Ferrate Water Treatment System

Ferrate Water Treatment "FWT" System Overview

Recovered Earth Technologies, LLC ("RET") is a global leader in recovery of natural resources through the combination of exclusively licensed and patented technologies. The **Ferrate Water Treatment ("FWT") System** is the first patented, on-site Ferrate reactor for municipal and industrial applications. With this breakthrough of small, inexpensive, transportable on-site synthesis reactors, Ferrate can now be delivered continuously for chemical, industrial, and environmental treatment processes in commercially significant quantities. The Ferrate Treatment System is made from off-the-shelf parts, can be scaled for any application, and pumps a liquid ferrate product directly into treatment process streams. The system has a small footprint. It can be skid-mounted and shipped by air or truck to any location or facility. The system easily retrofits into existing plant infrastructure by piping to and from a self-contained unit.

Ferrate Systems Capacity: 3.0 - 60.0 Million Gallons per Day

Historically, at over $20/lb, Ferrate had been just too expensive for bulk industrial use. Before the creation of the patented on-site synthesis process, no one had ever manufactured Ferrate in commercial quantities at a reasonable price. Synthesizing Ferrate on-site eliminates product handling and transport and reduces the traditional cost of manufacturing a Ferrate product by over 90%. Prior schemes tried to manufacture a dry, stable, powdered Ferrate product in a central plant which then had to be packaged in hermetically sealed containers to keep it from contacting air or water while it was transported to the site of use. RET's system now makes it possible to commercialize a highly reactive, Ferrate treatment product. By synthesizing Ferrate proximal to the site of its use, the systems eliminate all central-station manufacturing, transportation, distribution and product handling costs. Because our product is a liquid instead of a solid, it can be easily pumped and injected into standard industrial treatment processes. Most importantly, the system utilizes cheap, commodity-chemical feedstocks (caustic, bleach, ferric chloride) already found at most treatment plants. Substantial improvements in manufacturing economics enhance Ferrate's potential for multiple applications in treating drinking, ballast, municipal, and industrial waste waters and associated sludges and biosolids.

Recovered Earth Technologies has exclusively licensed the use of the Ferrate System in combination with RET's other technologies to create the most advance water treatment systems available today in any industry.

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Ferrate Water Treatment System

FWT Systems - Models, Dimensions & Capacities

Fe5

Fe50

Fe150

Fe300

Ferrate System Model	Dimensions (L x W x H) Feet / (Meters)	Treatment Capacity MGD / (Megaliters)*
Fe5	3.3′ x 2.0′ x 7.3′ (1.0 x 0.6 x 2.2)	3.0 / (11.4)
Fe50	14.0′ x 6.0′ x 8.0′ (4.2 x 1.8 x 2.4)	12 / (45.5)
Fe70	16.0′ x 7.0′ x 8.0′ (4.8 x 2.1 x 2.4)	14.5 / (55.0)
Fe150	18.0′ x 8.0′ x 8.0′ (5.5 x 2.4 x 2.4)	32.0 / (121.0)
Fe300	44.0′ x 8.0′ x 11.0′ (13.4 x 2.4 x 3.4)	60.0 / (226.0)

Ferrate Water Treatment Technology

- Is environmentally friendly and powerful enough to meet escalating treatment demands.
- Is cost-effective to operate and maintain.
- Can be synthesized from commodity feedstocks.
- Utilizes existing plant infrastructure and plugs into existing treatment processes.
- Is highly scalable, modular and easy to retrofit and implement.
- Requires a small footprint; critical for landlocked treatment facilities.
- Requires minimal incremental capital investment compared to UV or Ozone.
- Is NSF International Standard 61 Certified

Fe70

Ferrate Treatment Technology

Ferrate is extremely powerful, can deliver multiple treatments from a single application, does not create disinfection byproducts, is environmentally friendly, and solves difficult treatment challenges that other oxidants can't touch. Most importantly, Ferrate is often the least expensive and most effective treatment option.

Ferrate treatment units are powerful, high-valant $[FeO_4]^{2-}$ iron molecules that oxidizes process chemicals, disinfects pathogens and scale causing organisms, and coagulants or co-precipitates dissolved and particulate metals; all from a single dose. Ferrate is a supercharged iron molecule in which iron is in the plus 6 oxidation state; it is better known as Iron(VI).

