

RESEARCH ON PHYSICO-CHEMICAL PRETREATMENT OF WASTEWATERS FROM ANIMAL-ORIGIN WASTE UTILIZATION

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Abstract. This paper presents the results of one-year research carried out on the installation built to pretreat post-condensate effluents from the process of thermal pressure destruction of animal originated wastes. This prototype installation of capacity ca 5.0 m³/h consists of two stages of physico-chemical wastewater pretreatment. The first stage is used for the heat pipeline cooling of the raw effluents up to temperature 35-45°C, and for fat and suspended matter flotation with the use of hydrogen peroxide aided by induced air flotation (IAF). The second stage is used to oxidize and deodorize with hydrogen peroxide on coke beds under conditions of permanent effluent circulation. The applied technical solution made it possible to deodorize, defat and eliminate all dispersed substances and to achieve a high level of nitrate(III) nitrogen reduction. This developed process may be used in practice as a physico-chemical stage of pretreatment and deodorization of post-condensate effluents before the stage of their full-scale treatment with biological methods. It may also be applied for partial heat power recovery from raw, hot post-condensate wastewater, and thus may result in growing the profitability of animal- origin waste neutralization.

Keywords: deodorization, flotation, post-condensate effluent pretreatment, oxidizing.

1. Introduction

Processing waste material of animal origin with the use of thermal pressure methods is related with forming post-condensate effluents (Żak 2005; Żak 2005a). Literature reports present irrefutable evidence that soluble and dispersed pollutants in general effluents from animal originated waste utilising plants mostly come from vapour condensation (50-90%) (Żak 2005; Ruffer and Rosenwinkel 1991; Londong and Rosenwinkel 2007; Wildmoser 1980). Those wastewaters are characterized by a high level of the following loads: chemical oxygen demand (COD), five-day biochemical oxygen demand (BOD₅), a specific repelling odour and characteristic fluctuations in pollutant concentration levels with reference to the room temperature where the wastes are stored, and to the season of the year (Żak 2005; Żak 2005a; Londong and Rosenwinkel 2007; Wildmoser 1980; Oberthür 1981; Temper *et al.* 1987; Neumann 1972). In periods of elevated temperature, especially in the summer, a characteristic increase in concentrations of index parameters with reference to the winter time is observed (Żak 2005; Ruffer and Rosenwinkel 1991; Wildmoser 1980; Oberthür 1981; Temper *et al.* 1987; Neumann 1972). Different within a year levels of: COD, BOD₅, total nitrogen (TN), ammonium nitrogen (N-NH₄) and nitrite nitrogen (N-NO₂), as well as sulphur compounds inducing character-

istic odour of carrion, and also a seasonal changeability of: COD/BOD₅, COD/TN, BOD₅/TN, COD/TP and BOD₅/TP ratios cause a lot of problems concerning the treatment of those effluents mainly with the use of biological methods (Ruffer and Rosenwinkel 1991; Oberthür 1981; Temper *et al.* 1987; Neumann 1972; Neumann 1979; ATV (Hsrg.) 1986; Neumann 1986). Additionally, those effluents are characterised by alkaline reaction induced by high concentration of ammonium nitrogen, and by elevated amounts of fatty compounds which complicate the process of biological treatment and force the use of their physico-chemical pretreatment (Żak 2005; Żak 2005a; Londong and Rosenwinkel 2007; Wildmoser 1980). The post-condensate wastewater is formed in small volumes (approximately: ca 0.6-0.7 m³/1.0 Mg of carrion, ca 0.4 m³/1.0 Mg of bones, ca 0.9 m³/1.0 m³ of blood, and ca 0.4-0.5 m³/1.0 Mg of wet feathers), however, the concentrations of the pollutants they contain are extremely high (Żak 2005; Żak 2005a; Ruffer and Rosenwinkel 1991; Londong and Rosenwinkel 2007; Wildmoser 1980). Compared with vapour condensates, the effluents from cleaning the so called dirty processing section and clean processing section (appliances and areas which have a direct contact with waste material of animal origin) are of secondary significance since the amounts of those low loads pollutants in wastewater may be ca 0.1-0.5 m³/1.0 Mg of raw material (Ruffer and

Rosenwinkel 1991; Neumann and Viehl 1966). Recognized results taken from literature indicate that some part of the total COD in raw post-condensate effluents is also made by animal fats, different peptide, oligopeptide and oligosaccharide fractions that mainly occur in the dispersed phase (Rüffer and Rosenwinkel 1991). According to literature data, the content of total nitrogen (TN) occurs prevalently as ammonium (80-85%) and as the bound one in organic connections (15-20%) (Žak 2005; Rüffer and Rosenwinkel 1991). The registered content of total phosphorus (TP) in the form of orthophosphates ($P-PO_4$) is at low level and the COD:TP ratio as a rule does not exceed the level of 500, or even 1000 (Rüffer and Rosenwinkel 1991). Basing on the experiments, it was found that so far no physico-chemical pretreatment methods have been used in practice, but only to decrease the intensity of odours and the contents of fats (Žak 2005; Žak 2005a; Rüffer and Rosenwinkel 1991; Cavey *et al.* 1998; Žak 2010; Žak 2003).

