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THE QUANTITY AND QUALITY OF INDUSTRIAL WASTEWATER FROM LAUNDRY ON EXAMPLE OF "FLIEGEL TEXTILSERVICE" COMPANY IN NOWE CZARNOWO

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The quality and quantity data of industrial laundry wastewater from the Fliegel Textilservice laundry in Nowe Czarnowo in West Pomeranian Voivodship are presented. The output data for analysis were measurements of pollution indicators' concentrations made for mechanically pre-treated raw wastewater in the period from 12.2009. to 07.2010. The paper describes the conditions of laundry wastewater preparation for biological wastewater treatment, inter alia, by pH correction, lowering the temperature of wastewater, removal of foam. The factors associated with susceptibility to biological removal of carbon and biogenic compounds from the subject laundry wastewater were taken into account.

Keywords: quantity and quality of sewage, industrial-laundry sewage

1. INTRODUCTION

Fliegel Textilservice laundry is located in Nowe Czarnowo near Gryfino in West Pomeranian Voivodship. The plant runs a service activity in the range of classical – wet washing. The service of washing is provided in objects, where modern, high - duty sequences of laundry and auxiliary equipment are installed. The laundry's main customers are hotels. In tourist season, a quantity of washed textiles per day can achieve an average value 65 t/d. Work in the laundry runs in three shifts.

The service of washing is provided in following stages:

- preparatory work - sort of textilies to wet washing;
- pre-removal of stain;

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- wet washing - realized in water washing machines;
- finishing - drying and ironing products, packaging for shipment;
- expedition of textiles.

Nowadays wastewaters, generated during washing, are transported to communal sewage system and then to wastewater treatment plant in Gryfino. In 2009 year Fliegel Textilservice laundry acceded to the task of realisation of building their own laundry wastewater treatment plant. In order to find the most optimal technology of laundry wastewater treatment, pilot surveys were carried out in the period 12.2009 – 07.2010.

2. LITERATURE REVIEW

The wastewater management in each laundry is characterized by instantaneous wastewater flow from washing machines and other devices. This causes that the wastewater outflow into the sewer and pollutants outflow are irregular [3,4]. The water consumption at the laundry depends on the amount of washed fabrics and it is in the range from 4 to 30 m^3/ton of washed textiles [2, 4].

Table 1. Quality of raw laundry wastewater [1, 4]

No	Parameter	Unit	Range by [4]	Range by [1]
1	pH	pH	6.5 ÷ 10	8.33 ÷ 9.21
2	temperature	°C	20 ÷ 90	
3	surfactans	mg/dm^3	20 ÷ 50	15 ÷28 *
4	Total suspension solid	mg/dm^3	150 ÷ 400	
5	BOD_5	mgO_2/dm^3	300 ÷ 600	165 ÷ 205
6	COD	$mg\ O_2/dm^3$	500 ÷ 800	730 ÷1030
7	sulfates	$mg\ SO_4/dm^3$	50 ÷ 150	
8	chlorides	$mg\ Cl/dm^3$	50 ÷ 200	265 ÷930
9	dissolved substances	$mg\ /dm^3$	50 ÷ 300	
10	dry residue residue	mg/dm^3		2138 ÷ 3262
11	calcination losses	mg/dm^3		388 ÷ 750
12	residue on ignition	mg/dm^3		1554 ÷ 2512
13	ammonia nitrogen	mg/dm^3	6 ÷ 7	5.25 ÷ 7.5
14	organic nitrogen	mgN/dm^3		4.1 ÷ 8.5
15	total nitrogen	mgN/dm^3		9.25 ÷ 14.5
16	total phosphorus	mgP/dm^3		11.7 ÷ 28.1

* value applies anion surfactans

The quality of raw wastewater results directly from quantity of pollutants removed in the washing process, and the quantity and quality of used detergent. The types and quantities of pollutants removed in the washing process depends on the type of services provided by the laundry and the type of customers, such as the type and degree of soiling on textiles admitted to washing. Table 1 lists

the literature data on the quality of laundry wastewater. The concentrations of pollutants given by [1] (R Podedworna and Żubrowiska - Sudoł) were made for wastewater pre-treated mechanically (as in the subject laundry).

