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EFFICIENCY OF FERRIC SULPHATE FOR REMOVAL OF PHOSPHORUS FROM MEAT PROCESSING WASTEWATER

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Meat processing wastewater is heavily contaminated with phosphorus. It can be removed from wastewater by the use of flocculants. Phosphorus removal efficiency was estimated by treating wastewater with ferric sulphate flocculant, containing 11.5 percent of the active ingredient Fe^{3+} by weight. The research was conducted with wastewater pretreated in an aeration tank. Wastewater, containing 41.0 ± 3.5 mg l^{-1} of total phosphorus (TP), was dispensed into calibrated 1.0 liter containers with the following concentrations of flocculating agent: 0, 30, 75, 120, 150, 300, 450, 600, 750, 900 and 1,050 mg/l.
The study showed that TP removal efficiency depends on the flocculant dose used for treatment. Increasing the flocculant dose decreases the efficiency of TP removal. One gram of Fe^{3+}, given the flocculant dose of 40 gFe^{3+}/m^3, removed 0.5 g/m^3 of TP, while 120 g/m^3 of the flocculant removed around 40 percent less. According to the dependence of total P removed on the flocculant dose calculated by its active ingredient Fe^{3+}, ferric sulphate flocculant is the most effective at doses of up to 60–80 g/m^3 of Fe^{3+}.
The use of ferric sulphate may be limited by its impact on pH and sulphate concentrations in the effluent wastewater. If pH is not additionally adjusted, a maximum concentration of 70 g Fe^{3+}/m^3 can be used in order to maintain the pH of wastewater above 6.5 and to keep final sulphate concentration below 300 mg/l. In summary, a maximum of 70 g Fe^{3+}/m^3 can be used based on the total P removal efficiency and limiting factors. Such dose could remove 28 g total P/m^3 from the wastewater. Since the permissible total P concentration in effluent wastewater is 4.0 mg/l, it is reasonable to use the ferric sulphate flocculant, containing 11.5 % of Fe^{3+} as an active ingredient, for treating wastewater with an initial total P concentration of up to 32 mg/l.

Keywords: ferric sulphate, meat processing wastewater, total P removal

INTRODUCTION

Meat processing wastewater can be ten times more polluted compared to domestic sewage. The treatment of such wastewater is more complex and often requires chemical precipitation. Flocculant/coagulant chemicals are either metallic salts or polymers. Studies have shown that various types of flocculants or coagulants are effective in treating highly contaminated wastewater (Martinez et al., 1999; Aguilar et al., 2003; Amuda et al., 2006).

Chemical precipitation is most commonly applied for the removal of phosphorus. One of the flocculants used is ferric sulphate ($Fe_2(SO_4)_3$) in which Fe^{3+} ions are active ingredients. Aqueous solution containing 10–14 % of Fe^{3+} by weight is most commonly used for chemical precipitation. This flocculant works well in a wide range of pH. The sludge treated by ferric sulphate is easier to dewater than sludge generated by use of other products such as ferric chloride or aluminum sulphate. Ferric sulphate enhances clarification by forming rapidly settling flocs, whereas ferrous sulphate does not form flocs suitable for clarification (Amuda et al., 2006).

Large coagullant/flocullant doses need to be used for the reduction of large phosphorus concentrations. Experimental results showed that the optimal dose of $FeCl_3$, $Fe_2(SO_4)_3$, $FeCl_2$ and $FeSO_4$ for the treatment of piggery wastewater is 2.0 g l^{-1} (Lee at al., 2004). Similarly, for the treatment of wastewater from various food industries, 450 mg/l of ferric sulphate was used (Konieczny at al., 2005). One of the shortfalls of using high doses of ferric salts is the fact that they have a significant negative effect on wastewater chemical parameters post-treatment.

Therefore the aim of this study was to research the efficiency of ferric sulphate $Fe_2(SO_4)_3$ for the removal of phosphorus from meat processing wastewater and to determine its impact on wastewater chemical parameters after treatment.

