirements. Yet, usefulness of measurement results for further processing is determined by accuracy of measuring devices and skills of the analyst who performs the test, but also but whether the sample can be considered a representative sample. Lack

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of „good measuring material" is the reason why, despite state-of-the-art devices and qualified staff, test results frequently can not be considered reliable. Devices which help meeting of the reliability criterion, and furthermore, significantly facilitate the laboratory technicians' work, are samplers.

In accordance with the Polish Norm PN – ISO 5667 – 10, 1997 „Water quality, Sampling, Guidelines for sewage sampling", there are:

– Random samples - indicating physical-chemical parameters of the sewage at the moment of sampling.

– Qualified random samples – consisting of at least 5 samples. Interval between individual sampling must be at least 2 minutes long, whereas the duration of such sampling cannot exceed 2 hours. A qualified random sample, taken and analysed regularly, provides somewhat more complete quality image of the measured utility. A definite drawback of this sort of sampling are its time and labour requirements.

– Time-proportional samples – are characterized by taking of a small sample volume, performed at specified and permanent intervals. Such form of sampling does not take into account changes in the flow rate. Yet for an accepted, possibly short, interval, the taken sample is relatively representative. This method is characterised by the following features: regular sampling, permanent volume of single samples and permanent frequency of sampling.

– Quantitative-proportional samples – are characterized by combination of sampler with a flow meter. The are characterized by permanent size of the taken sample, perfumed at intervals which result from flow of specified volume of sewage. In order to control the sampler operation, a quantitative measurement signal is required. This type of sampling provides good and representative results, because it considers the actual flow.

  A drawback of this solution is the fact that there is no correlation between the taken sample and the contamination load (especially with high flow fluctuation). This problem occurs often in small sewage treatment plants, where at nigh-time, the flow drops almost to zero. In such situation, the sampling is performed at relatively long intervals, which can prevent disturbances in the plat operation from being recorded. Quantitative-proportional sampling is currently becoming increasingly popular. This method is characterised by the following features: sampling after a specified quantity has flown, constant volume of single samples and changeable frequency of sampling.

– Flow-proportional samples – are taken by combining sampler with a flowmeter. Such mode of sampling is characterized by collection of variable volume of a single sample, depending on the current flow.

Moreover, the sample – as in the time-proportional mode – is taken at constant intervals.

This method of sampling provides very good, representative results, and the results are the best with fluctuating flow and variable contamination load. Unlike the quantitative-proportional sampling, here the sample is taken even if the flow is very low. In practice, this means a possibility of detecting all disturbances in the treatment plant operation. This method is characterised by the following features: changeable volume of single samples and permanent frequency of sampling.

– Event-proportional samples – make use of samplers cooperating with appropriate meter, e.g. pH. In this mode, the sampler waits for an „event" Only when this event occurs, the sampling is initiated. An impulse which triggers the sampling can be exceeding of a boundary value (e.g. liquid level, pH, conductivity, etc.) As long as the "event" lasts, the sampling is performed at specified intervals.

  This sort of sampling is particularly recommended for sewage quality control, as long as we are not interested in the very fact of exceeding some boundary values, but rather in the reason of such state of affairs. With the previously described modes of sampling, seizing a sample taken during the "event" is difficult. This method is characterised by the following features: sampling depending on the event, permanent volume of single samples and permanent frequency of sampling.

– Combined sampling programs, i.e. event-proportional sampling can be made parallel to other modes (e.g. with the quantitative-proportional method). Advances of the combined mode are the resultant of the employed, single modes of the sampler operation. This method is characterized by the following trait: combination of time-related, quantitative and event-based criteria of sampling.

Modernization works and optimization of sewage treatment technologies as well as treatment plant classification expressed with PE (equivalent of population) require determining of equivalent contamination loads, which shall be the basis for further calculations and studies. An optimal solution for measurement for quantity of sewage and determination of physical-chemical composition of the sewage, and, as a result, of contamination loads, is a permanent measurement (on-line) of flow and concentration of factors significant for operation of the treatment plant. As long as the flow measurement is not difficult, systems which measure concentrations are still rather unpopular, due to technical capabilities and costs.

In the case of an existing system of sewerage – treatment plant – receiver, an archival database, containing information about volume and composition of sewage which comes into the treatment plant, is used.

An order of the Minister of environment regarding requirements for introducing sewage into waters or ground, and regarding substances particularly harmful for water environment (Journal of Laws 2006, no. 137, item 984), as well as Directive 91/271/EEC regarding treatment of municipal sewage state that representative values of concentration are those indicated in medium samples resulting from mixed samples, taken manually or automatically within 24 hours, at intervals not longer than 2 hours, proportional to the sewage flow. Yet, automatic samplers in treatment plants usually take time-proportional samples, at regular intervals (as a rule every 2h), a constant volume of single raw sewage samples is taken, which are then merged.