In the above summary, the divergence given values in the range of basic indicators such as BOD5 and COD was surprising. However, a much higher concentration of chloride according to [1] followed from the fact that mixing laundry sewage with wastewater coming from regenerating ion exchange resins. There was a similar conditioning of high chloride concentration in laundry wastewater in Nowe Czarnowo.

3. THE QUANTITY OF SEWAGE FROM LAUNDRY

In the subject laundry, which has been working for almost 20 years, a retention tank allows the averaging of the wastewater outflow. It allows to hold out almost 70% of average daily flow. After realizing the draft wastewater treatment plant the retention tank will retain its function.

The planned laundry wastewater treatment plant will treat the following types of wastewater:

- wastewater stemming from washing processes (industrial – laundry wastewater);
- wastewater from regeneration of ion exchangers that are used for softening of technological water (polluted mainly by chlorides).

The quantity of industry wastewater from the washing process follows directly from the amount of washed textiles in the laundry Fliegel Textilservice. As a result of processes, which are subject to fabric in laundry (washing, drying and ironing), part of the water used for washing is evaporated. The difference between the inflow of water and outflow of wastewater is about 10 - 17% (from 10% in winter to 17% in summer) in subject laundry. The water consumption for process purposes – to run the washing process - is carried out with own ground water intake. Water is treated in the company water treatment plant.

A modern automated technological line is used in this laundry. The production line can operate with a capacity of more than 70 tons per day. However, water consumption at the plant is about 8 m^3/ton of washed textiles, which is similar to the literature data (4-30 m^3/ton of washed textiles) [2, 4].

The planned wastewater treatment plant will purify wastewater discharged currently to the municipal sewage treatment plant in Gryfino. It was assumed, that the quantity of wastewater currently discharged to municipal wastewater treatment plant is reliable capacity to be established for the draft plant.

As an integral part of the current wastewater management in this laundry is the retention tank, so instantaneous flow from washers wasn't analyzed. Only

the daily flow was analyzed. Table 2 shows the amount of wastewater discharged by the laundry to municipal wastewater treatment plant in Gryfino in the last three years 2008-2010. These data were extracted from the laundry daily records of the quantities of discharged wastewater.

Table 2. The annual and daily flow of industrial wastewater discharged from laundry Fliegel Textilservice in 2008-2010

Period	Qyear [m^3/year]	Qd average [m^3/d]	Qd max [m^3/d]
I – XII 2008	174 568	478	600
I – XII 2009	160 277	439	535
I – XII 2010	184 648	506	649

In 2010 year, the productivity of the Fliegel Textilservice laundry increased from 65 ton/d to more than 70 ton/d, because the automatic loading washers line was installed. The loading belt was changed for a more efficient, automated bag's system. Therefore, values of wastewater flows generated in 2010 were assumed as a reliable. It was assumed that the installation of more automated systems in the laundry will increase the quantity of discharged wastewater by about 5% in the future. On the basis of above data, the characteristic wastewater flows for plant under research were determined and shown in Table 3:

Table 3. The characteristic wastewater flows for plant

Wastewater flow	current	in future
the average daily flow $Q_{d\text{-}average}$ [m^3/d]	510	540
the maximum daily flow Q_{dmax} [m^3/d]	650	690
the hour average flow $Q_{h\text{-}average}$ [m^3/h]	27.1	29.0
the hour maximum flow Q_{hmax} [m^3/h]	29.0	31.0

4. THE QUALITY OF WASTEWATER FROM LAUNDRY

Laundry wastewater taken from the retention tank and mechanically pre - treated was analyzed. The tank volume was 350 m^3, which represents approximately 70% of current average daily flow of wastewater.

