

Potassium ferrate (K_2FeO_4) oxidation of Landfill Leachate and Sewage: Removal of COD and BOD

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Abstract: Oxidation of landfill leachate and sewage from different locations using potassium ferrate and percentage removal of Chemical oxygen demand (COD) and Biochemical oxygen demand (BOD) using K_2FeO_4 at 298 K for 30 minutes were investigated. Ferrate oxidized the landfill leachate and sewage and was effective within 30 minutes at 298 K temperature. The percentage COD reduction after treatment ranged from 61.70 to 70.00 % and 61.00 to 68.70 % for landfill leachate and sewage respectively. The concentration of BOD reduced with the range of 42.60 to 53.56 %, and 48.30 to 60.30 % for landfill leachate and sewage respectively. The results obtained for landfill leachate ranged from 13400 ± 0.80 to 20420.13 ± 0.60 MgL^{-1} , BOD; 16930 ± 2.00 to 33400 ± 0.20 MgL^{-1} COD; 1.03 ± 0.05 to 2.50 ± 0.50 MgL^{-1} , DO; 6450 ± 1.30 MgL^{-1} , TDS; 693.40 ± 0.20 , TSS; 1634.00 ± 1.10 to 3140.15 ± 3.40 μsCm^{-1} , EC and 6.80 to 8.60, pH. The concentration for sewage ranged from 113.30 ± 0.30 to 310.60 MgL^{-1} , BOD; 840.30 ± 0.60 to 7540.70 ± 1.80 MgL^{-1} , COD; 0.06 ± 0.30 to 0.10 ± 0.00 MgL^{-1} , DO; 959.00 ± 1.40 to 1070.60 ± 1.20 MgL^{-1} , TDS; 14560 ± 1.60 to 21000 ± 1.80 MgL^{-1} , TSS; 970.60 ± 0.70 to 1600.80 ± 0.90 μsCm^{-1} , EC and 6.60 to 8.70, pH.

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Keywords: Leachate, Sewage, Ferrate, Oxidation, COD, BOD.

1. Introduction

Potassium ferrate K_2FeO_4 is most common and relatively easily synthesized ferrate salt moreover, the stability of this compound is fairly good under certain specified conditions. It is black-purple in color and remains stable in mixture excluded air exposure for longer period. In aqueous solution, the $Fe^{IV}O_4^{2-}$ is monomeric with a high degree of four covalent character equivalent oxygen atoms [Diwakar and Lee 2011]. Ferrate oxidizes organic compounds and reduces to ferric which, in turn, leads to precipitation as ferric oxide/hydroxide promoting physical removal of organic compounds [Graham et al., 2004].

Potassium ferrate is insoluble in commonly used organic solvents and can be suspended in benzene, ether, chloroform etc. without having rapid decomposition of compound [Diwakar and Lee, 2011]. Leachate is one of the main problems in the landfill sites due to its considerable amounts of organic matter, ammonia and total Kjeldahl nitrogen (TKN), heavy metals, chlorinated organic compounds and inorganic salts [Aygun et al., 2012]. Leachate is heavily polluted waste water with a composition of complexes containing four groups of pollutants; dissolved organic matter, inorganic macro-compounds, heavy metals and xenobiotic organic compounds [Filho et al., 2012, Kjeldsen et al., 2002].

The composition of landfill leachates varies depending on the nature of the deposited wastes, on soil characteristics, rainfall patterns and on the “age”

of the landfill usually in “young landfill leachates” the dissolved organic matter is mostly made up of volatile fatty acid (i.e. a high BOD/COD ratio) that decrease with increasing landfill age as a result of the anaerobic decomposition that takes place in the landfill site [Mashal et al., 2012].

Potassium ferrate has high oxidation capacity, it also possesses the coagulation function, and it is reduced to form ferric ions or ferric hydroxide in the oxidation of other contaminants. Potassium ferrate (VI) as a chemical reagent for water and wastewater treatment has been well reviewed by the authors [Jiang et al., 2005, Jiang and Lloyd 2002].

Potassium ferrate (K_2FeO_4) is the best known member among the family of iron (IV) derivatives. It is made and purified more easily, and it is also used in making other ferrates. It is both more stable and more readily made [Delaude and Laszlo 1996]. The ferrate dianion FeO_4^{2-} has a tetrahedral structure slightly distorted in the crystal state [Delaude and Laszlo 1996]. The ion remains monomeric in aqueous solution and its four oxygen atoms become equivalent and exchange slowly with the solvent [Delaude and Laszlo 1996].

This study investigates the performance of K_2FeO_4 for the removal of COD and BOD by the oxidation of landfill leachate and sewage. The physical and chemical properties of sewage and landfill leachate were also investigated.

2. Material and Methods

Sample collection and preparation

The leachate samples were collected from three different locations and were labeled LFLA, LFLB and LFLC which represent Obehe Landfill site (Abia, Nigeria), Oba landfill (Onitsha, Nigeria) and Asaba landfill (Delta, Nigeria) respectively. Sewage samples were also collected from septic tanks in three locations, labeled SWA, SWB and SWC which represent Port Harcourt, Aba and Onitsha respectively.

Sample analyses:

The samples were taken to the laboratory in sealed plastic bottle, stored at -4°C before analyses. The initial pH of the sample was determined by a pH meter, the COD and BOD were determined at 298 K for 30 minutes following standard methods for the examination of water and wastewater [APHA-AWWA, 1989].