A few practically known two-stage solutions of physico-chemical pretreatment consist in using flotation in order to separate solids and fats (which generally occur as protein-fat or oligosaccharide-fat bounds), while the second stage is of stabilizing-averaging and cooling character (Žak 2005; Rüffer and Rosenwinkel 1991; Londong and Rosenwinkel 2007; Cavey *et al.* 1998; Žak 2010). In these cases, the flotation methods are used to pretreat effluents from waste utilization plants, for both preliminary disposal of fats and greases and for disposal of hydrolyzed protein forms, poly- and oligosaccharides, usually by chemical precipitation of suspended matter (Rüffer and Rosenwinkel 1991; Londong and Rosenwinkel 2007). With the use of such solution, literature reports that you can achieve the reduction of total suspended solids (TSS) exceeding 95% and 30-40% COD reduction (Rüffer and Rosenwinkel 1991; Londong and Rosenwinkel 2007). However, the reduction of fats is a function of specificity of technical solution of systems for cooling wastewater and their efficiency (Žak 2005; Rüffer and Rosenwinkel 1991; Londong and Rosenwinkel 2007). It should be also emphasized that these methods have not been permanently used in practice because of their relatively high costs (Rüffer and Rosenwinkel 1991). In a full-scale application practice, at this stage of technical progress, biological methods of pretreatment get priority (Rüffer and Rosenwinkel 1991; Londong and Rosenwinkel 2007). The currently used solutions are based on the following methods: a) activated sludge (Rüffer and Rosenwinkel 1991; Londong and Rosenwinkel 2007; Wildmoser 1980; Neumann 1979), including a one-stage low loaded variant (Rüffer and Rosenwinkel 1991; Neumann 1979), or, for example, with simultaneous nitrification (Rüffer and Rosenwinkel 1991; Neumann 1979; ATV (Hrsg.) 1986) and with a variant of alternative nitrification-denitrification (Rüffer and Rosenwinkel 1991; Wolf 1986; Wildmoser and Gregor 1981), b) anaerobic-thermophilic (Fuchs H. and Fuchs L. 1980) or anaerobic (Temper *et al.* 1987; Wolf 1986), c) which use the reactors with the so called jet elevator (Brauer and Sucker 1979; Spigler and Brauer 1982), d) combined aerobic-

anaerobic (Rüffer and Rosenwinkel 1991; Londong and Rosenwinkel 2007; Bode 1986), and also with the use of biofilters (Koch *et al.* 1982; Lurch 1981; Fischer and Bardtke 1987).

2. Materials and methods

One-year research was conducted on a prototype system built in order to pretreat post-condensate effluents in volume of ca 5.0 m³/h, which is shown in a simplified flowchart in Figure 1. The system consisted of two stages of pretreatment (Žak 2003; Žak 2010): cooling and flotation with a induced air flotation (IAF) technique (aided with hydrogen peroxide) and a combined oxidizing and deodorizing set with the use of hydrogen peroxide. Raw wastewater (CW) - condensates of vapours from a thermal pressure destructor were introduced continuously into a ground reservoir (1), volume 50.0 m³ equipped with heat pipe sets (1.1) (mobile sets of 3000 heat pipes each and with the capacity of a single heat pipe – 100-120 W), where heat energy was received by using glycol (G1 and G2). After cooling raw post-condensate wastewater from ca 75-85°C up to ca 35-45°C, 0.3% solution of flocculent Praestol 859 BC (Stockhausen) was metered before a slow-running gate agitator (1.2) from the station (2) in a dose of 25.0 g/m³ of effluents, and then, before the effluents were directed into the aeration grate (1.5) (equipped with diffusers type Pfaiderer), 30% solution of hydrogen peroxide was dosed in the amount of 250.0 gH₂O₂/m³ from the station (3). A separated flotote was disposed by a surface skimmer (1.4) into a thickening chamber (1.3), and then disposed outside the installation with a sludge pump. The wastewater free of suspensions and fats was pumped (1.6) onto the second stage of pretreatment, into a ground averaging-cooling chamber (4), volume 50.0 m³, after previous introduction of hydrogen peroxide from the station (3) in the amount of 350.0 gH₂O₂/m³. In the set of the second stage of pretreatment, the effluents were submitted to circulating pump mixing (4.1) and directed by circulation onto catalytic columns (5) (filled with coke), with the use of pumps (4.2). The total time spent by treated wastewater at both stages of physico-chemical pretreatment was 20 hours (10 hours per each stage). In taken and averaged samples of raw effluents (point A in Fig 1), after the 1st stage of the pretreatment (point B in Fig 1) and at the outlet from an oxidizing reactor (point C in Fig 1), the following parameters were determined according to the following standards for water and wastes: reaction (pH) (PN-90/C-04540.01), total suspended solids (TSS) (PN-EN 872:2007), chemical oxygen demand, COD, determined by a dichromate method (PN-ISO 15705:2005), biochemical oxygen demand, BOD_n, determined by a dilution method (PN-EN 1899-1:2002), ether extract (EE) (PN-EN 1899-1-2002), total phosphorus (TP) (PN-EN 1189-2000), orthophosphate phosphorus ($P-PO_4$) (PN-EN ISO 6878:2006.4), total nitrogen (TN) (PN-73/C-04576.12), ammonium nitrogen ($N-NH_4$) (PN-C-04576-4:1994), and nitrite nitrogen ($N-NO_2$) (PN-EN 26777:1999). While determining COD, a correction of value was introduced.