4.1. Detergents used in the laundry Fliegel Textilservice in Nowe Czarnowo

The analyse of the detergents composition showed. that they were biodegradable materials, mostly organic. All surfactants used in the laundry met the

biodegradability criteria laid down in Regulation (EC) No. 648/2004 on detergents. Agents used in the laundry were approved for use in the washing process. Dosage of detergent is fully automated. Besides detergents, removers of stains, bleaches and softeners were added to the washing.

The analysis of the detergents and support agents composition allowed to determine the pollutants, whose concentrations could be important from the viewpoint of the laundry wastewaser treatment. Those pollution were: total petroleum hydrocarbons and boron compounds. Boron compounds are used in bleaching chemicals added to the laundering. The total petroleum hydrocarbons are used in removers of stains. However, as indicated in table 4, the contents of both pollutants in laundry wastewater were negligible.

4.2. The quality of raw wastewater – the results obtained

It was taken mechanically pre–treated laundry wastewater for laboratory testing, the composition of wastewater has been aligned in the retention tank.

Currently, all laundry wastewater is discharged to the municipal sewage system in Gryfino. Discharging of wastewater is based on the contract for discharging of wastewater to the sewage system owned by third parties. For the mentioned above wastewater dischargement. the company posseses a valid water permit. Under this valid water permit, raw wastewater is regularly tested by the accredited laboratory. The results of test were presented in the table below.

Table 4. The range of test results required in the water permit

Element	Data				
	09.07	21.10	28.01	08.05	09.02
Total phosphorus [mg/dm^3]	8.4	7.1		8.7	5.6
Ammonia nitrogen [mg/dm^3]	1.24	2.09		36.6	
Cadmium [mg/dm^3]	< 0.001	< 0.001	< 0.001	< 0.001	<0.0005
Antimony [mg/dm^3]	< 0.010	0.148		< 0.000	<0.003
Nickel [mg/dm^3]	0.003	0.006		0.006	0.018
Lead [mg/dm^3]	< 0.001	0.002		0.006	<0.010
Copper [mg/dm^3]	0.012	0.026		0.040	0.110
Zinc [mg/dm^3]	0.053	0.059		0.123	0.130
Boron [mg/dm^3]	0.816	< 0.050		0.0500	0.480
Total petroleum hydrocarbons		< 0.10		19.3	
Aliphatic hydrocarbons					0.38
Aliphatic hydrocarbons					3.40

Analysing the concentration of subsequent heavy metals in discharged wastewater it was be concluded, that these were slight amounts, far below concentrations permited in Regulation [5] and in some cases even below the

detection limit for reference metodologies for samples determination or beyond the range of aplication for the method.

In addition, test of raw wastewater quality was conducted in pilot tests done between 12.2009 and 07.2010. Pilot tests were conducted to match the optimal treatment technology for subject wastewater. Under these tests, two times a week, basic raw wastewater tests mechnicaly treated were conducted in the company's laboratory. Only the total suspension solid tests were conducted in an acredited outside laboratory, owing to lack of the appropriate equipment. The results of conducted tests are presented in table 5. Laboratory measurements of contamination indicators were made using LANGE Cell tests.

Table 5. Summary of tested indicators' values for mechanicaly tested raw wastewater and permited values in treated wastewater according to regulation [5]

Parameter	Range of indicators' values of the tested wastewater		Permited values in treated wastewater according to [5]
pH	7.4-10	pH	6.5 – 9.0
temperature	24-40	°C	35
BOD_5	122 - 386	g O_2/m^3	25
COD	814 - 1159	g O_2/m^3	125
Total suspension solid	130 - 415	g/m^3	35
total phosphorus	2.69 – 12.7	gP/m^3	3
phosphates	7.92 – 33.8	gPO_4/m^3	
total nitrogen	8.3 – 15.2	gN/m^3	30
ammonia nitrogen	0.29 - 1.63	$gN\text{-}NH_4/m^3$	10
Anion surfactans	13.2 – 32.9	g/m^3	5*
Nonionic surfactans	24.9 – 43.7	g/m^3	10*
chlorides	436 – 787	g/m^3	1000
sulfates	236 - 305	g/m^3	500

* The sum of surfactant anionic and nonionic concentrations cannot excedd 35.