3. Results

Table 1: Physiochemical Properties of Landfill Leachate

PARAMETERS	SAMPLES		
	LFLA	LFLB	LFLC
BOD (MgL ⁻¹)	20420.13 ± 0.60	17700 ± 0.60	13400 ± 0.80
COD (MgL ⁻¹)	33400 ± 0.20	28031 ± 2.60	16930 ± 2.00
DO (MgL ⁻¹)	1.03 ± 0.05	1.80 ± 0.01	2.50 ± 0.50
TDS (MgL ⁻¹)	16340 ± 2.20	9340.40 ± 1.50	6450 ± 1.30
TSS (MgL ⁻¹)	693.40 ± 0.20	1430.70 ± 1.30	1780.20 ± 2.30
EC(μSCM ⁻¹)	3140.15 ± 3.40	1634.00 ± 1.10	2130.00 ± 1.80
pH	6.80	7.40	8.60

Table 2. Physiochemical Properties of Sewage

PARAMETERS	SAMPLES		
	SWA	SWB	SWC
BOD (MgL ⁻¹)	310.60 ± 0.10	260.10 ± 0.30	113.30 ± 0.30
COD (MgL ⁻¹)	840.30 ± 0.60	1094.40 ± 1.40	7540.70 ± 1.80
DO (MgL ⁻¹)	0.06 ± 0.30	0.10 ± 0.00	NIL
TDS (MgL ⁻¹)	1070.60 ± 1.20	959.00 ± 1.40	1120.70 ±
TSS (MgL ⁻¹)	14560 ± 1.60	18800.50 ± 0.70	21000 ± 1.80
EC(μSCM ⁻¹)	970.60 ± 0.70	1279.00 ± 2.40	1600.80 ± 0.90
pH	8.70	7.50	6.60

Table 3. Percentage Removal of COD by K₂FeO₄ at 298 K for 30 minutes

Samples	Co	Ct	% Removal
LFLA	33400	12792.20	61.70
LFLB	28031	9979	64.40
LFLC	16930	5079	70.00
SWA	840.30	307.55	63.40
SWB	1094.40	342.50	68.70
SWC	7540.70	2940.87	61.00

C₀= Initial concentration, C_t= Concentration at 30 minutes

Table 4. Percentage Removal of BOD by K₂FeO₄ at 298 K for 30 minutes

Samples	Co	Ct	% Removal
LFLA	20420	11721.08	42.60
LFLB	17700	8796.90	50.30
LFLC	13400	6231	53.50
SWA	310.60	160.20	48.30
SWB	260.10	109.50	57.90
SWC	113.30	44.98	60.30

C₀= Initial concentration, C_t= Concentration at 30 minutes

4. Discussions

The concentration levels of COD, BOD, TSS, TDS, DO and electrical conductivity of selected landfill leachate and sewage were presented in table 1. The results obtained for landfill leachate ranged from 13400 ± 0.80 to $20420.13 \pm 0.60 \text{ MgL}^{-1}$, BOD; 16930 ± 2.00 to $33400 \pm 0.20 \text{ MgL}^{-1}$ COD; 1.03 ± 0.05 to $2.50 \pm 0.50 \text{ MgL}^{-1}$, DO; $6450 \pm 1.30 \text{ MgL}^{-1}$, TDS; 693.40 ± 0.20 , TSS; 1634.00 ± 1.10 to $3140.15 \pm 3.40 \mu\text{S cm}^{-1}$, EC and 6.80 to 8.60, pH. The concentration for sewage ranged from 113.30 ± 0.30 to 310.60 MgL^{-1} , BOD; 840.30 ± 0.60 to $7540.70 \pm 1.80 \text{ MgL}^{-1}$, COD; 0.06 ± 0.30 to $0.10 \pm 0.00 \text{ MgL}^{-1}$, DO; 959.00 ± 1.40 to $1070.60 \pm 1.20 \text{ MgL}^{-1}$, TDS; 14560 ± 1.60 to $21000 \pm 1.80 \text{ MgL}^{-1}$, TSS; 970.60 ± 0.70 to $1600.80 \pm 0.90 \mu\text{S cm}^{-1}$, EC and 6.60 to 8.70, pH.

The results presented in table 3 and 4 demonstrated the performance of potassium ferrate (VI) in reducing/removal the concentration of BOD and COD in landfill and sewage from selected locations. The COD reduction after treatment ranged from 61.70 to 70.00 % and 61.00 to 68.70 % for landfill leachate and sewage respectively. The concentration of BOD reduced with the range of 42.60 to 53.56 %, and 48.30 to 60.30 % for landfill leachate and sewage respectively. The percentage reduction COD with potassium ferrate was greater than reduction of BOD. The results obtained in this study is similar to results obtained by Aygun, Shirang, Chatterjee, Shirang, Saleem [Aygun et al., 2004, Barbusiński and Pieczykolan, Shirang and Kaustavo, 2004, Saleem, 2007].

Conclusion

This study reveals the effect of K_2FeO_4 in chemical oxygen demand (COD) and biochemical oxygen demand (BOD) load reduction of landfill leachate and sewage. The physiochemical properties were determined and percentage removal of COD and BOD were calculated. It was observed the technique was a fast and efficient procedure and about 60 to 70 percent removal efficiency was obtained in 30mins for total COD removal and 40 to 70 percent removal was achieved in 30 min of reaction for removal of BOD.

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