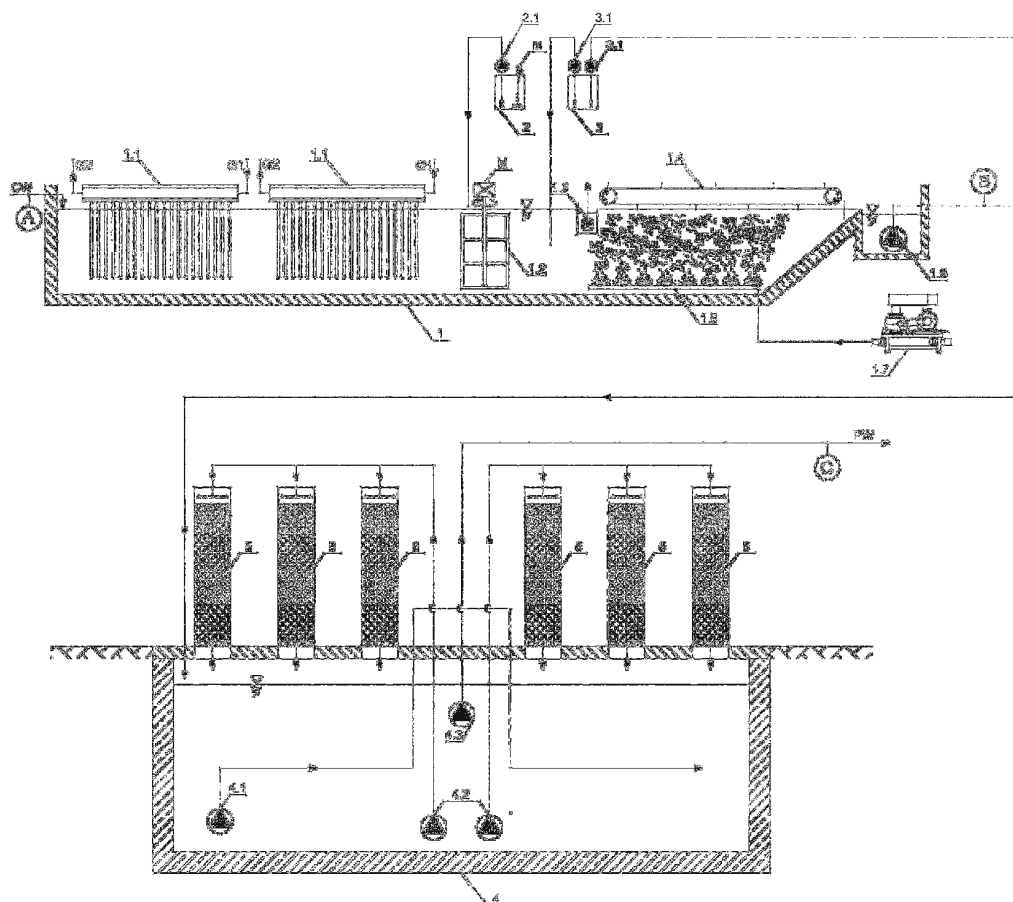


Fig 1. The flowchart of the experimental installation, where: CW, PW – raw and pretreated post-condensate effluents, 1) storage-averaging ground basin for cooling and disposing dispersed substances, 1.1) heat pipe packets (G1 and G2 – glycol for taking heat energy), 1.2) slow-running gate agitator, 1.3) flotage pump, 1.4) flotage skimmer, 1.5) a set of bottom aerating diffusers (Pfaiderer's diffusers), 1.6) wastewater pump, 1.7) compressor, 2) flocculant (0.3% Praestol 859 BC Stockhausen) preparation and metering station, 2.1) flocculant pump, 3) tank for 30% solution of hydrogen peroxide, 3.1) perhydrol pumps, 4) oxidizing-deodorizing ground reactor, 4.1) wastewater inner circulation pump, 4.2) wastewater pumps for column circulation, 4.3) pressure pump for pretreated wastewater, 5) catalytic columns (filled with coke). A, B and C – wastewater sampling points for analyses

3. Results and discussion

Actual chemical oxygen demand was calculated taking into account corrections by deducting a fraction of residual hydrogen peroxide, basing on the following relationship $COD_r = COD_p - f \cdot d$ (COD_r – actual, COD_p – determined in a sample after the process of wastewater pretreatment, d – H_2O_2 concentration in the analyzed sample – determined iodometrically, $f = 0.25$ – literature correction factor (Talinli and Anderson 1992; Yun Whan *et al.* 1999; Zak 2008).

Basing on literature (Rüffer and Rosenwinkel 1991), for the purpose of qualitative and quantitative recognition of the contents of: COD and BOD_5 loads, the determination of low molecule carboxylic acids was made with the use of the following techniques: GC-FID and GC-MS (HP-5890 series II, tubular column HP-1: length $l = 30.0$ m, $\phi = 0.53$ mm, phase Hypersil ODS Shandon), and mass spectrometer (Hewlett Packard MS 5972 series Mass Selective Detector – column Pona 1 = 25.0 m, $\phi = 0.33$ mm), according to the method given in papers (Manni and Caron 1995; Banel and Zygmunt 2009).