RESEARCH METHODS

The research of phosphorus removal efficiency was carried out with wastewater from meat processing plant. Generally wastewater is treated in biological treatment plants. Wastewater is pre-treated by quicklime prior to entering the aeration tank. Quicklime treatment increases the alkalinity of wastewater and the concentration of positively

charged ions, which aid the formation of flocs. Some pollutants sediment in primary sedimentation tanks after lime treatment. Primary treatment removes more than 50 percent of organic pollutants according to BOD. Wastewater, treated in aeration tank, conforms to the normative level according to BOD_7 but does not meet the requirements for permitted phosphorus concentration.

The phosphorus removal efficiency was performed in bench-scale testing. A widely used flocculant ferric sulphate $Fe_2(SO_4)_3$ was selected for phosphorus removal. The flocculant used in the study had the following characteristic properties: physical state - liquid, Fe^{3+} – 11.5 %, SO_4^{2-} – 32 %, pH – 1.0 and specific gravity – 1550 kg m^3.

The research was conducted with wastewater pretreated in an aeration tank. Wastewater was dispensed into calibrated 1.0 liter containers and the following concentrations of flocculating agent were added: 0, 30, 75, 120, 150, 300, 450, 600, 750, 900 and 1,050 mg/l. Wastewater was mixed with a flocculant and allowed to settle. After sludge sedimentation water was sampled for testing chemical properties. The following parameters were measured in wastewater samples: pH, BOD_7, COD, total P (TP), total N (TN), chlorides and sulphates.

RESEARCH RESULTS

Meat processing plants generate heavily contaminated wastewater. Chemical characteristics of wastewater used in the study are presented in Table 1.

Table 1. Main parameters of meat processing wastewater used in the study (average ± standard deviation).

Study parameter	pH	BOD_7, mgO_2/l	COD, mgO_2/l	Total N, mg/l	Total P, mg/l	Chlorides, mg/l	Sulphates, mg/l
Before treatment	6.8±0.3	2189±717	3071.0±728.0	302.0±81.9	78.0±31.8	626.0±443.0	68.0±24.0
After treatment, prior to addition of flocculant	7.65±0.05	9.87±2.63	93.0±0.50	25.2±5.6	41.0±3.5	336.0±10.0	54.0±6.5
Maximum permissible concentration (MPC) for environmental release*	>6.5–<8.5	29.0	125.0	30.0	4.0	1000.0	300.0

* Nuotekų tvarkymo reglamentas (Wastewater treatment regulations). Valstybės žinios, 2006-05-25, Nr. 59-2103 (in lithuanian)

Parameters, indicated in Table 1, show that wastewater was heavily contaminated prior to treatment. The level of contamination was around 5–6 times higher compared to household wastewater. After fully treating wastewater in an aeration tank, most of the parameters met or were close to the maximum allowable concentrations for wastewater release into the environment. The normative parameters for the discharge of wastewater usually depend on the volume of wastewater to be discharged and the capability of wastewater receiver to accommodate the wastewater without compromising water quality to unacceptable levels. In this study, no such restrictions applied; therefore Table 1 shows the minimum requirements for wastewater after treatment. According to the data, total P concentration after treatment did not meet the requirements for environmental release. Even though removal efficiency of total P was 53.1 percent, it still exceeded the permissible concentration by around 8.5 times. Therefore, additional treatment was necessary to remove phosphorus from meat processing wastewater.

Since the wastewater was heavily contaminated with phosphorus, it was necessary to use a large enough flocculant dose to reduce the concentration of phosphorus to acceptable levels. The dependence of total P concentration change on the flocculant dose used is presented in Figure 1. The given data showed that 930 g flocculant dose per 1 m^3 of wastewater ought to be used in order to reduce total P concentration to 4.0 mg/l.