The aim of this study was to check the extent to which the sampling method and the volume of sewage (size of the wastewater treatment plant) influence the determined daily average concentrations of pollution components.

2. MATERIAL AND METHODS

Monitoring of the quality and quantity of raw sewage carried out in two wastewater treatment plants: designed for flow of 820 m^3/d (WWTP1) and 51 000 m^3/d (WWTP2). Sampling and measurement was performed within three days (Monday, Tuesday, Wednesday) of dry weather.

Every two hours, starting from 7^{00} on the first day of research, a raw sewage sample was taken before the drum sieve, manually at WWTP1 and using automatic sampler at WWTP2. Physical-chemical parameters within the range of: total suspension, BOD_5, COD, TKN, $N\text{-}NH_4^+$, total phosphorus (P_{tot}) were marked in each of the 12 samples during subsequent days of monitoring.

3. RESULTS

3.1. Quantity of sewage

The volume of sewage influent into the WWTP1 within three days of permanent monitoring varied between 347 and 424 m^3/d, whereas the volume of sewage delivered via vacuum trucks within 24 hours was 10 to 28 m^3/d. The share of the delivered sewage in the general volume of sewage influent into the wastewater treatment plant within two hours did not exceed 12%.

Whereas WWTP2 received from 14287 m^3/d to 14720 m^3/d, and the share of the delivered sewage was 2,9 to 3,7%. Oscillations of raw sewage inflow to WWTP1 and WWTP2 within 24 hours are presented in Fig. 1.

Within three days of testing, the amount of sewage flowing into a WWTP1 varied from 3 m^3/h to 33 m^3/h, and for WWTP2 from 338 m^3/h to 784 m^3/h. In both wastewater treatment plant after 11PM the quantity of sewage decreased to about 25% of maximum flow. Hourly average of quantity of sewage was 16 m^3/h and 607 m^3/h, for WWTP1 and WWTP2 respectively.

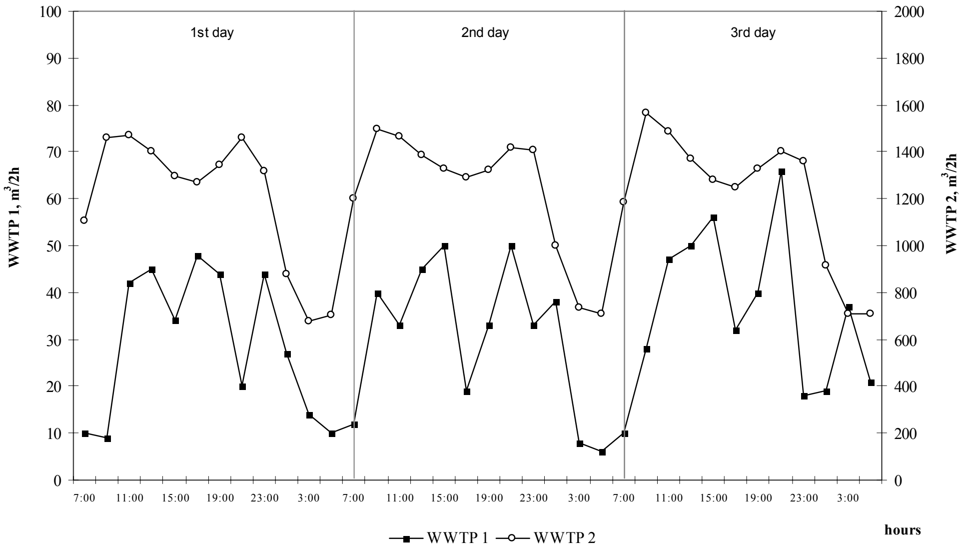

Fig. 1. Changes in raw sewage inflow to WWTP 1 and WWTP 2

3.2. Characteristic of raw sewage

Pollution concentration values, marked in raw sewage sampled in WWTP1 and WWTP2 are presented in Table 1.

Data analysis explicitly indicates high unevenness of volume and concentration of raw sewage for WWTP1, as well as values of pollution index concentration higher, than for WWTP2, which could be caused by significant share of delivered sewage. In particular, these differences were observed for concentration of TKN, ammonia nitrogen, and total phosphorus.

Were also found large changes in concentrations of pollutants in raw wastewater. For example, COD determined in instantaneous samples collected every 2 hours changed in the range from 640 mg/dm^3 to 1840 mg/dm^3 and from 240 mg/dm^3 to 1040 mg/dm^3, for WWTP1 and WWTP2 respectively.