The full treatment of post-condensate effluents from thermal and pressure destruction of wastes of animal origin with the use of biological methods (mainly with activated sludge) is connected with considerable disturbances induced by: their high temperature, seasonal instability of waste composition, excessive amounts of fatty substances and problems with oxygen balance as well as with results caused by excessive concentrations of ammonium nitrogen (Wildmoser 1980; Neumann 1979; Wolf 1986; Wildmoser and Gregor 1981; Rüffer and Rosenwinkel 1991). Cooled and effectively degraded wastewaters affect high efficiency of their treatment and considerably reduce operating costs of biological treatment. In practice, flow capacity of biological wastewater treatment systems is significantly limited not due to hydraulic loads of the appliances but because of contamination load processing limits of activated sludge where the post-condensate effluents are directed. It results from a considerable seasonal increase in loads of COD and BOD_5 as well as TN and $N-NH_4$ in the produced wastewaters in

the summer. It is a rule that at that time a day level of these contamination indexes increases by app. 150-300%, or even more, compared with the winter months (Žak 2005; Ruffer and Rosenwinkel 1991).

The primary aim of the present study and the experimental installation building was to find an effective physico-chemical method for pretreating post-condensate wastewaters which would guarantee their cooling up to temperatures enabling a trouble-free work of activated sludge at the final stage of biological treatment, considerable defatting to the level of EE (the so called Ether Extract) below 50.0 mg/l and eliminating odour-creating substances (mainly sulfo-organic compounds) (Žak 2008a; Bull *et al.* 1982; Gariépy *et al.* 1989; Cammarota and Freire 2006). Detailed research on the subject installation was conducted for one year and the presented results are monthly average values (Fig 2-5). The changes shown in diagrams reflect differences recorded at the outlet of the installation (Fig 1, point C) with reference to the values which were recorded at the inlet (Fig 1, point A), taking into account the time when the effluents were on the installation. Such an approach can be defined as a general efficiency of the installation and the process. The quality structure of the animal-originated wastes, of which the post-condensate wastewaters were formed during the year of the experiment, was shaped typically and considering monthly averages was as follows: carrion ca 50% (mainly ruminants), slaughterhouse offal (mostly from slaughter and processing pork raw material – deadweight, waste material, waste fats, etc.) ca 30%, poultry waste materials ca 10% and feathers ca 10%. Seasonally, in the summer months, owing to floods occurring in the area where raw material was collected, an increase in fraction of pork-beef deadweight by ca 15-20% was observed, which also resulted in a considerable increase in load. The experimental installation consisted of two pretreatment sets. The first set was to cool the raw wastewater down so that animal fats could be congealed and then eliminated together with suspended solids (a mixture of peptide-polysaccharide substances in most part), with the use of the induced air flotation (IAF) additionally oxidized with hydrogen peroxide. The second pretreatment set was to oxidize bad odorous compounds and some low-molecular substances forming COD and BOD₅ loads on coke catalyst beds (Fig 1). The analyses made for raw wastewaters enabled us to find a characteristic variability of the indicating parameters, depending on the season of the year (Fig 2-5), with reference to known literature data (Ruffer and Rosenwinkel 1991; Temper *et al.* 1987; Wildmoser 1980; Neumann 1979; Neumann 1972; Neumann and Viehl 1966). Relatively higher concentrations of analytical parameters recorded in summer months could be a result of different specificity of this season with reference to the previous years and were demonstrated by processing larger amounts of animal deadweight which organic decay was advanced. This raw material was collected from the areas afflicted by flood, which means it was lying in open fields for a long time and without control. In order to eliminate fats effectively, it is necessary to cool wastewater below 40-45°C (the

temperature of congealing animal fats), which guarantees that the emulsion phase changes into a dispersed phase of solid suspensions and then it is separated by flotation. Basing on own experiments, it was found that the use of heat pipes connected into the so called heat pipe sets would be a less complicated solution. It does not require any special time necessary to clean membranes of heat exchange. The presence of both potassium in raw post-condensate effluents and free fatty acids originating from biochemical and thermal-pressure hydrolysis of fats induces a spontaneous synthesis of soaps. The soaps act as surfactants on the surfaces of heat pipes and keep them relatively clean under conditions of permanent flow of hot raw wastewaters. The elimination of fatty substances is necessary owing to a specificity of the second stage of pretreatment consisting in the application of coke catalyst beds which must be free from their silting-up effect. Eliminating fats below the amount of 50.0 mg/l of effluents provides undisturbed processes of the final biological treatment of this type of wastewaters (Žak 2008a; Bull *et al.* 1982; Gariépy *et al.* 1989; Cammarota and Freire 2006). The flotation enhanced with chemical reagents producing gases intensifying the process of hydrostatic lift may become an interesting trend in pretreating post-condensate effluents (Žak 2005; U.S. Peroxide 2009; Steiner and Gec 1992). Such a reagent is hydrogen peroxide, the use of which neither enlarges the amounts of troublesome sewage sludge nor increases the secondary salinity of the pretreated wastewaters (U.S. Peroxide 2009; Steiner and Gec 1992). This compound is able to oxidize selectively and completely as well as to mineralize some organic compounds being a part of general load of pollutants, which is applied to reduce COD and BOD₅ as well as to oxidize nitrite nitrogen to nitrate nitrogen (acc. to the reaction: $\text{NO}_2^- + \text{H}_2\text{O}_2 \rightarrow \text{NO}_3^- + \text{H}_2\text{O}$) and to oxidize and degrade odour-forming sulfur compounds with final generation of sulfates (U.S. Peroxide 2009). The use of hydrogen peroxide results in oxidation and faster flocculation of liberated particles of organic matter joining into larger aggregates, and increases the amounts of dispersed oxygen which originates from the oxidizer decay. Additionally, the release of inert products of decay resulting from the use of H₂O₂ or carbon dioxide considerably supports the process of pollutant flotation (Steiner and Gec 1992). Such a phenomenon, under condition of alkaline reaction (pH) of post-condensate effluents, mainly results from the decomposition of oxidizer acc. to the reaction: $\text{H}_2\text{O}_2 + 2\text{OH}^- \rightarrow \text{O}_2 + 2\text{H}_2\text{O}$ and influences the effectiveness of eliminating the dispersion of suspended solids at the first stage of pretreatment. Hydrogen peroxide also reveals bacteriostatic and fungistatic properties, additionally strengthening the disinfection of the processed wastewaters, which is crucial owing to sanitary safety (U.S. Peroxide 2009). Conducting pretreatment on the discussed installation with the addition of H₂O₂ did not result in any changes in pH. The recorded values of this parameter were within the pH limits 9.3-12.7 for both raw and pretreated effluents, at 1st and 2nd stage of pretreatment. The recorded reduction in total suspended solids (TSS) took place at the 1st stage of the pretreatment

