Ferrate(VI)™

MULTIFUNCTIONAL OXIDATION FOR WATER & WASTEWATER

Ferrate(VI), FeO_4^{2-}, combines contaminant oxidation with formation of Fe(III) solids.

Its performance depends on dose, pH, contact time and competing demand. [1,2]





Conceptual system illustration.

1. OXIDATION



Reacts with sulfide and selected organic and inorganic contaminants.

Transformation does not necessarily mean complete mineralization.

2. MICROBIAL INACTIVATION



Demonstrated against bacterial indicators; validate organism-specific exposure and treatment credit.

3. COAGULATION & CAPTURE



Reduction produces Fe(III) oxyhydroxide solids that can capture particles and phosphorus.

Remove these solids downstream.

CHEMISTRY THAT GUIDES DESIGN

- **Iron oxidation state:** +6; commonly supplied as potassium or sodium ferrate, or generated on site.
- Fe(VI) reduction to Fe(III) accepts three electrons per iron atom.
- Acidic standard potential: approximately +2.20 V versus SHE.
- Strongly alkaline standard potential: approximately +0.70 V versus SHE.

Standard potentials are reference-condition values—not operating ORP readings or a universal ranking of treatment effectiveness.

pH & STABILITY

Lower pH often increases reaction rates but accelerates ferrate decay. **Alkaline solutions** generally favor stability. Determine the practical window by water-specific tests.

DIRECT VS ACTIVATED FERRATE

Direct ferrate treatment is selective oxidation plus coagulation. Activated processes may involve Fe(V)/Fe(IV) and, depending on activation, radicals; validate each configuration separately.

ENGINEERING VALUE

One reagent can perform multiple functions, potentially simplifying selected treatment steps. Pilot testing must establish chemical demand, solids handling and lifecycle cost.

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[1] Sharma, 2002, Advances in Environmental Research 6:143–156. [2] Zhang et al., 2020, Chemosphere 242:125134.

References continued on page 4.

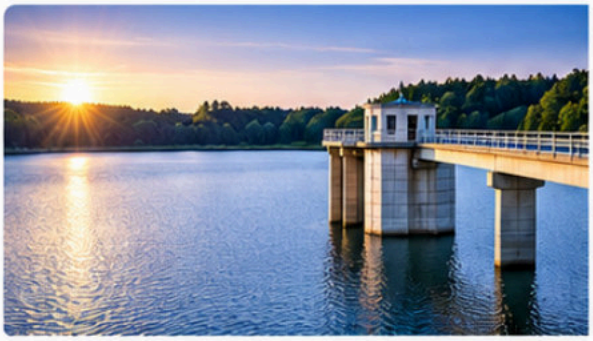
Ferrate VI

ADVANCED WATER TREATMENT OXIDIZER



WATER APPLICATIONS

Source water • Drinking water • Industrial process water







APPLICATION	TREATMENT ROLE	DESIGN CHECK
Particles & turbidity	Fe(III) coagulation and capture	Mixing, settling, filtration and residual iron
Natural organic matter	Selective oxidation and capture	DOC/UV_{254}, finished-water quality and DBP testing
Micropollutants	Compound-specific transformation	Parent compound, products and toxicity
Arsenic	As(III) oxidation with iron-based capture	Speciation, competing ions and solids removal
Manganese	Oxidation and solids separation	pH, kinetics, residual manganese
Microbial indicators	Inactivation potential	Organism-specific exposure; approved disinfection strategy

PUBLISHED PILOT EVIDENCE [3]

93% particle-count removal: raw water plus ferrate and filtration.

97% particle-count removal: ozonized water plus ferrate and filtration.

Reported ferrate dose: 0.1 **mg/L** in the study abstract.

Particle-count results from specific pilot conditions; not turbidity percentages or universal performance guarantees. Confirm dose reporting basis before replication.