On the basis of the obtained pollution concentrations in 12 samples for each day, average daily concentrations were calculated, which, in accordance with the Polish Norm PN-ISO 5667-10, reflect values marked in time-proportional and flow-proportional samples (table 2).

Table 1. Characteristic of raw sewage influent to WWTP 1 and WWTP 2

Time of sampling		WWTP1						WWTP2						
		Flow $m^3/2h$	COD	TKN	N-NH_4	P_{tot}	Total suspens.	Flow $m^3/2h$	COD	BOD_5	TKN	N-NH_4	P_{tot}	Total suspens.
			mg/dm^3						mg/dm^3					
1st day	7^{00}	10	960	175	90	45	630	1108	440	189	98	54	11	720
	9^{00}	9	640	140	78	44	822	1461	480	226	70	41	11	890
	11^{00}	42	1560	196	176	68	646	1470	520	152	70	42	9	360
	13^{00}	45	1560	154	123	42	730	1401	640	263	70	58	7	480
	15^{00}	34	1200	182	106	42	492	1298	520	226	70	46	7	160
	17^{00}	48	1560	280	238	41	588	1270	480	152	56	54	6	400
	19^{00}	44	1680	140	91	35	522	1346	840	374	70	56	21	680
	21^{00}	20	1840	126	86	41	992	1462	600	263	56	50	8	500
	23^{00}	44	1840	126	94	39	516	1317	440	189	56	51	6	800
	1^{00}	27	1440	126	89	49	894	878	400	115	56	53	3	920
	3^{00}	14	1480	112	97	35	1360	676	440	189	56	47	2	380
	5^{00}	10	1760	154	93	38	754	704	400	189	56	44	4	860
2nd day	7^{00}	12	1120	119	93	34	378	1201	560	115	112	63	7	780
	9^{00}	40	820	112	92	31	728	1496	680	152	70	52	7	240
	11^{00}	33	1080	147	144	51	976	1464	1040	152	56	51	8	1040
	13^{00}	45	1380	112	112	44	778	1385	320	189	98	54	5	1080
	15^{00}	50	1120	147	113	32	236	1328	680	152	70	57	5	580
	17^{00}	19	1260	105	88	27	324	1293	600	189	56	49	6	300
	19^{00}	33	1320	105	92	38	516	1323	800	263	56	53	6	300
	21^{00}	50	1340	105	82	42	520	1417	320	226	70	58	4	220
	23^{00}	33	1120	105	85	39	564	1408	800	78	56	45	3	600
	1^{00}	38	1320	105	95	36	356	999	320	26	70	48	3	400
	3^{00}	8	1120	112	84	43	448	733	240	152	56	48	2	880

	5^{00}	6	1040	105	85	44	214	707	240	189	70	54	3	200
3rd day	7^{00}	10	736	105	78	27	338	1185	880	203	84	42	16	860
	9^{00}	28	848	112	83	24	154	1568	840	203	98	44	5	880
	11^{00}	47	1088	140	132	33	618	1489	560	175	84	38	3	940
	13^{00}	50	688	119	97	28	298	1371	480	148	56	41	3	460
	15^{00}	56	896	140	103	22	300	1282	560	175	84	42	3	160
	17^{00}	32	928	119	94	35	622	1247	720	312	56	45	2	360
	19^{00}	40	880	112	78	19	444	1330	680	230	70	43	5	840
	21^{00}	66	928	105	77	26	414	1401	320	148	56	44	3	100
	23^{00}	18	1136	112	74	29	728	1359	240	203	56	43	4	400
	1^{00}	19	896	105	71	29	202	914	560	175	56	42	2	600
	3^{00}	37	864	140	80	37	220	710	560	120	42	36	2	600
	5^{00}	21	896	123	78	29	224	709	560	94	56	40	10	900

Table 2. Average daily values of pollution concentrations determined for flow-proportional samples and time-proportional samples