The characteristic of raw wastewater (mechanicaly treated) was nearing to values presented in the literature (particularly [1]). Increased concentration of chlorides can be explained that its source was wastewater from regeneration of ion exchange resins used to technological water softening, where salinity was a major pollution.

4.3. Analysis of data concerned the wastewater quality

Summary of subsequent contaminants' values with legal requirements for the quality of wastewater discharged to waters or to the ground (table 5) allowed to formulate several postulates:

- wastewater treatment will require correction of pH and decrease of wastewater temperature;
- the removal of nitrogen compounds is not necessary;

- it will be necessary to remove phosphorus compound from wastewater;
- selection of compounds added to wastewater (e. g. to decrease pH) must comply with the high level of chlorides and sulfates in raw wastewater;
- significant concentration of sufactants causes foaming of wastewater.

4.3.1. pH and temperature correction

Laboratory measurements of contamination indicators for mechanicaly pre-treated wastewaser let observe pH of laundry wastewater nearing even 10. It meant the necessity to aply the correction of pH at the early stage of treatment by the use of acid (e. g. H_2SO_4 or HCl). This correction was necessary not only to keep the boundary value of pH stated in current Regulation [5]. but also because of the conditions of conducting technological processes during biological treatment.

The temperature measurement also exceeded permited values stated in Regulation [5]. Maximal observed temperature was 40^{o}C so it exceeded the limit value for 5^{o}C. However, it should be noted that tests were conducted for wastewaser downloaded from retention tank, while regulation [5] determines permited values of indicators in the place where wastewater is introduced to the environment. So it can be supposed that wastewater flowing through objects of future industrial wastewater treatment plant and treated wastewater pipe to the outflow will cool itself below the required temerature of 35 ^{o}C. Otherwise, it will be necessary to aply the heat exchanger which will be more efficient than the one functioning currently.

4.3.2. Biological removal of carbon compound

Analysing the laboratory measurements of indicators for mechanicaly pre-treated wastewater, values obtained for analysed wastewater were compared to exploitation indicators adopted for demestic sewage. Possible convergence of characteristic parameters was an argument in favor of susceptibility of subject wastewater for biodegradation. According to [6] the ratio of core indicators BOD_5 i COD in domestic sewage equals:

$$\frac{COD}{BOD_5} = 1 \div 2.22 \tag{4.1}$$

In the tested wastewater, for measurements conducted using cell tests LANGE. the obtained ratio ranged:

$$\frac{COD}{BOD_5} = 3.2 \div 6.5 \tag{4.2}$$

These are values devianting from obtained according to relation (4.1) for domestic sewage. Beacause the susceptibility of wastewater for biodegradation

is an important argument in aplication of biological wastewater treatment technology, measurements of BOD_5 and COD were conducted using methods advised in norms. Additional BOD_5 measurements were done using the manometric method with the addidion of nitrogen source to tested wastewater (in form of urea). The addition of nitrogen resulted from its lack in wastewater (see point 4.3.3). COD measurements were done using titration method. Measurements were done in the laboratory of municipal wastewater treatment plant in Gryfino.

Table 6. The summary of measurement results for BOD_5 i COD using norm methods with addition of nitrogen and cell tests without addition of nitrogen

Date of measurement	Measurement using cell tests		Measurement using norm methods		COD/BOD_5	
	BZT_5	ChZT	BZT_5	ChZT	LANGE	norm
04.03.2010	142	834	330	810	5.87	2.45
11.03.2010	227	889	350	868	3.92	2.48
17.03.2010	306	1120	450	1007	3.66	2.24

Tests using norm methods with addition of nitrogen conducted on a choosen samples showed that determination of BOD_5 done using cell method were most likely lowered. Obtain by that method the ratio COD/ BOD_5 was close to the upper limit for domestic sewage [6], what allowed to assume a hypothesis that organic compounds in subject laundry wastewater could be susceptible to biodegradation. In the period from 12.2009 to 07-2010 a pilot research used moving bed biofilm reactor (MBBR) has been performed on wastewater from Fliegel Textilservice laundry. This research confirmed the assumption about the biodegradability of the laundry wastewater. Pilot results confirmed the reliability of a measurement conducted using norm methods with addition of nitrogen.