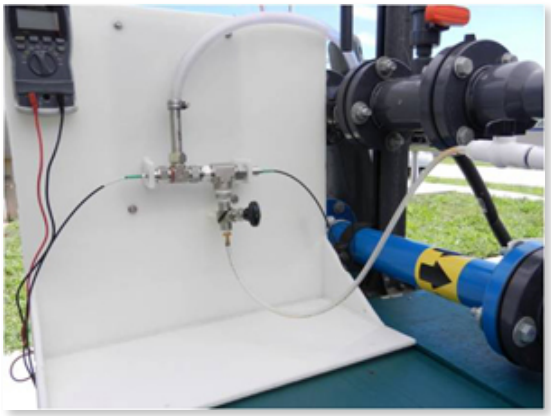
As Ferrate (iron six) is reduced (by stealing electrons from something else) it falls back down from iron 6+ to 5+ to 4+ to 3+ (ferric iron), in the process acting as an Oxidant, then Coagulant, and finally as a Flocculent. Uniquely, Ferrate performs these three distinct treatment functions from the application of a single dose. Therefore, Ferrate has the potential to work in many water and wastewater treatment markets worldwide. In a single application, Ferrate can simultaneously perform as an oxidant, disinfectant and coagulant.

Ferrate is more powerful than other oxidants such as ozone and chlorine dioxide. It can replace coagulants such as ferric chloride, alum and polymers for the removal of metals, non-metals and humic acids. It outperforms other disinfectants such as UV, hydrogen peroxide, and chlorine and can kill many chlorine resistant organisms such as aerobic spore-formers and sulphite-reducing clostridia.

Table 5.1 is a long but only partial list of the contaminants that Ferrate can be used to treat. This list was compiled from independent research results found in the published studies around the world. Note that we have not attempted to include efficacious dosages or the particular treatment regimen employed. For more detailed information, please lookup specific studies and results.

Ferrate Water Treatment System

Guaranteed Regulatory Compliance



Ferrate Dose Monitor: Flow Through Cell

Miniaturized Electronics Package: Small profile at 3"x5"x1" thick.

4 to 20 milliamp Output: PLC Control.

Real-time Feedback: System provides control to increase or decrease dosing pump rate based on the measured concentration of Ferrate in the stream being dosed.

Data logging: Provides regulatory assurance that the designed Ferrate dose is maintained even if characteristics of a wastewater stream vary.

Industrial Effluent / Wastewater Applications

In industrial effluent, Ferrate's powerful and unique chemistry can be used in the following applications:

- Removal of Heavy Metals (ex. Arsenic, Chromium)
- Disinfection (Without Disinfection Byproducts)
- Pesticide Removal
- Phosphorus Reduction
- Deodorization
- Biosolid Stabilization
- Pre-Oxidation of Organics
- Coagulation
- Algae Removal
- Biofouling and Biofilm Control
- Destruction of Emerging Contaminants (ex. EDCs, PPCPs)
- Frac Water Recycling
- Mine Waste Treatment

Other Ferrate System Applications

- Produced Water from Oil Industries
- Power Generation
- Mining / Fracking
- Ballast Water & Invasive Species
- Water & Wastewater Reuse
- Municipal Wastewater
- Pulp & Paper Production
- Drinking Water Purification
- Sludges: Municipal, Industrial & Agricultural

Industrial wastewater is a fertile field for RET's Ferrate treatment oxidant. Industrial wastewater contaminants vary widely across such diverse industries as pulp and paper, mining, food and beverage, pharmaceutical manufacturing, electroplating, metal fabricating, aquaculture, leather tanning, oil and gas extraction, hazardous waste, and industrial farming. There are some distinct advantages for RET to target the industrial wastewater market. These facilities are often privately owned and governed by closely-knit boards that can quickly make decisions and will spend money to solve problems.

The effectiveness of ferrate as a powerful oxidant in the entire pH range, and its use in environmental applications for the removal of abroad range of contaminants has been well documented by several researchers (Sharma, 2002; de Luca et al, 1992; White and Franklin, 1998). Numerous possibilities exist for the use of Ferrate technology in industrial and agricultural wastes. There is scientific evidence that ferrate can effectively remove arsenic, algae, viruses, pharmaceutical waste, and other toxic heavy metals of concern (Lee et al. 2004; Kazama, 1995).

