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TECHNICAL AND ECONOMIC ASPECTS OF INDUSTRIAL LAUNDRY WASTEWATER TREATMENT

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Three biological methods of laundry wastewater purification were tested, in pilot scale, in Fliegel Textilservice laundry in Nowe Czarnowo. Among tested methods, rotating biological contactor, membrane bioreactor and sponge activated sludge reactor, the last one has been pointed out as optimal for laundry wastewater treatment. Biological treatment of laundry wastewater, assisted by nitrogen addition, phosphorus chemical precipitation and neutralisation, generated purified wastewater with satisfactory quality. Case study of industrial laundry shows that total costs of wastewater utilization may be reduced by 39% and payback period of total investment costs is estimated at 7-8 years.

Keywords: laundry, wastewater, membrane biological reactor, rotating biological contactor, sponge activated sludge reactor

1. INTRODUCTION

Industrial laundry Fliegel Textilservice, located in Nowe Czarnowo, commune Gryfino, westpomeranian voivodchip, in year 2009 started activity towards optimization of wastewater management. Capacity of laundry exceeding the level of 70 Mg per day and water consumption on the level of 8 m^3/Mg cause that amount of taken water as well as discharged wastewater is significant and generate high costs. Analysis of available data shows that average daily volume of wastewater is equal to 540 m^3/d. From the point of view of company's management the most important issues, related to water and wastewater management, are sureness of good quality water delivery and wastewater reception as well as, costs of water taking and wastewater discharging.

At present laundry exploits their own ground water intake and water treatment plant while wastewater are dumped to communal sewerage. In such

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situation company controls quality, delivery and price of water and in emergency situation has access to the water from waterworks of neighbouring company. Wastewater price is fixed by local Communal Services Company and sureness of wastewater reception depends on proper maintenance of sewerage and communal wastewater treatment plant. In case of sewerage break-down there is a possibility of wastewater delivering by road transport.

2. EXISTING SITUATION

Presently the wastewater, at the washers outlet, are filtered and flows to the hot wastewater tank. Then hot wastewaters flows through heat exchanger followed by Noggerath sieve to remove suspended solids. Mechanically pre-treated wastewaters are collected in retention tank with capacity of 350 m^3. Retention tank collects also wastewater from car washer (after their pre-treatment in separator of petroleum substances) and wastewater after regeneration of water softeners (ion exchangers).

Hitherto existing way of wastewater utilization guarantee sureness of wastewater reception enabling uninterrupted activity of the company. In that situation, deciding factor to change wastewater system, is costs of wastewater utilization.

Key parameters, used for wastewater price calculation, are COD, BOD_5, Suspended solids (SS) and surfactants content. Limits value of that parameters, for basic price, are set on:

- COD 1,000 mg O_2/dm^3
- BOD_5 500 mg O_2/dm^3
- SS 500 mg $/dm^3$
- Surfactants (sum of anionic and non-ionic) 35 mg $/dm^3$

One can assume, that for presently way of wastewater utilization, average price is equal to 6.30 PLN/m^3. The price mainly depends on surfactant level and occasionally on COD value. Maximal price for wastewater, when surfactants content exceeds 70 mg /dm^3, may reach level of 11 PLN/m^3.

3. PLANNED CHANGES

According to the information presented above, the aim of taken activity is to built wastewater management system which will guarantee stable wastewater reception on acceptable price. Three main options have been investigated:

- keeping existing way of wastewater management combined with negotiation with local Communal Services Company conditions of agreement (wastewater parameters and price),

- implementing of biological pre-treatment of wastewater in retention tank combined with negotiation with local Communal Services Company conditions of agreement (wastewater parameters and price),
- constructing of biological wastewater treatment plant and discharging purified wastewater to surface water.

Based on data analysis the decision, to prepare documentation for constructing of biological wastewater treatment plant and discharging purified wastewater to surface water, has been taken. Final solution depends on the result of organisational measures towards wastewater price reduction.