BENCH-SCALE EVIDENCE [2]

Real surface-water tests demonstrated simultaneous turbidity removal, NOM treatment and bacterial-indicator inactivation. Dose and pH strongly influenced results.

PROCESS INTEGRATION



Conceptual system illustration.
Process selection and residual disinfectant requirements remain site-specific.

QUALITY CONTROLS

Measure pH/alkalinity, oxidant demand, iron residual, turbidity and target contaminants. Assess bromide/bromate and transformation products where relevant. Bromate has been observed under certain acidic, bromide-containing conditions. [4]

Design note: Confirm suitability and applicable drinking-water chemical approvals for the actual product and generator output.

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[2] Zhang et al., 2020. [3] Jiang, Stanford & Petri, 2018, Water-Energy Nexus 1:42–46. [4] Huang et al., 2016, Chemosphere 155:528–533.

Ferrate(VI)

ADVANCED WATER TREATMENT OXIDIZER



Conceptual system illustration

WASTEWATER APPLICATIONS

Odor control • Primary treatment • Effluent polishing



SULFIDE & CORROSION CONTROL [5,6]

Ferrate oxidizes dissolved sulfide. Reducing the sulfide available for release can support H_2S odor and corrosion management. Product distribution depends on reaction conditions; do not assume all sulfide always becomes sulfate.

Sewer-biofilm research also demonstrated suppression of sulfide- and methane-producing activity. This evidence supports site trials, not a permanent biofilm-elimination claim.

LABORATORY MUNICIPAL PRIMARY-TREATMENT STUDY [7]

52%	34%	47%	3.30-log	3.67-log
TSS removal	total COD removal	total phosphorus removal	total-coliform removal	*E. coli* removal

9.0 mg/L ferrate(VI), expressed as Fe; pH 7.5.
Laboratory-scale results for one wastewater; not a plant guarantee.

BOUNDARIES

- Ferrate does not replace bulk biological treatment by default.
- COD reduction may reflect both oxidation and solids removal.
- Verify downstream iron solids, nutrients and biomass response.

MONITOR THE RIGHT VARIABLES

- Dissolved total sulfide, reported as mg/L as S
- Headspace H_2S, reported as ppmv
- Flow, pH, temperature, retention time and competing demand
- Downstream sulfide rebound and biological-process compatibility

Liquid sulfide and gas-phase H_2S are different measurements. ORP alone does not demonstrate sulfide removal.

EFFLUENT POLISHING [8]

Ferrate can oxidize selected micropollutants and assist phosphorus capture. Dissolved-organic-phosphorus removal depends on dose, pH and wastewater constituents.

APPLICATION POINTS

- **Collection systems and lift stations:** evaluate dissolved-sulfide control.
- **Primary treatment:** evaluate oxidation and enhanced solids separation.
- **Secondary effluent:** evaluate targeted polishing and phosphorus capture.
- **Industrial wastewater:** characterize the matrix before process selection.

SOURCES: [5] Sharma et al., 1997, DOI:10.1021/es960755z. [6] Water Research, 2019, PMID:31670088. [7] Zheng et al., 2021, DOI:10.1002/wer.1473. [8] IJERPH, 2023, 20:2849.

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Ferrate VI

ADVANCED WATER TREATMENT OXIDIZER

DESIGN & VALIDATION

From bench testing to a controlled treatment system





Conceptual system illustration—not a certified equipment drawing.

SPECIFY THE ACTIVE DOSE

Report ferrate dose as mg/L Fe(VI), expressed as Fe, and state active assay.

Conversion for pure K_2FeO_4:
1.00 mg/L as Fe = 3.55 mg/L K_2FeO_4.

For product mass, correct for measured active ferrate content.

Mass balance:

Active Fe feed (kg/day) =
Flow (ML/day) × Dose (mg/L as Fe).

Illustrative example (arithmetic only):
1 ML/day × 5 mg/L as Fe = 5 kg/day active Fe; equivalent to 17.7 kg/day pure K_2FeO_4.