and was observed at the efficiency 98-99%. Similarly, a very high reduction in fatty substances, ca 99%, was achieved at the same stage. Apart from considerable reductions in fatty and suspended substances (Fig 1), a slight reduction in loads of COD and BOD₅ was observed at the 1st stage of the pretreatment, which was mainly a result of eliminating fatty and suspended solids (Fig 2-5). Similarly, low reductions at the same pretreatment stage were observed for TN and N-NH₄ (Fig 2-5).

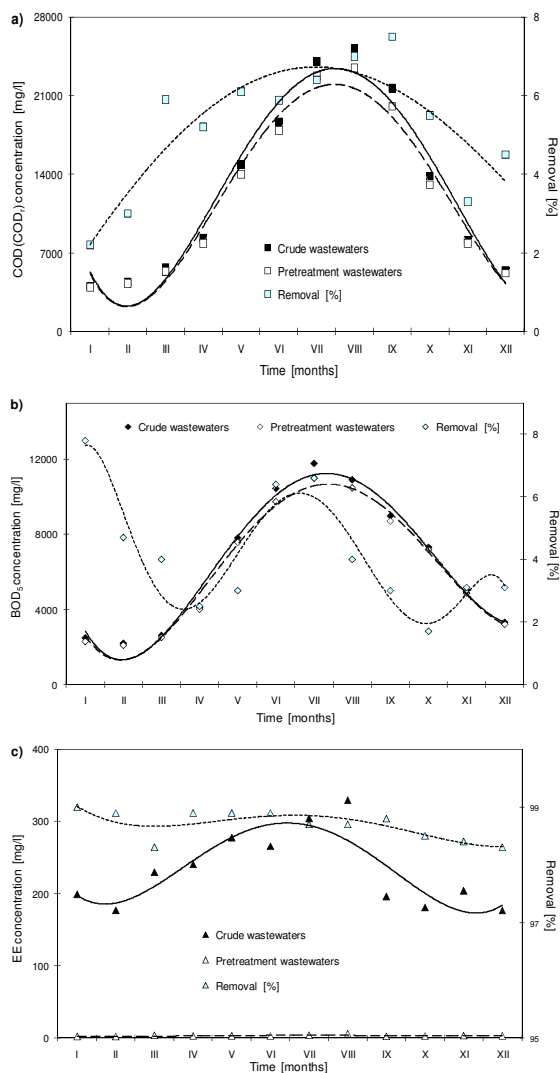


Fig 2. The efficiency of pretreating post-condensate effluents on the experimental installation, analyzed in monthly average periods during the experimental year, measured by the reduction in: a) COD(COD_T), b) BOD₅, c) EE. Diagram lines: full line – raw effluents, dashed line – pretreated effluents, dotted line – %, the efficiency of pollutant elimination

The reduction in ammonium nitrogen was at ca 1-5%, but for total phosphorus (TP) the reduction was 2-5%. This inconsiderable level of the reduction in phosphate phosphorus was probably caused by processes of sorption on the dispersed solid phases eliminated by flotation. A faster course of eliminating ammonium nitrogen was clearly observed for the effluents with higher pH,

especially at the 2nd stage of the wastewater pretreatment. It can be interpreted by shifting the balance towards producing a form of ammonium nitrogen acc. to the reaction: $\text{NH}_4^+(\text{aq}) \leftrightarrow \text{NH}_3(\text{aq}) \rightarrow \text{NH}_3(\text{g})$ and its expelling during intense aeration. It was found that with reference to raw effluents, supporting flotation and oxidation processes changed the COD/TN, BOD₅/TN ratios after 2nd stage, which resulted from relatively higher elimination of ammonium nitrogen with reference to the elimination of COD and BOD₅.

