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Case Study

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ENHANCEMENT OF PRIMARY TREATMENT OF COMBINED SEWER OVERFLOW (CSO) BY USING FERRATE (VI)

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1 Project Overview

The main objective of this project is to conduct a comprehensive study in the area of enhancement of primary treatment of combined sewer overflow (CSO) by using different chemicals. During periods of high flow, exceeding the secondary treatment capacity of the plant, some flow receives preliminary and primary treatment, which has a potential impact on the ecological life of the receiving water body. In this paper, we highlight the use of ferrate, a well-known green and effective coagulant and oxidant (Jiang, 2013; Gombos et al., 2013). Numerous studies have shown the high removal capacity of ferrate for different types of contaminants such as diclofenac, carbamazepine, estrone COD, TSS, *E. coli*, bisphenol A (Lee et al.,2009, Yang et al.,2012, Zhou and Jiang, 2015; Han et al., 2015; Sun et al., 2016; Wang et al., Yates et al., 2014, Sharma, 2011; Dobosy et al., 2016).The main goal of the project is to reduce regulated parameter such as total suspended solids (TSS), turbidity and chemical oxygen demand (COD) to the regulated limits as per the Alberta guidelines. Laboratory scale experiments using a jar test apparatus were designed to optimize both the doses of the used chemical for the targeted parameters and the mixing conditions.

2 Innovation

Samples were collected from the wastewater treatment plant in four sampling events during November 2016, December 2016, and February 2017. Factorial design was designed to assess the jar test performance, aiming to optimize the ferrate dose levels and mixing conditions. Both high and low ferrate dose levels and the mixing condition for rapid and slow mixing were tested at high and low levels as shown in Table 1. Two different doses of ferrate were used 0.5 and 8 mg/L with and without cationic polymer of 1.25 mg/L. A jar treated with polymer only and blank jar were used as a control.

Table 1. Factorial design for four experiments

Experiment	Rapid mixing (rpm/min)	Slow mixing (rpm/min)	Symbol
1	300/3	30/20	(1/1)
2	300/3	15/10	(1/-1)
3	150/1	30/20	(-1/1)
4	150/1	15/10	(-1/-1)

3 Results and Discussion

As shown in Table 2 and Figure 1, 0.5 mg/L of ferrate with 1.25 mg/L of polymer showed the best removal efficiencies for the tested parameters in terms of mg of contaminant removed per mg of ferrate added. High dose of ferrate (8 mg/L) didn't show good results and that might be attributed to overdosing and reverse effect for the tested parameters. Moreover, the addition of polymer improved the removal efficiency of ferrate for 0.5 mg/l of Ferrate. The removal mechanism of TSS and COD might attribute to good coagulation and oxidation function of ferrate for the tested parameters. The pH of the samples was around 7 without any adjustment during the course of the entire experiments.

Table 2. The obtained values of mg removed /mg of coaglant.

Sample ID	mg TSS removed/mg Fe				mg COD removed/mg Fe			
	(1/1)	(1/-1)	(-1/1)	(-1/-1)	(1/1)	(1/-1)	(-1/1)	(-1/-1)
Ferrate 0.5 mg/L	241.0	216.0	210.0	271.0	450.6	266.4	301.9	219.0
Ferrate 0.5 mg/L + Polymer	*259.0*	*248.0*	*244.0*	*257.0*	*472.2*	*369.0*	*399.5*	*282.6*
Ferrate 8 mg/L	15.1	12.8	13.3	16.3	27.2	19.7	20.2	19.3
8mg/L Ferrate + Polymer	15.9	14.5	15.3	15.4	25.6	21.7	22.4	17.6
FeCl3 -8 mg/l Fe+ Polymer	18.3	16.6	20.3	17.9	23.1	21.0	26.8	19.1