This is not a recommended treatment dose.

PILOT DESIGN CHECKLIST

1. Define influent range, peak flow and measurable treatment targets.
2. Test dose × pH × contact time; include untreated and incumbent-treatment controls.
3. Verify active ferrate assay and decay between generation and injection.
4. Establish rapid mixing, contact capacity and solids separation.
5. Validate treated-water quality, downstream biology and sludge handling.
6. Compare lifecycle cost per volume and per mass of contaminant removed.

ON-SITE GENERATION

Confirm capacity, turndown, uptime, precursor consumption, power, residual chemicals and maintenance. On-site generation still requires feedstocks and appropriate chemical-handling controls.

CONTROL PHILOSOPHY

Use flow-paced dosing with validated feedback. Trend active assay, pH, target pollutant, residual iron and process alarms; do not rely solely on ORP.

SELECTED PEER-REVIEWED REFERENCES

[1] **Sharma (2002).** Potassium ferrate(VI): an environmentally friendly oxidant. *Advances in Environmental Research* 6:143–156.
[2] **Zhang et al. (2020).** One-step ferrate(VI) drinking-water treatment. DOI:10.1016/j.chemosphere.2019.125134
[3] **Jiang et al. (2018).** Practical application: site studies. DOI:10.1016/j.wen.2018.05.001
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[5] **Sharma et al. (1997).** Hydrogen sulfide oxidation. DOI:10.1021/es960755z
[6] Sewer biofilm study (2019). Water Research. PMID:31670088
[7] **Zheng et al. (2021).** Municipal CEPT. DOI:10.1002/wer.1473
[8] **Organic phosphorus study (2023).** DOI:10.3390/ijerph20042849

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Research synthesis • October 2026 •
Site-specific treatability testing required.

Ferrate(VI)™

EMERGING CONTAMINANTS & SAFE OPERATION

Targeted oxidation. Engineered integration.



ANTIBIOTIC OXIDATION — RESEARCH BASIS [9]

Ferrate(VI) has demonstrated oxidation of selected antibiotics, including sulfamethoxazole and trimethoprim. Reaction kinetics, reagent demand and products vary by compound and pH. The ACS chapter reports reduced toxicity for studied oxidation products and no significant antibacterial activity for oxidized trimethoprim products. These findings are compound-specific, not a guarantee for every effluent.



VALIDATE THE COMPLETE TREATMENT ENDPOINT

Measure parent compounds, transformation products and relevant toxicity or antibacterial activity. Parent-compound disappearance does not establish complete mineralization, removal of all antibiotic-resistance genes, or regulatory compliance. Test real water with competing oxidant demand, then verify solids capture and downstream treatment compatibility.



REACTION CHEMISTRY — IDEAL HALF-REACTIONS [1]

Acidic: $FeO_4^{2-} + 8\,H^+ + 3\,e^- \rightarrow Fe^{3+} + 4\,H_2O$

Alkaline: $FeO_4^{2-} + 4\,H_2O + 3\,e^- \rightarrow Fe(OH)_3(s) + 5\,OH^-$

Ferrate accepts electrons and forms Fe(III); resulting solids can aid coagulation and adsorption. Actual pH effects depend on reaction demand, buffering and generator chemistry. Capture and characterize iron-bearing residuals.



SAFE, RELIABLE IMPLEMENTATION

Strong oxidizer: follow current reagent and precursor SDS, compatible materials, PPE, spill controls and operator training. On-site production still requires precursor storage and safe handling. Confirm active ferrate assay at injection, output capacity, standby provisions and off-spec procedures. Evaluate residual precursors, residual iron, sludge handling and total lifecycle cost. For potable use, verify applicable approvals, product certification and disinfection requirements; ferrate does not provide a persistent distribution residual.