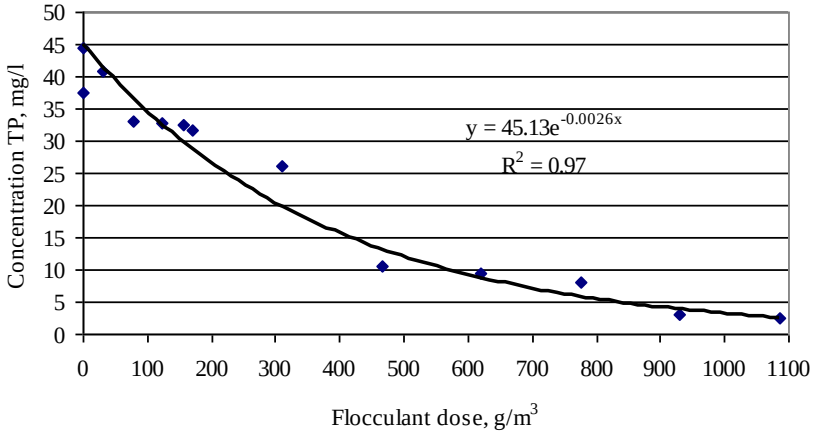

Figure 1. The change of total P concentration relative to the flocculant dose used

The use of flocculant had a positive impact on the COD parameter. With increasing flocculant dose, COD concentration in the wastewater was logarithmically decreasing. The change of COD concentration relative to the flocculant dose is shown in Figure 2.

The use of flocculant did not affect the concentration of other study parameters, such as total N or chlorides. Since ferric sulphate is very acidic, the treatment with flocculant had an impact on the pH of wastewater. The variation in pH depending on the dose of the flocculating agent is presented in Figure 3. The data shows that the flocculant dose of 930 g/m^3 brings the final effluent pH to 6.23, which does not meet the requirements for environmental release. Therefore, wastewater acidity could be modified by increasing the amount of lime used for the primary treatment. Wastewater pH could also be subsequently adjusted after treatment with flocculant.