It may lead to conclusion that this alternative to standard BOD measurements of laundry wastewater should be carefully investigated. This will be a matter of the future research.

Verification of BOD measurements method was not the aim of this paper.

4.3.3. The removal of nitrogen compounds from wastewater

Nitrogen concentration in raw wastewater mechanicaly pre-treated ranged 8.3 – 15.2 gN/ m^3 (table 5). This was a value significantly lower than maximal allowed in the valid Regulation [5], which equals 30 gN/ m^3. It meant that it was not necessary to conduct the nitrogen removal processes in subject wastewater.

In order to check if nitrogen concentration in wastewater allowed to conduct the process of carbon removal, the relation between the amount of nitrogen and BOD_5 was checked. According to the literature [7] the amount of

nitrogen, which is inbuilt in bacterias cell in the process of carbon removal, describes the relation:

$$\frac{N_{total}}{BOD_5} \leq 0.05 \tag{4.3}$$

This means that if the nitrogen compounds level is higher than it is apparent from the above relation, it will not be removed from wastewater during the removal of carbon compounds. The calculation results of ratio of total nitrogen to BOD5 in the laundry wastewater was presented in table 7. It was compared the measurement results for BOD5 using the manometric method with adding of nitrogen to the sample and LANGE cell tests.

Table 7. The ratio of total nitrogen to BOD_5

Date of measurement	N_{total}/BOD_5	
	Measurement using LANGE cell tests	Measurement using the manometric method
04.03.2010	0.064	0.028
11.03.2010	0.037	0.024
17.03.2010	0.044	0.030

In accordance with the considerations carried out in point 4.3.2, results for the value of BOD_5 measured using the manometric method should be considered to be meaningful. The calculated ratio of total nitrogen concentration to BOD_5 in wastewaser was significantly lower than the described in relation (4.3). This meant that the wastewaser was deficient in nitrogen, which was necessary to be built into bacterias cell during the process of removing carbon compounds from the wastewater. Therefore. the nitrogen compounds (such as urea or ammonium nitrate) must be added in treatment process of the subject laundry wastewater.

4.3.4. The removal of phosphorus compounds from wastewater

Phosphorus concentration in raw sewage mechanicaly pre-treated ranged from 2.69 to 12.7 gP/m^3 (tabela 5). This is a value significantly higher than maximal allowed in the valid Regulation [5], which equals 3 gP/ m^3. It means that it was necessary to conduct the phosphorus removal processes in subject wastewater. Biological phosphorus removal in wastewater without the use of external sources of carbon, or chemical precipitation, is possible only when the ratio of BOD_5 to total phosphorus is adequate.

According to the literature [7] this ratio is as follows:

- $P_{total}/BOD_5 < 0.015$ – there is a removal of carbon and nitrogen. phosphorus is built into bacterias cell;
- $P_{total}/BOD_5 < 0.04$ – there is a biological phosphorus removal;

- $P_{total}/BOD_5 > 0.04$ – it is necessary to support biological processes by chemical precipitation of phosphorus and / or use of an external carbon source (which will reduce the ratio of the concentrations).

The calculation results of ratio of total phosphorus to BOD_5 in the laundry wastewater were presented in table 8. The measurement results for BOD_5 using the manometric method with adding of nitrogen to the sample and LANGE cell tests were compared.

Table 8. The ratio of total phosphorus to BOD_5

Date of measurement	P_{total}/BOD_5	
	Measurement using LANGE cell tests	Measurement using the manometric method
04.03.2010	0.049	0.021
11.03.2010	0.032	0.020
17.03.2010	0.031	0.021

In accordance with the considerations carried out in step 3.4.2, results for the value of BOD_5 measured using the manometric method should be considered to be meaningful. The calculated ratio of total phosphorus concentration to BOD_5 in laundry wastewater let assume that the biological phosphorus removal was possible. However, the chemical precipitation of phosphorus was accepted because laundry has a limited area for the construction of wastewater treatment plant and limited number of staff employed to operate future plant.