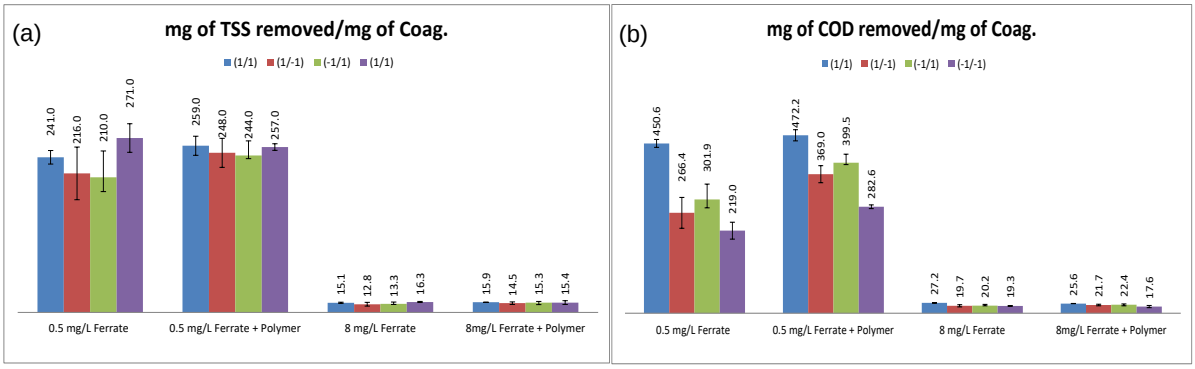

Figure 1. (a) mg of TSS removed per mg of Fe+ added; (b) mg of COD removed per mg of Fe+ added.

4 Lessons Learned and Future Work

1) The results showed that mixing condition is not a major factor affecting the ferrate effectiveness on removing target contaminants. . The results also indicated that 0.5 mg/L of Fe+ with polymer (-1/-1) was the optimum condition for the tested parameters.
2) The disinfection capacity of ferrate will require more investigations and might be more effective if ferrate is used for post treatment.
3) Different water matrices will be used to check the removal capacity of ferrate with different model micropollutants (MPs). Moreover, kinetics study for selected MPs will be conducted.

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References

Dobosy Péter, Éva Cseperke Vizsolyi, Imre Varga, József Varga, Győző G. Láng, Gyula Záray. 2016. Trichloroethylene removal from water by ferrate treatment. *Microchemical Journal* **127**: 74-78.

Gombos Erzsébet, Katalin Barkács, Tamás Felföldi , Csaba Vértes, Magdolna Makó, György Palkó and Gyula Záray. 2013. Removal of organic matters in wastewater treatment by ferrate (VI)-technology. *Microchemical Journal* **107**: 115-120.

Han Qi, Hongjie Wang, Wenyi Dong, Tongzhou Liu, Yulei Yin, Hongkai Fan. 2015. Degradation of bisphenol A by ferrate (VI) oxidation: Kinetics, products and toxicity assessment .*Chemical Engineering Journal* **262**: 34-40.

Yang Bin, Guang-Guo Ying, Jian-Liang Zhao, Shan Liu, Li-Jun Zhou, Feng Chen.2012.Removal of selected endocrine disrupting chemicals (EDCs) and pharmaceuticals and personal care products (PPCPs) during ferrate (VI) treatment of secondary wastewater effluents. *Water research* **4 6**: 2194-2204.

Yates Brian J., Radek Zboril and Virender K. Sharma. 2014. Engineering aspects of ferrate in water and wastewater treatment – a review. *Journal of Environmental Science and Health*, **Part A: 49**: 603-1614.

Jiang Jia-Qian. 2013. The role of ferrate (VI) in the remediation of emerging micro pollutants. *Procedia Environmental Sciences* **18**: 418-426.

Sharma Virender K.. 2011. Oxidation of inorganic contaminants by ferrates (VI, V, and IV) kinetics and mechanisms: A review. *Journal of Environmental Management* **92:**1051-1073.

Sun Xuhui, Qi Zhang, He Liang, Li Ying, Meng Xiangxu, Virender K. Sharma. 2016. Ferrate (VI) as a greener oxidant: Electrochemical generation and treatment of phenol. *Journal of Hazardous Materials* **319**: 130-136.

Lee Yunho,Saskia Gisela Zimmermann, Anh Trung Kieu, and Urs Von Gunten. 2009. Ferrate (Fe(VI)) Application for Municipal Wastewater Treatment: A Novel Process for Simultaneous Micropollutant Oxidation and Phosphate Removal.*Environ. Sci. Technol*. **43**: 3831-3838.

Wang Yingling, Haijin Liu, Guoguang Liu, Youhai Xie and Shuyan Gao. 2015. Oxidation of diclofenac by potassium ferrate (VI): Reaction kinetics and toxicity evaluation. *Science of the Total Environment* **506–507**: 252-258.

Zhou Zhengwei, Jia-Qian Jiang . 2015. Reaction kinetics and oxidation products formation in the degradation of ciprofloxacin and ibuprofen by ferrate (VI).*Chemosphere* **119**: S95-S100.