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Ferrate VI: An Environmentally Friendly Oxidant for Water Treatment

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ABSTRACT

Water contamination is a common problem all over the world. Safe drinking water, sanitation, and hygiene are crucial to human health and well-being. Some of the common water purification methods are sedimentation or settling, boiling/distillation, chemical treatment, disinfection, and filtration. Chlorine and its compounds can kill waterborne bacteria and viruses, and they are used as disinfectants in water treatment. However, some of their byproducts can cause harmful health effects. The higher oxidation state of iron i.e., Ferrate (VI) possesses relatively higher redox potential as compared to other commonly used oxidants (chlorine dioxide, iodine, bromide, ozone), in water treatment. Further, Ferrate (VI) forms non-toxic, non-mutagenic, and non-carcinogenic byproducts during water treatment processes [1].

This research focuses on three important aspects that make Ferrate (VI) a preferred environmentally friendly oxidant for water treatment; namely: i) removal of toxic heavy metals like Cadmium - Cd (II) [2]; ii) destruction and removal of antibiotics, such as tetracycline; and iii) destruction of bacteria such as tetracycline-resistant *E. coli* from wastewater [1]

FERRATE(VI): REMOVAL OF CADMIUM (II)

Cadmium (Cd) is known as a non-biodegradable and corrosion resistant heavy metal that was used widely in various industries including painting, alloying, and electroplating (Pérez-Rama, Alonso, López, & Vaamonde, 2002; Solisio, Lodi, Soletto, & Converti, 2008) [4],[5].

As being used and released into the environment, an overabundant amount of Cd become a significant threat to human and other living organisms in the ecosystem. An excessive amount of Cd may cause chronic exposure, which leads to kidney failure or liver damage, bone degeneration, and even cancers (Muehe et al., 2013)[6].

With high oxidation potential, Ferrate (VI) could be reduced to Fe(III) oxides which were popularly used to remove diverse contaminants via coagulation or absorption [2].

According to an experimental research project conducted by Wang, Zhang and others in 2019, efficiency of removing Cadmium- Cd(II) from aqueous solution by potassium ferrate (K2FeO4, as a source of Fe(VI)) is as high as 98.97%[2]. The results of this experimental research [2] were shown in **Figure 1; Ref 2.** The result data charts in **Figure 1** illustrate the rate of Cd removal by potassium ferrate as a function of Fe(VI) dosage (**A**); initial pH (acidity) of the Cd solution (**B**); and initial concentration of Cd **(C)**. As shown in **figure 1**, higher doses of Fe(VI), basic [pH] conditions, and higher Cd(II) concentration results in efficient removal of Cd(II) from the solution.