As a consequence of such decision, three methods of biological wastewater treatment, have been tested on place in pilot scale (ca. 1 m^3/d):

- typical rotating biological contactor (RBC),
- membrane bioreactor (MBR): Microfiltration membrane modules have been immersed in aeration tank to separate purified wastewater from activated sludge particles,
- sponge activated sludge reactor (SASR): Activated sludge microorganisms were fixed on sponges floating in aeration tank.

Results of analysis confirm possibility of adaptation of activated sludge process for laundry wastewater treatment. Values of purified wastewater indicators reached the level required for wastewater discharged to surface water. The major conclusions were:

- organic substances in laundry wastewaters are biodegradable enabling reduction of indicators COD and BOD5 below the values required for wastewater discharged to surface water,
- ratio of basic nutrients C:N:P in laundry wastewater indicate necessity of introducing additional amount of nitrogen for proper biological removal of organic carbon as well as implementing of chemical phosphorus precipitation,
- high reaction of wastewater forced usage of acids for neutralization,
- because of high concentration of surfactants, an antifoaming agents, should be used in aeration chamber,
- usage of polymeric flocculants, to raise the efficiency of fibres fine particles separation, is recommended in secondary settler.

Conducted pilot tests allowed to point out the SASR method as optimal among tested ones.

Most likely because of low aeration efficiency, the results reached on RBC were unsatisfactory.

Purified wastewater obtained in MBR was enough good quality. This method was not taken into account because of problems with membrane modules cleaning. The problem was caused probably by fine fibres particles membrane fouling. After mechanical and chemical tests of membranes modules cleaning supplier of MBR changed the method to SASR.

4. TECHNICAL ASPECTS

Eventually proposal for target solution consists of:

- adapting of retention tank for biological pre-treatment (introducing activated sludge microorganisms, immobilized on sponges and constructing of aeration system in retention tank),
- constructing of biological wastewater plant in the company (SASR, secondary settler),
- constructing the outlet pipeline from wastewater treatment plant to surface water,
- constructing of access sludge processing unit.

Comparison of key indicators of wastewater quality maximal values registered for raw wastewater with permissible ones shows necessity of deep removal of organic substances, total phosphorus, suspended solids and surfactants as well as neutralization of wastewater. Biodegradable organic substances can be removed by typical activated sludge methods of wastewater treatment [1]. For efficient laundry wastewater treatment typical biological wastewater treatment should be modified because of specific for the laundry wastewater relatively low nitrogen content, relatively high phosphorus content and high pH value.

Table 1. Comparison of key indicators of wastewater quality maximal values registered for row wastewater with permissible ones [2].

Indicator	Maximal value in raw wastewater		Maximal permissible value in treated wastewater
pH value	10	pH	6.5 – 9.0
Temperature	40	°C	35
BOD_5	386	g O_2/m^3	25
COD_{cr}	1159	g O_2/m^3	125
Suspended Solids	415	g/m^3	35
Total phosphorus	12.7	g P/m^3	3
Total nitrogen	15.2	g N/m^3	30
Ammonia nitrogen	1.63	g $N\text{-}NH_4/m^3$	10
Surfactants-anionic	32.9	g/m^3	5
Surfactants-non-ionic	43.7	g/m^3	10
Chloride	787	g/m^3	1 000
Sulphate(VI)	305	g/m^3	500

Table 2. Results of pilot plant test (SASR – 18.05-11.06.2011)

Indicator	Unit	Range of values in treated wastewater
pH value	pH	8.0 – 8.9
BOD_5	g O_2/m^3	11 - 18
COD_{cr}	g O_2/m^3	73.5 - 125
Total phosphorus	g P/m^3	2.4 – 3.0
Total nitrogen	g N/m^3	3.1 - 14
Ammonia nitrogen	g $N\text{-}NH_4/m^3$	0.2 - 9
Surfactants-anionic	g/m^3	0.9 – 2.1
Surfactants-non-ionic	g/m^3	1.9 – 4.1
Chloride	g/m^3	443 - 527
Sulphate(VI)	g/m^3	140 - 203

4.1. Wastewater neutralisation.

Pilot tests showed that to reach required pH value of wastewater, dosage of 10 dm^3 of 35% solution of sulphuric acid per 24 m^3 of wastewater, is necessary (0.417 dm^3 of 35% solution of H_2SO_4 per 1 m^3 of wastewater which is equal to 193 g of H_2SO_4 per 1 m^3 of wastewater). Because of relatively high concentration of sulphates in wastewater possibility of usage of hydrochloric acid has been analysed. Equivalent amount of hydrochloric acid is 144 g of HCl per 1 m^3 of wastewater.