Parameter/test type		WWTP1			WWTP2		
		1st day	2nd day	3rd day	1st day	2nd day	3rd day
COD mg/dm^3	flow-proportional sample	1536	1189	899	532	585	580
	time-proportional sample	1460	1170	899	516	550	580
	difference between methods of sampling	4,9%	1,6%	0,0%	3,0%	6,0%	0,0%
BOD_5 mg/dm^3	flow-proportional sample	-	-	-	217	159	188
	time-proportional sample	-	-	-	210	157	182
	difference between methods of sampling	-	-	-	3,2%	1,3%	3,2%
TKN mg/dm^3	flow-proportional sample	169	117	122	66	70	69
	time-proportional sample	159	115	119	65	70	67
	difference between methods of sampling	5,9%	1,7%	2,5%	1,1%	0,0%	3,2%
$N\text{-}NH_4$ mg/dm^3	flow-proportional sample	127,0	100,0	91,0	49,8	52,9	41,9
	time-proportional sample	113,0	97,0	87,0	49,8	52,7	41,6
	difference between methods of sampling	11,0%	3,0%	4,4%	0,0%	0,4%	0,7%
P_{tot}	flow-proportional sample	43,9	38,4	28,1	8,3	5,2	4,7

mg/dm^3	time-proportional sample	43,1	38,4	27,8	7,7	5,0	4,7
	difference between methods of sampling	1,8%	0,0%	1,1%	7,2%	3,8%	0,0%
Total suspension mg/dm^3	flow-proportional sample	680	540	382	583	557	583
	time-proportional sample	745	503	380	596	552	592
	difference between methods of sampling	-9,6%	6,9%	0,5%	-2,2%	0,9%	-1,5%

Determined authoritative concentrations of pollutants in the wastewater influent to analyzed wastewater treatment plant were different in the subsequent days of measurement for both: time-proportional and flow-proportional samples.

For both WWTP the highest values concentration of pollutions were obtained in the first day of testing (on Monday), irrespective of the method of sampling.

4. CONCLUSIONS

The calculated differences between values calculated for flow-proportional and time-proportional samples are 0 to 11%, but for most samples they come to about 4%. This indicates good assessment of the reliable concentration values, both for sampling of permanent sewage volumes at regular intervals, and for volumes proportional to the flow.

There was also no evidence of any significant influence of the size of the treatment plant, and thus unevenness of raw sewage inflow, on the calculated pollution concentration values.

It is also obvious that pollution concentrations specified in random samples reflect the physical-chemical parameters of the sewage at the moment of sampling, and in no circumstances can they be a foundation for calculations which require reliable concentrations. For example, concentration of TKN marked within the first 24 hours of the monitoring for WWTP1 changed from 112 to 280 mg/dm^3. Such a large range of values indicates the possibility of making significant errors in the design, if you will be taken into account the instantaneous values. On the other hand, it is important to provide buffering capacity of the inequality of pollutants influent into wastewater treatment plant.

REFERENCES

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2. PN-ISO5667-10,1997 *Jakość wody. Pobieranie próbek. Wytyczne pobierania próbek ścieków.*

WYZNACZANIE MIARODAJNYCH STĘŻEŃ ZANIECZYSZCZEŃ W ŚCIEKACH SUROWYCH W OPARCIU O RÓŻNE METODY POBORU PRÓBEK

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

Nowelizacja i dostosowywanie przepisów prawnych do wymagań UE wymusza na eksploatatorach oczyszczalni ścieków wykonywanie precyzyjnych pomiarów ilości i analiz składu fizyko-chemicznego ścieków. Postęp techniczny oraz bogata oferta producentów urządzeń umożliwia sprostanie tym wymaganiom. Jednak o przydatności wyników pomiarowych do projektowania oczyszczalni ścieków obok dokładności urządzeń pomiarowych decyduje fakt, czy próbkę ścieków można uznać za próbkę reprezentatywną. Często pomimo najnowocześniejszych urządzeń i wykwalifikowanego personelu wyniki badań nie mogą być traktowane wiarygodnie.

W artykule na podstawie pomiarów ilości i analiz składu ścieków surowych zweryfikowano w jakim stopniu metoda poboru próbek oraz ilość dopływających ścieków (wielkość oczyszczalni ścieków) wpływa na wartość wyznaczonych średniodobowych stężeń wskaźników zanieczyszczeń. W ciągu trzech dób w pogodzie suchej przeprowadzono ciągły monitoring składu ścieków surowych w oczyszczalniach zaprojektowanych na przepływ 820 m^3/d (OŚ1) i 51000 m^3/d (OŚ2). W próbkach zbieranych czasowo-proporcjonalnie i przepływowo-proporcjonalnie wyznaczono stężenia miarodajne wskaźników zanieczyszczeń. Uzyskane wartości wskazują na możliwości przyjmowania do projektowania stężeń miarodajnych wyznaczonych w próbkach zlewanych w jednakowych interwałach czasowych, jak i proporcjonalnie do przepływu. Nie stwierdzono również istotnego wpływu wielkości oczyszczalni, a tym samym nierównomierności dopływu ścieków surowych na obliczone wartości stężeń wskaźników zanieczyszczeń.