For observable reduction in COD and BOD, the reactions taking place between an organic substrate and hydrogen peroxide alone may have a key significance. This phenomenon is essential in destabilizing colloidal systems, particularly fatty, protein-grease, oligo- and polysaccharide emulsions due to changes taking place on the interfaces induced by the activity of the used oxidizer.

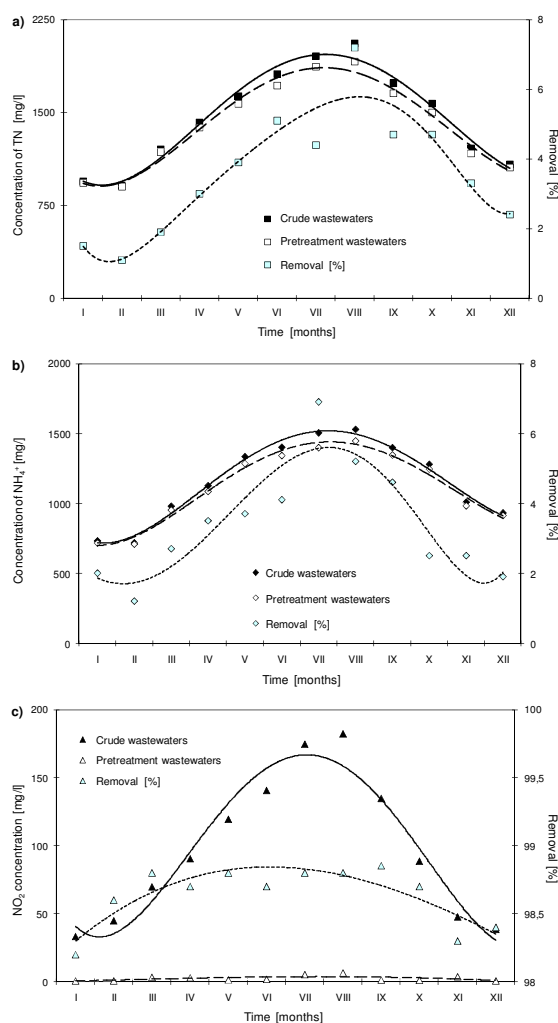


Fig 3. The efficiency of eliminating nitrogen forms from post-condensate effluents on the experimental installation, analyzed in monthly average periods during the experimental year, measured by the reduction in: a) total nitrogen (TN), b) ammonium nitrogen (N-NH₄), c) nitrite nitrogen (N-NO₂). Diagram lines: full line – raw effluents, dashed line – pretreated effluents, dotted line – %, the efficiency of pollutant elimination

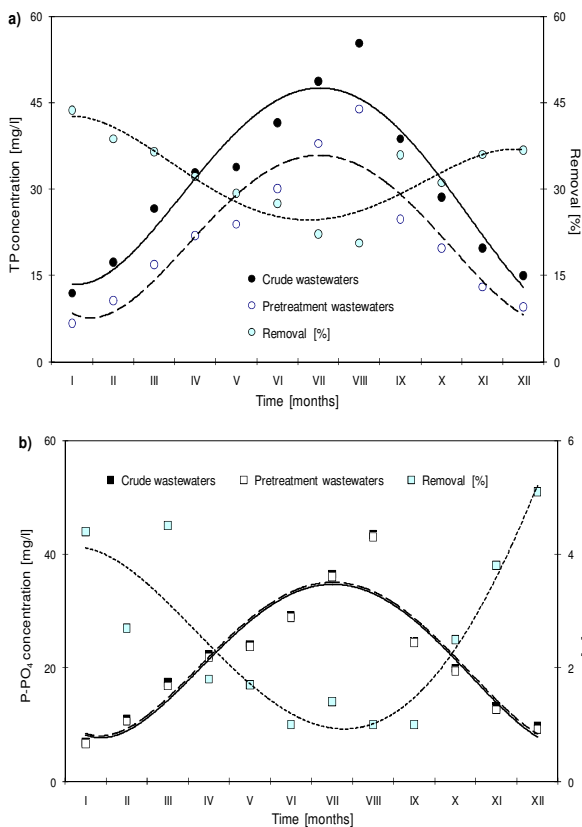


Fig 4. The efficiency of eliminating phosphorus forms from post-condensate effluents on the experimental installation, analyzed in monthly average periods during the experimental year, measured by the reduction in: a) total phosphorus (TP), b) phosphate phosphorus (P-PO₄). Diagram lines: full line – raw effluents, dashed line – pretreated effluents, dotted line – %, the efficiency of pollutant elimination

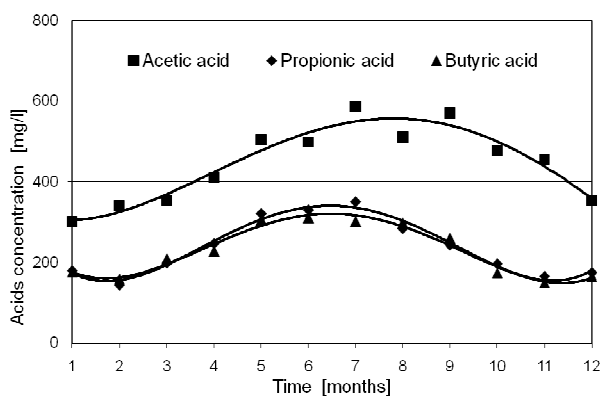


Fig 5. The concentration of volatile organic acids determined in raw post-condensate effluents on the experimental installation, analyzed in monthly average periods during the experimental year