4.2. Nitrogen dosing

Based on ratio between basic nutrients C:N:P required amount of nitrogen has been calculated [3]. For pilot tests, commercial urea (46% of nitrogen content), has been used. Required dosage is equal to 15-20 g N/m^3 which gives 44 g of urea per 1 m^3 of wastewater.

4.3. Chemical precipitation of phosphorus

Assuming that chemical precipitation should remove ca. 5 gP/m^3, the dosage of commercial solution of $Fe_2(SO_4)_3$ (12% of Fe(III) content) has been calculated on 13 g $Fe(III)/m^3$ (108 g of commercial $Fe_2(SO_4)_3$ solution per 1 m^3 of wastewater) [4, 5].

4.4. Salinity of the wastewater

Laundry raw wastewater under investigation contains relatively high amounts of chlorides and sulphates. In connection to neutralisation of wastewater and chemical precipitation of phosphorus the concentrations of chlorides and sulphates in wastewater after treatment may reach values closed to the permissible ones. This is the reason why hydrochloric acid is taken into account as an alternative to sulphuric acid.

Dosage of 193 g of H_2SO_4 per 1 m^3 of wastewater could rise sulphate concentration by 189 g of sulphate per 1 m^3 of wastewater. Additionally usage of 108 g of commercial $Fe_2(SO_4)_3$ solution per 1 m^3 of wastewater delivers 33.4 g of sulphate per 1 m^3 of wastewater. Combining that with maximal content of sulphates in raw wastewater (both chlorides and sulphates are not removed in biological treatment) one can conclude that permissible value for sulphates may be exceeded.

Replacement of sulphuric acid by hydrochloric acid will reduce the increase of sulphates concentration but will increase the concentration of chlorides. Dosage of 144 g of HCl per 1 m^3 of wastewater will deliver 140 g of chlorides per 1 m^3 of wastewater.

High concentration of chlorides may be caused by collecting, in retention tank, wastewater from water softeners regeneration. In case of necessity, this stream of wastewater may be utilized separately.

4.5. Sludge utilization

Suggested method for sludge utilization is based on:

- sludge thickener,
- filter press,
- sludge liming (optionally, depends on a way of final sludge disposal).

Total amount of excces sludge dry mass has been estimated on 198 kg/d [6]:

- biological growth of activated sludge organisms – ca. 63 kg/d,
- removed suspended solids – ca. 116 kg/d,
- chemical precipitation of phosphorus – ca. 19 kg/d.

For technical and economic calculations, one can assume, that 200 kg/d of excess sludge dry mass will be generated by wastewater treatment plant. Mixing of sludge with CaO, in dry mass ratio 1:1, is planned in case of sludge hygenization necessity. After sludge liming, 400 kg/d of sludge dry mass will be generated.

5. ECONOMIC ASPECTS

5.1. Investment costs

Total investment costs of construction and adapting of buildings, pipelines and purchasing necessary equipment is estimated on ca. 3.600.000 PLN. Main items are:

- wastewater treatment plant (ca. 2.700.000 PLN),
- sludge filter press with building (180 000 PLN),
- wastewater pump station (45 000 PLN),

- pumping pipeline for purified wastewater discharging (150 000),
- technological pipelines (50 000 PLN),
- installation for sludge liming (75 000),
- electrical connections (20 000 PLN),
- automatization (200 000 PLN),
- other costs: sludge thickener, construction of wastewater outlet to surface water, documentation and administrative fees (180 000 PLN).

