An assessment of synthesis and effectiveness of potassium ferrate(VI) as a green agent in the treatment of carwash wastewater

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Abstract – The paper deals with possible synthesis and use of potassium ferrate(VI) (K₂FeO₄) for the treatment and disinfection of carwash wastewater. Potassium ferrate(VI) was synthesized by wet method and the quality of the product was studied by SEM/EDX. The purity of the product was 90%. The treatment process was optimized by CCD and RSM. The optimum conditions for COD were established at pH 5.8, 0.97 g/L dose of K₂FeO₄ and with reaction time 23 min. Simultaneously, COD was decreased by 79.8%. At the same conditions the total proteolytic bacteria decreased by 92.1%. The application of ferric chloride as coagulant was also evaluated. The study indicated that the use of potassium ferrate(VI) and anionic flocculant is the better option than the use of ferric chloride and the same flocculant. The application of potassium ferrate(VI) is a viable option for the treatment of carwash wastewater.

Keywords – potassium ferrate(VI), carwash wastewater, central composite design, response surface methodology, water treatment

Introduction

One of the leading clean water consumers are carwashes. In many countries, the law requires 70–80% of carwash wastewater to be recycled [1]. This wastewater is characterized by certain physicochemical parameters that differ based on the cleaning processes, the amount of reused water, and the detergents or conditioners used in washing process. The main characteristic of this wastewater is low surface tension caused by the presence of residual surfactants [2]. It was found that for carwash wastewater the temperature is in the range of 28 to 30°C, pH of 5.9 to 8.8, total suspended solids (TSS) from 265 to 794 mg/L, chemical oxygen demand (COD) from 320 to 1019 mg O₂/L, oil and grease from 180 to 200 mg/L, turbidity from 118 to 380 NTU, and electrical conductivity from 84 to 100 μS/cm [3]. Recently, K₂FeO₄, a green chemical, is frequently proposed for the treatment of various types of wastewater and waste [4-6]. Because of thet, the aim of this paper is to examine the suitability of K₂FeO₄ as a green alternative, in the treatment of carwash wastewater. By adjusting the most important process parameters and monitoring the outcome, the efficiency of the treatment process was evaluated. The pH-value, reaction time, and amount of K₂FeO₄ were optimized using central composite design (CCD) and response surface methodology (RSM). The reduction of the number of microorganisms in wastewater under both treatments was compared in discussed processes.

Materials and Methods

The wastewater used in the research was collected from an automatic carwash located in Cracow, Poland. The wastewater from carwash was collected in 1-L bottles every hour per 24 hours by an autosampler and were transported and stored at 4°C. From average wastewater the microbiological and physicochemical analysis were performed. The properties and quality of synthesized potassium ferrate(VI) was studied by SEM/EDS, UV-VIS. All chemical used in the study were analytical or microbiological grade. All physicochemical and microbiological analysis
were performed according to ISO standards. In optimizing carwash wastewater treatment, CCD/RSM were used to plan the experiments and analyze the effects of three input parameters (pH, concentration of K$_2$FeO$_4$ (g/L), and process time (min)) on COD value (g O$_2$/L). COD is one of the most important parameters that characterizes wastewater contamination. For this reason, it was selected to gauge the wastewater treatments’ effectiveness.

**Results**

The SEM/EDX analysis indicated that crystal potassium ferrate(VI) was characterized by a purity of 90% and a typical appearance of crystals. Fig. 1 presents SEM/EDS analysis results.

Fig. 1. SEM/EDS analysis results

The tested wastewater was characterized by pH 7.1, COD 0.89 mg O$_2$/L and TOC 0.28 g/L. In addition, the wastewater had an intense putrefactive odor, the intensity of which was rated as 5 (very strong). The number of proteolytic bacteria was $2.4 \times 10^3$ cfu/mL. The conducted research with the use of planning and optimization of experiments made it possible to identify the most favorable parameter values, at which the reduction of the COD value was the greatest. Statistical studies showed a very good fit of the experimental values to the values approximated from the model ($R^2$ 0.9496, $R^2_{adj}$ 0.9160). Fig. 2 shows the change in the COD value of wastewater, depending on pH, K$_2$FeO$_4$ dose and reaction time. It was calculated that the lowest COD values (0.18 g O$_2$/L) can be obtained at pH 5.8, K$_2$FeO$_4$ dose 0.97 g/L during 23 min. A confirmation experiment was performed and the estimated value was in agreement with the experimental value, and the reduction in COD was 79.8%.

Fig. 2. The Change of COD value depending on pH, K$_2$FeO$_4$ concentration and reaction time
Conclusions

The use of K$_2$FeO$_4$ for the treatment of wastewater from truck washes allowed, among others, to reduce the COD value by 79.8% and significantly reduce the intensity of the odor (very weak, putrefactive), which was related to the reduction in the number of proteolytic bacteria (92.1%).

References