Table 5.1 - Contaminants Treatable by Ferrate

Endocrine Disrupting Chemicals (EDCs)
Bisphenol A
Estrone (E1)
17b-Estradiol (E2)
17 a-Ethynylestradiol (EE2)
16a-Hydroxyestrone
4-Nonylphenol
4-tert-Octylphenol

Pharmaceuticals
Sulfamethoxazole
Ibuprofen

Oxidation (Inorganic and Organic Contaminants)
1,-Diaminopropane
1,2-Ethanediol
1,2-Propanediol
I,2,4-Butanetriol
1,3-Propanediol
2-Mercaptobenzoic acid
2-Mercaptoethanesulfonic acid
3-Amino-1-propanol
3-Mercaptopropionic acid
Acetaldehyde
Acetone
Alpha-Hydroxy toluene
Ammonia
Aniline
Benzenesulfinate
Chloral
Cyanide
Cysteine
Cystine
Diethylamine
Diethylsulfide
Dimethylamine
Dimethylglycine
Dimethylsulfoxide
Ethyl alcohol
Ethyl Ether
Ethylene glycol
Ferrocyanide
Fonnic acid
Formaldehyde
Glycerol
Glycine
Glycolaldehyde
Glycolic acid
Glyoxal
Glyoxylic acid
Hydrazine
Hydrogen sulfide
Iminodiacetic acid
Isopropyl alcohol
Methionine
Methyl alcohol
Methylamine
Methylhydrazine
Neopentyl alcohol
Nitriloacetic acid
Nitrite
Nitrosamines
Methanol
N-methyliminodiacetic acid
Oxalic acid
Phenol
p-Aminobenzoic acid
p-Hydroquinone
p-Nitroaniline
p-Toluidine
Sarcosine
Thioacetamide
Thiodiethanol
Thiosulfate
Thiourea
Thioxane
Trimethylaldehyde

Disinfectant
Aerobic spore-bearers
B. cereus
Brine Shrimp (Artemia salina)
Bryopsis sp.
Caulerpa taxifolia
Dasya baillouviana
Enteromorpha intestinalis
Eschericha coil (E. coli)
F-specific RNA-coliphage QB
f2 Coliphage
Hermit Crab
Mangrove gribbles
Portunid Crab
S. aureus
S. bovis
S. globigii
Sea Urchin Eggs
S. facalis
S. fiexneri
Sphaerotilus
S. typhimurium
Styela plicata
Suplfite-reducing clostridia
Thermotolerant coliforms
Total coliform

Oxidant and Coagulant
1,1,2,2-tetrachloroethane
1,1,2-tichloroethane
1,1-dichloroethane
1,2-dichlorobenzene
1,2-Dichloroethylene
1,2,3-Trichlorobenzene
2-Chlorophenol
2-Nitrophenol
2,4,6-Trichlorophenol
2,4-Dichlorophenol
Acenaphene
Anthracene
Bromodichloromethane
Chemical Oxygen Demand (COD)
Chlorobenzene
Dichloromethane
Diethylphthalate
Dimethylphthalate
Ethylebenzene
Hexachlorobenzene
Nitrobenzene
Naphthalene
Pentachlorophenol
Phenanthrene
Toluene
Trichloroethylene

Pesticides
2,4-D (2,4-Dichlorophenoxyacetic acid)
2,4,5-T (2,4,5-Trichlorophenoxyacetic acid)
Dursban (0,0-Diethyl 0-(3,5,6-trichloro-2-pyridyl)-phosphorothiote)
EDB (Ethylene di-bromide or dibromoethane)
Rotenone
Silvex (Lso Octyl Ester)

Metal Cations Removed by Potassium Ferrate in Solution
Aluminum (A1(111))
Arsenic (As (III))
Barium (Ba(II))
Cadmium (Cd(III), Cd(II))
Calcium (Ca(II))
Cerium (Ce(I1I))
Cobalt (Co(II))
Copper (Cu(II))
Lead (Pb(II))
Magnesium (Mg(B))
Manganese (Mn(II))
Mercury (Hg(II))
Potassium (K(I))
Silver (Ag(I), Ag(II))
Thalium (T1(III))
Tin (Sn(li))

Metals, Including Other Contaminants, Removed by Potassium Ferrate in Industrial Wastewater
Cadmium
Chromium
Copper
Lead
Phosphorous
Zinc

Anions Removed by Potassium Ferrate in Solution
Arsenate
Arsenite
Chromate (CrO4 2-)
Molybdate (MoO4 2-)
Phosphate (PO4 3-)
Selenite (SeO3 2-)
Silicate (SiO2 2-)
Sulfate (SO 4 2-)
Sulfite (SO32-)