5.2. Operational costs

Operational costs have been estimated based on results of pilot tests, local market condition and information delivered by suppliers of equipment and technology. Each item has been recalculated per 1 m^3 of wastewater.

Comparison of total investment costs, calculated operational costs and actual price of wastewater enables to estimate simplified (capital cost is not included) expected payback period for planned investment. Actual average price for wastewater equal 6.30 PLN/m^3, predicted price – 3,85 PLN/m^3, average daily volume of wastewater – 540 m^3/d and total investment costs - 3.600.000 PLN indicate that estimated payback period could be on the level of 7-8 years.

Table 3. Operational costs estimation.

Item	Notes	Cost in PLN per 1 m^3 of wastewater
Energy	Average power of installation – 20 kW. Average unit price of electrical energy 0.25 PLN/kWh	0.24
Labour	One and half time work. Costs 7.500 PLN per month	0.50
Chemical analysis	Depends on a regulations in water permit. Assumed on the level 1,000 PLN per month	0.03
Flocculant	According to the technology supplier	0.22
Neutralisation	Calculated for sulphuric acid and prices on local market. Solution of 35% H_2SO_4 – 1.80 PLN/dm^3.	0.75*
Nitrogen	Commercial urea (46% of nitrogen) – 1,000 PLN/Mg	0.05
Antifoaming agent	According to the technology supplier	0.05
Phosphorus precipitation	Commercial solution of $Fe_2(SO_4)_3$ – PIX-113 price 500 PLN/Mg	0.06
Sludge liming	Commercial CaO. Dosage of 1 kg CaO per 1 kg of sludge dry mass. Price 150 PLN/Mg	0.05
Sludge deposition	Local dump. Price 400 PLN/Mg	1.00*

and transportation		
Maintenance	Estimated on the level of 1% of total investment cost annually	0.20
Amortization	Assumed on 2,5% of total investment cost annually	0.50
Environmental fees	Based on purified wastewater parameters and actual fees level	0.20
Total operational cost		3.85

* Because of relatively high contribution in total costs, these items should be carefully investigated

6. CONCLUSIONS

1. Organic substances in investigated laundry wastewater are biodegradable. Activated sludge biological treatment process assisted with neutralisation, nitrogen addition and phosphorus chemical precipitation allowed purified wastewater to be discharged to surface water.
2. Among three tested methods: rotating biological contactor, membrane bioreactor and sponge activated sludge reactor the last one has been pointed out as optimal for laundry wastewater treatment.
3. Simplified costs analysis indicate that, in investigating company, cost of wastewater discharging may be reduced in 39% and payback period of investment costs is on the level of 7 – 8 years.

ADDITIONAL INFORMATION

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TECHNICZNE I EKONOMICZNE ASPEKTY OCZYSZCZANIA ŚCIEKÓW PRALNICZYCH

Streszczenie

Wiele zakładów przemysłowych doświadcza problemu wysokich kosztów odprowadzania ścieków. Szczególnie dotyka to zakłady, w których prowadzone są procesy o wysokim zapotrzebowaniu na wodę. Jako alternatywę do odprowadzania surowych, lub podczyszczonych, ścieków do komunalnych systemów kanalizacyjnych, należy rozważać budowę własnego systemu oczyszczania ścieków i ich zrzut do wód powierzchniowych. W przemysłowej pralni Fliegel Textilservice, w Nowym Czarnowie, przetestowano trzy metody biologicznego oczyszczania ścieków pralniczych. Wśród testowanych metod: biologiczne złoże obrotowe, bioreaktor membranowy i osad czynny utwierdzony na gąbkach, ostatnia z wymienionych wskazana została jako optymalna do oczyszczania ścieków pralniczych. Biologiczne oczyszczanie ścieków pralniczych, wspomagane dozowaniem azotu, chemicznym strącaniem fosforu i neutralizacją, generowało ścieki oczyszczone o satysfakcjonującej jakości. Analizowany przypadek wskazuje na możliwość redukcji kosztów gospodarki ściekowej o 39% oraz okres zwrotu nakładów inwestycyjnych rzędu 7-8 lat.