4.3.5. Analysis of water salinity

The subject laundry wastewater contains wastewater from regeneration of ion exchangers that are used for softening of technological water. where salinity is a major pollution. For this reason, an increased chloride content - at 436 ÷ 787 g/m^3 (table 5) was observed in subject wastewater. The laundry wastewater (from wet washing) was polluted sulfates, which concentration ranged 236 ÷ 305 g/m^3 (table 5). According to the valid Regulation [5] allowable concentrations of sulphates and chlorides in treated wastewater are respectively: 500 g/m^3 and 1000 g/m^3, and their sum cannot exceed 1500 g/m^3.

However, according to the previous establishing, following agents increasing wastewater salinity will be used during wastewater treatment process:

- to correction of pH - sulfuric acid or hydrochloric acid;
- to chemical precipitation of phosphorus – iron or aluminium sulfate or chloride.

Both supplements increase the salinity of the wastewater. Therefore, a precise balance of chloride and sulphate in treated wastewater must be made at the stage of the selection of substances used to correct pH in laundry wastewater

and the agent to remove phosphorus. It is possible that the best solution is separation of wastewater from regenerating ion exchangers and and appropriate dosage them into the treated wastewater. Probably such action let to not exceed the maximum concentration values of sulfate in chloride in the outflow from wastewater treatment plant.

5. CONCLUSIONS

Basing on the survey and on the laundry wastewater quality analysis, it could be concluded that this laundry wastewater are susceptible to degradation by biological methods. This conclusion was consistent with test results put by Podedworna and Żubrowiska – Sudoł [1].

However. the wastewater dispensing auxiliary agents are necessary in the wastewater treatment process. These agents aim to:

- correct (reduce) pH of raw wastewater;
- prevention of foaming wastewater in the chambers aerated;
- enrichment of the raw wastewater in the nitrogen compounds;
- the chemical precipitation of phosphorus.

A precise balance of chloride and sulphate in treated wastewater must be made at the stage of the selection of substances corrective reaction pH laundry wastewater and the agent to remove phosphorus.

ADDITIONAL INFORMATION

The authors would like to thank Fliegel Textilservice company which provided the laundry data.

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ILOŚĆ I JAKOŚĆ ŚCIEKÓW PRZEMYSŁOWYCH POPRALNICZYCH NA PRZYKŁADZIE PRALNI FLIEGEL TEXTILSERVICE W NOWYM CZARNOWIE

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

Przeprowadzenie analizy ilości i jakości ścieków pochodzących z zakładu przemysłowego jest ważnym etapem doboru technologii oczyszczania ścieków przemysłowych W pracy przeanalizowano dane dotyczące jakość i ilość ścieków przemysłowych pralniczych z pralni Fliegel Textilservice w Nowym Czarnowie. województwo zachodniopomorskie. Danymi wyjściowymi do analizy były pomiary stężeń wskaźników zanieczyszczeń wykonane w okresie od 12.2009r. do 07.2010r. dla ścieków surowych. mechanicznie podczyszczonych na sicie. o składzie wyrównanym w zbiorniku retencyjnym. W pracy opisano uwarunkowania przygotowania ścieków do biologicznego ich oczyszczania. między innymi poprzez korektę odczynu pH. obniżenie temperatury ścieków. usunięcie piany. Poddano również analizie wskaźniki związane z podatnością na biologiczne usuwanie związków węgla oraz związków biogennych z przedmiotowych ścieków pralniczych. Ustalenie radzajów i dawek środków dawkowanych do ścieków pralniczych w planowanym procesie ich oczyszczania musi też uwzględnić wysokie stężenie chlorków i siarczanów występujące obecnie w przedmiotowych ściekach surowych.