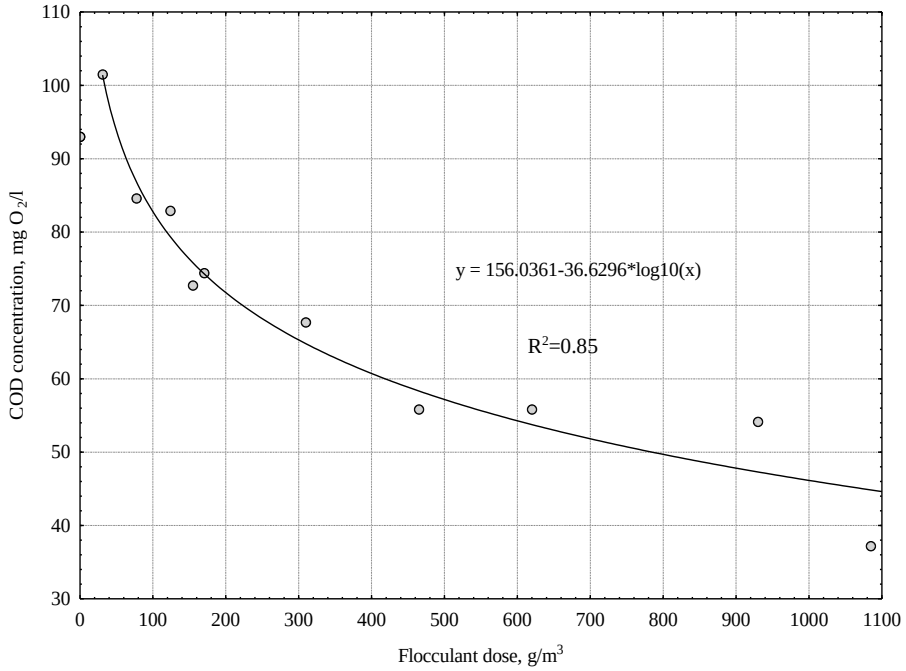

Figure 2. The change of COD concentration plotted against the flocculant dose

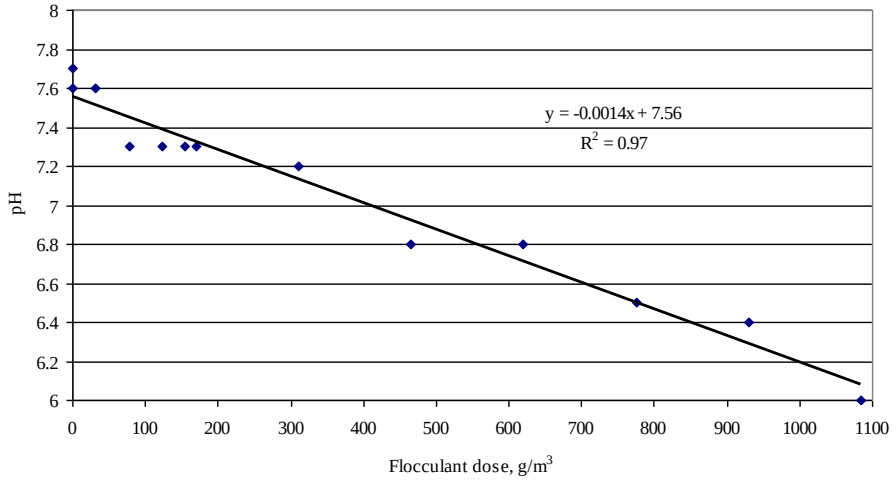

Figure 3. The change of pH in wastewater relative to the flocculant dose

The sulphate content of ferric sulphate flocculant forms 32 % by weight. Therefore, the use of flocculant impacted the concentration of sulphates in wastewater after treatment. The concentration of sulphates relative to the dose of the flocculant used is shown in Figure 4. According to regulations, sulphate concentration in wastewater receiver is limited to 300 mg/l. According to the graph in Figure 4, the maximum flocculant dose that does not result in exceeded sulphate concentration in treated wastewater is 690 g/m^3.

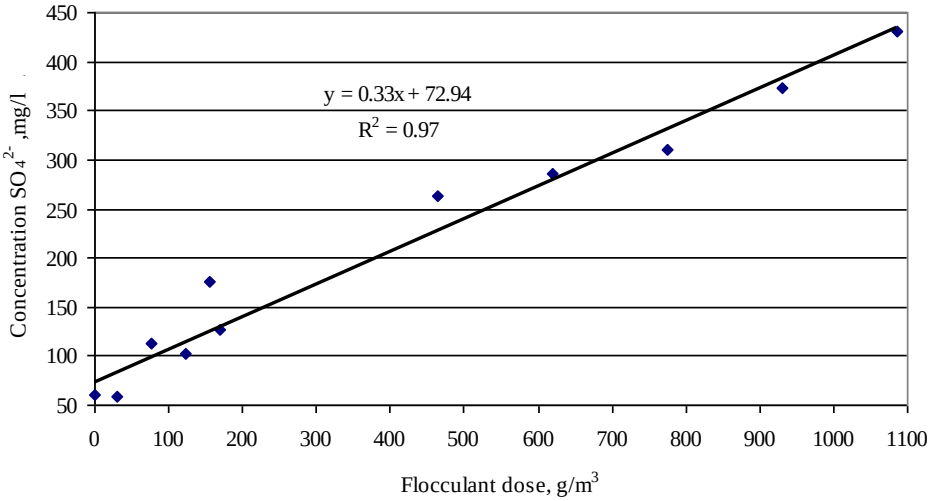

Figure 4. Concentration of sulphates in wastewater plotted against the flocculant dose used for treatment

The aforementioned dependencies could be used to estimate wastewater parameters relative to the flocculant dose used for treatment. It should be noted that these parameters may vary depending on the initial concentrations of pollutants after treatment in the aeration tank. The flocculant was primarily used for the removal of total P. In order to calculate the flocculant dose required for different initial concentrations of total P, the total P removal efficiency of different flocculant doses was estimated based on the concentration of active substance Fe^{3+}. Calculation results are depicted in Figure 5.