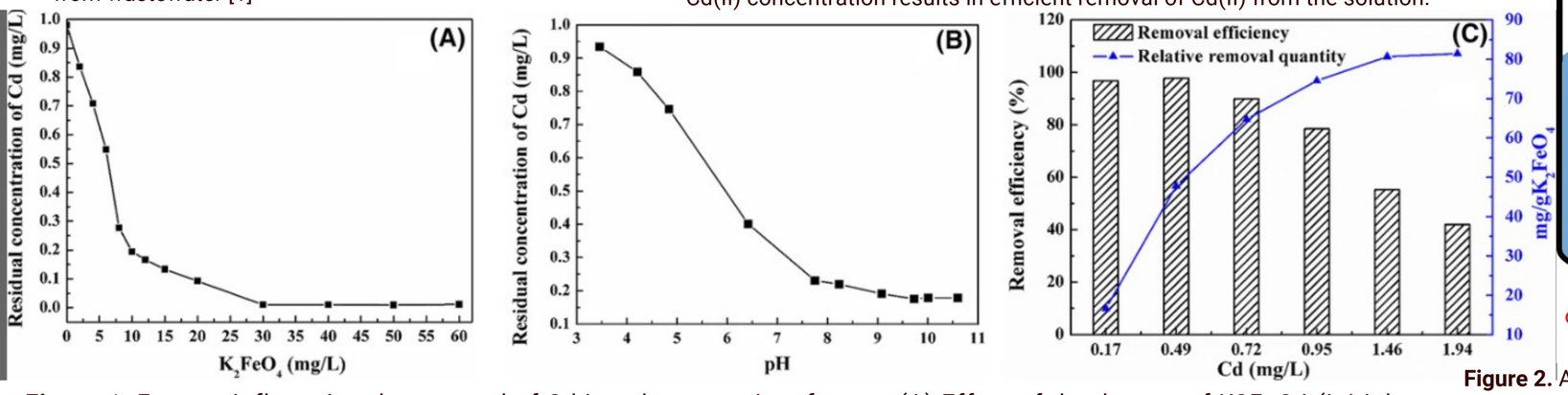

Figure 1. Factors influencing the removal of Cd ions by potassium ferrate: (A) Effect of the dosage of K2FeO4 (Initial concentration of Cd(II) = 1 mg/L; pH≈6.9); (B) Effect of initial solution pH (Dosage of Fe(VI) = 10 mg/L; initial concentration of Cd(II) = 1 mg/L); (C)Effect of the initial concentrations of Cd(II) (Dosage of Fe(VI) = 10 mg/L; pH≈6.9) (Wang et al., 2019). [2] ***Note: figure 1** came from the research project (Wang et al., 2019) [in reference 2].

CONCLUSION

Based on the potential and promising properties of Ferrate (VI) as a green oxidant, the application of Ferrate (VI) should be considered as an environmentally friendly and effective method in the water treatment process.

Thanks to other experimental research, Fe(VI) was confirmed to have the ability to react with other contaminants to form non-toxic compounds, non-mutagenic, non-carcinogenic by-products during water treatment processes [1].

CONCLUSION

Those figures, data and information also demonstrate how Ferrate (VI) behaves as an effective reagent for the water treatment processes, including purifying raw water from toxic heavy metals like Cadmium - Cd (II) [2], inactivating a wide range of pathogenic microorganisms, e.g.,, *E.coli* in wastewater [1]. Overall, Ferrate(VI) behaves as a competent disinfectant and a green oxidant which is sufficient for the wastewater treatment processes to benefit human wellness and the aquatic environment in the long term.

FERRATE(VI): REMOVAL OF TETRACYCLINE AND TETRACYCLINE RESISTANT *E. COLI* BACTERIA

Tetracycline is a type of antibiotic that has been used widely in medical treatment and was released into the environment via urine and wastewater [3],[8]. This antibiotic consumption and excessive release have become a serious concern to public health since they contaminated the aquatic environment, and has resulted in antibiotic-resistant bacteria [7],[3].

During water treatment, one of the properties of Ferrate (VI) is its ability to degrade an antibiotic substance named tetracycline and tetracycline resistant bacteria *E.coli* and related genes, viz., *tet*A/ *tet*R simultaneously [3].

According to scientific research conducted by Zhang, and others (Zhang et al., 2021) [3], Ferrate (VI) was confirmed to have the ability to remove tetracycline and its resistant bacteria *E.coli* simultaneously. Moreover, the oxidized byproduct of tetracycline appears to be less toxic than the parent antibiotic.

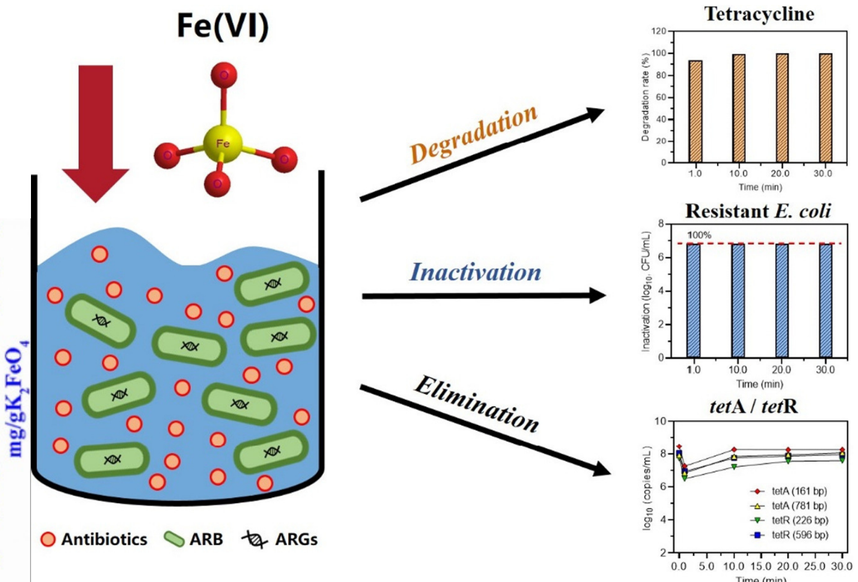

Figure 2. A graphical abstract from scientific research (Zhang et al., 2021) [3] showed how Ferrate(VI) helps remove tetracycline via degradation, inactivate resistant *E.coli*, and eliminate related antibiotic-resistant genes *tet*A/ *tet*R in a sample solution.

***Note: figure 2** came from the research project (Zhang et al., 2021)[in reference 3].

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