According to literature data, a fraction of organic acids C₂ – C₅ evaporating with water steam amounted to app. 75% during thermal and pressure destruction of animal originated waste in a total load of COD contained in post-condensate effluents (Rüffer and Rosenwinkel 1991). The following acids are the most important: acetic,

propionic and n-butyric, occurring in mole ratio, respectively, (3.5-4.0):(1.2-1.5):1 (Rüffer and Rosenwinkel 1991). Moreover, the presence of iso-butyric, n-valeric and isovaleric acids is also observed. But lactic acid and ethanol are detected rather occasionally (Žak 2005; Rüffer and Rosenwinkel 1991). Basing on own chromatographic analyses, a lower fraction of low-molecular organic acids C₂ – C₅ (Fig 5) was found in the load of COD, and their small transformation into peracid forms during the pretreatment was also observed (acc. to the general equation: R-COOH + H₂O₂ → R-COOOH + H₂O, where R – acid radicals: CH₃, C₂H₅, C₃H₇, C₄H₉, etc.). Their presence strengthens the deposit effect of the effluents (Roeske 2007). The final phase of the research showed that the dose of H₂O₂ used to support the flotation and oxidation of the pollutants contained in the subject effluents undergoes the reaction to such a degree that the residual amounts of this compound do not induce any disturbances in the further process of biological treatment of the pretreated wastewaters.

4. Conclusion

The cooling and the physicochemical pretreatment of post-condensate effluents before final and complete treatment with the use of biological methods is a must. The processes of particular importance include losing high temperature and eliminating fats and odorous compounds. The solution presented here makes it possible to detoxicate, deodour, defat, and to eliminate suspended solids completely and permits high level of reduction in nitrite nitrogen. The wastewaters pretreated with the use of the method under discussion may be further directed onto biological treatment plant in order to treat and dispose them completely. Another advantage of this method which makes it worth considering under the conditions of full technological scale is the use of hydrogen peroxide and, at the same time, the elimination of side effects occurring when the process of treatment is aided with chemical agents in a conventional way, such as secondary salinity or loading of sludge effluents with metals contained in the applied coagulant.

References

- ATV (Hrsg.), Lehr- und Handbuch der Abwassertechnik, Bd. 6 6 (Organische Industrieabwässer), Verlag W. Ernst & Sohn, Berlin und München 1986. 20–57.
- Banel, A.; Zygmunt, B. 2009. Volatile fatty acids in a landfill – occurrence and determination. *Ecological Chemistry and Engineering S*, 16(2): 193–206.
- Bode, H. 1986. Reinigung von stark stickstoffhaltigen Abwasser der Tiermehlindustrie (Gegenüberstellung der aeroben und der aerob-aeroben Behandlung). *Gas- und Wasserfach*, 127: 223–229.
- Brauer, H.; Sucker, D. 1979. Biological waste water treatment in high efficiency reactor. *Germany Chemical Engineering*, 2: 77–86.
- Braun, R.; Atanasoff, K.; Dörfler, J.; Huss, S.; Haberl, R. 1986. Anaerobe Vorreinigung von Brüdenkondensat der