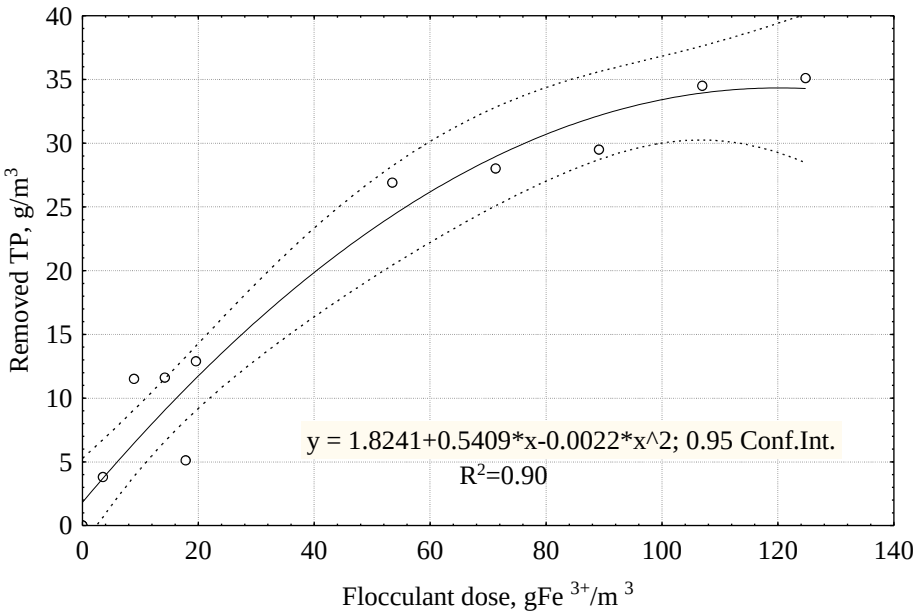

Figure 5. The concentration of total P removed relative to the flocculant dose, which is expressed as a concentration of an active ingredient Fe^{3+}

DISCUSSION AND CONCLUSIONS

Meat processing wastewater is heavily contaminated with phosphorus. It can be removed from wastewater by ferric sulphate flocculant containing 11.5 percent of active ingredient Fe^{3+} by weight. Total P removal efficiency is dependent on the dose of flocculant calculated by its active ingredient Fe^{3+}. The efficiency of total P removal decreases with an increasing flocculant dose. Given the flocculant dose of 40 g/m^3 calculated by Fe^{3+}, one gram of Fe^{3+} removes 0.5 g/m^3 of total P; however the flocculant dose of 120 g/m^3 removes around 40 percent less of total P. According to the dependence of total P removed on the flocculant dose calculated by its active ingredient Fe^{3+}, ferric sulphate flocculant is the most effective at doses up to 60–80 g/m^3 of Fe^{3+}.

The use of ferric sulphate may be limited by its impact on wastewater pH and sulphate concentrations. If pH is not additionally adjusted, a maximum concentration of 70 gFe^{3+}/m^3 can be used in order to maintain the pH of wastewater above 6.5. Similarly, flocculant dose should not exceed 70 gFe^{3+}/m^3 in order to keep final sulphate concentration below 300 mg/l. In summary, a maximum of 70 gFe^{3+}/m^3 can be used based on the total P removal

efficiency and limiting factors. Such dose could remove 28 g total P/m^3 from the wastewater. Since the permissible total P concentration in effluent wastewater is 4.0 mg/l, it is reasonable to use the ferric sulphate flocculant for treating wastewater with an initial total P concentration of up to 32 mg/l.

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