- Tierkörperbeseitigung. *Österreichische Wasserwirtschaft*, 38: 93–105.
- Bull, A. M.; Robert, M. S.; Lester, J. N. 1982. The treatment of wastewater from the meat industry: a review. *Environmental Technology Letters*, 3: 117–126.
- Cammarota, M.C.; Freire, D. M. G. 2006. A review on hydrolytic enzymes in the treatment of wastewater with high oil and grease content. *Bioresource Technology*, 97: 2195–2210.
- Cavey, A.; Eyars, R.; Hill, S.; Kubicki, M.; Niewiadomska, U.; Orzeszko, G.; Sarnacka, A.; Simpson, A. 1998. *Environment protection in utilization industry. General Guide. Publishing House of FAPA, the work edited by Kubicki M., 1st Edition*, Warsaw 1998, 41–54 [in Polish].
- Fischer, K.; Bardtke, D. 1987. Abluftreinigung durch Biofilter. *Entsorgungspraxis*, 10: 470–473.
- Fuchs, H.; Fuchs, L. 1980. Exotherme, aerob-thermophile Stabilisation (Verfahrenstechnik, Energiehaushalt, Hygiene). *Korrespondenz Abwasser*, 27: 241–243.
- Gariépy, S.; Tyagi, R. D.; Couillard, D.; Tran, F. 1989. Thermophilic process for protein as an alternative to slaughterhouse wastewater treatment. *Biological Wastes*, 29: 93–105.
- Hoybye, O.; Bundgaard, E.; Bangsbo, D. 1980. Advanced biological treatment of wastewater from rendering plants. In *Proceedings of International Congress on Industrial Waste Water and Wastes*, Stockholm (Sweden) 1980, 23–26.
- Yun Whan, K.; Min-Jung, C.; Kyung-Yup, H. 1999. Correction of hydrogen peroxide interference on standard chemical oxygen demand test. *Water Research*, 33: 1247–1251.
- Koch, W.; Liebe, H. G.; Striefler, B. 1982. Betriebserfahrungen mit Bio-Filtern zur Reduzierung geruchstintensiver Emissionen. *Die Fleischmehlindustrie*, 34: 165–177.
- Londong, J.; Rosenwinkel, K. H. 2007. Industrie abwasserbehandlung, Weiterbildendes Studium Wasser und Umwelt Bauhaus-Universität Weimer, Weimer, 158–163. [in German]. ISBN 978-3-86068-321-7.
- Manni, G.; Caron, F. 1995. Calibration and determination of volatile fatty acids in waste leachates by gas chromatography. *Journal of Chromatography A*, 690: 237–242.
- Lurch, C. H. 1981. Abluftreinigung in der Tierkörperbeseitigung. *Die Fleischmehlindustrie*, 33: 29–32.
- Neumann, H. 1972. Die Kläranlage der Teirkörperverwertungsanstalt in Icker – ein Beispiel für die Möglichkeiten des Belebungsverfahrens und für die des Einsatzes von Tropfkörpern mit Kunststoff-Füllelementen. *Städtehygiene*, 23: 122–131.
- Neumann, H. 1979. Weitergehende Abwasserreinigung bei Tierkörperbeseitigungsanstalten. *Die Fleischmehlindustrie*, 31: 1–8, 17–25, 33–40.
- Neumann, H. 1986. Erfahrungen mit der weitergehenden Abwasserreinigung bei Tierkörperbeseitigungsanstalten. *Korrespondenz Abwasser*, 33: 944–953.
- Neumann, H., Viehl, K. 1966. Erfahrungen mit einem Belebungsgraben für die Abwässer einer Tierkörperbeseitigungsanstalt. *Gas- und Wasserfach*, 107: 1151–1154.
- Oberthür, R.C. 1981. Untersuchungen zur jahreszeitlichen Schwankung der Versmutzung des TKV-Abwassers. *Die Fleischmehlindustrie*, 33: 73–77.
- Roeske, W. 2007. *Tinkwasserdesinfektion*. Oldenbourg Industrieverlag GmbH, München: 87–94. ISBN 978-3-8356-3119-9.
- Rüffer, H.; Rosenwinkel, K. H. 1991. *Taschenbuch der Industrieabwasserreinigung*. Oldenbourg Verlag, München Wien. 248-273. ISBN 3-486-26131-2.
- Spigler, R.; Brauer, H. 1982. Biologische Reinigung des Abwassers einer Tierkörperbeseitigungsanstalt in einem Hochleistungsreaktor. *Die Fleischmehlindustrie*, 34: 142–150.
- Steiner, N.; Gec, R. 1992. Plant experience using hydrogen peroxide for enhanced fat flotation and BOD removal. *Environmental Progress*, 11: 261–264.
- Talinli, I.; Anderson, G. K. 1992. Interference of hydrogen peroxide on the standard COD test. *Water Research*, 26: 107–110.
- Temper, U.; Müller, R.; Metzner, G. 1987. Untersuchungen an einer hochbelasteten Sauerstoff-Belebungsanlage für TBA-Abwasser im Hinblick auf ein neues Abwasserreinigungskonzept mit anaerober Vorbehandlung. *Die Fleischmehlindustrie*, 39: 102–110.
- U. S. Peroxide. 2009. Available on the Internet: <<http://www.h2o2.com/industrial/applications.aspx?pid=83&name=Industrial-Applications>>
- Wildmoser, A. 1980. Betriebsauswertung von LINDOX-Abwasserreinigungsanlagen bei Tierkörperverwertungen. *Die Fleischmehlindustrie*, 32: 1–5.
- Wildmoser, A.; Gregor, K. H. 1981. Biologischer Abbau und Stickstoffentfernung bei hochbelasteten TKV-Abwässern. *Die Fleischmehlindustrie*, 33: 79–82.
- Wolf, E. 1986. *Beitrag zur anaeroben Behandlung von Schweinegülle und organisch hochverschmutzten Abwässern aus der tiermehlherstellung*. Veröffentlichungen des Institutes für Siedlungswasserwirtschaft und Abfalltechnik der Universität Hannover. Heft 67: 376–379.
- Żak, S. 2003. The reaktor for chemical pretreatment and detoxication of wastewaters from organic utilization. *Pol. Pat. Appl.*, 358441 [in Polish].
- Żak, S. 2005. Pretreatment technology of the after-condensation sewage from animal origin material utilization. *Polish Journal of Chemical Technology*, 7(2): 85–93.
- Żak, S. 2005a. Use of pressure flotation and oxidation to pre-treat the post-condensing wastewaters from the process of utilizing material of animal origin. In *Proceedings of ECOpole'05, 2005*, 323–328.
- Żak, S. 2008. Problem of correction of the chemical oxygen demand values determined in wastewaters treated by methods with hydrogen peroxide. In *Proceedings of ECO-pole, 2*: 409–414.
- Żak, S. 2008a. Separation of fats from wastewaters and processing wastes using flotation for the needs of efficient sludge management. In *Management of Pollutant Emission from Landfills and Sludge*, Edited by: M. Pawłowska and L. Pawłowski. Copyright by Taylor & Francis Group. 265–271. ISBN 978-0-415-43337-2.
- Żak, S. 2010. The method of organic origin wastewater pre-treatment. Patent PL 204396 B1 [in Polish].