MULTIFUNCTIONAL CHEMISTRY. VERIFIED TREATMENT RESULTS.

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October 17, 2026

References: [9] Sharma, V.K.; Anquandah, G.; Kim, H.; Jiang, J.-Q.; Zboril, R. (2013). Ferrate(VI): A Green Chemistry Oxidant for Removal of Antibiotics in Water. *ACS Symposium Series* 1123, 31–44. DOI 10.1021/bk-2013-1123.ch003. [1] Sharma (2002), *Advances in Environmental Research* 6, 143–156.
Supporting engineering: *OCPE Ferrate(VI) Technical White Paper* (2026); Gagliardo & Dozortsev, *The Power of Ferrate(VI)* (2024).

Ferrate(VI)™

FROM RESEARCH TO RELIABLE OPERATION

Generation. Treatment. Separation.



ENGINEER THE COMPLETE SYSTEM [10]

The 2026 engineering perspective identifies three linked subsystems: ferrate generation, treatment, and solid–liquid separation. Commercial generators exist, but broad municipal deployment remains limited. Verify active assay at injection, storage decay, capacity, uptime, precursor consumption and energy per unit of useful treatment. Evaluate sodium/potassium loading and residual chlorine species where relevant to the actual generation route. Compare an auxiliary installation within an existing plant with a dedicated standalone process.



HYBRID SYSTEMS: TARGETED OPPORTUNITIES [10–12]

Research includes perborate-assisted ferrate for sulfamethoxazole, UV/chemical activation and advanced electrochemical anodes such as porous iron foam. These are study-specific developments, not features established for every commercial generator. Activator ratio and water matrix can cause activation or deactivation. Faster micropollutant oxidation can reduce disinfection exposure; validate each objective separately and benchmark against mature alternatives.



ANTIBIOTIC RESISTANCE: PROMISING, MATRIX-SPECIFIC [13]

A secondary-effluent study reported 1.10–4.37-log removal of tested intracellular resistance genes at 10 mg/L as Fe. Both DNA damage and coagulation contributed; resistance genes were found in settled residues. Verify target genes, viable resistant bacteria and residual solids. Liquid-phase removal does not prove complete destruction or identical performance in sludge.



RESIDUALS & LIFECYCLE VALUE [10]

Iron(III) formation supports coagulation, but does not make the complete waste stream harmless. Ferrate treatment residuals contain iron-bearing solids and captured contaminants. Depending on matrix and dose, particles may be dense and settleable or fine and difficult to capture. Measure residual iron, turbidity, solids yield, settling, filterability, dewaterability, polymer demand and disposal requirements. Reduced sludge or operating cost is a potential outcome to demonstrate—not a universal benefit. Assess transformation products and DBPs; avoid a blanket zero-byproduct claim.



MULTIFUNCTIONAL POTENTIAL. MEASURABLE ENGINEERING VALUE.

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Ferrate(VI)™



BEYOND REMOVAL: VERIFY TOXICITY REDUCTION

Evidence for advanced wastewater polishing and reuse evaluation.

SECONDARY-EFFLUENT TOXICITY STUDY [14]

Published laboratory testing reported 44–71% lower cytotoxicity and 40–59% lower genotoxicity in mammalian-cell assays after treatment at 5.0 mg/L ferrate(VI), expressed as Fe. Both oxidation and coagulation contributed. These are reductions in the tested bioassay responses, not proof that every contaminant is removed or that reclaimed water meets all safety requirements.



FERRATE + OZONE: A VALIDATED RESEARCH PATH [15]

A study using 5 mg/L ozone plus 10 mg/L ferrate(VI) as Fe at pH 7.0 reported 39.8% lower cytotoxicity and 71.1% lower genotoxicity in low-bromide wastewater. The combined process also suppressed organic bromine and bromate relative to ozonation in the studied waters. Validate bromide, dose, pH and transformation products for each site. These findings do not establish zero byproducts or eliminate the possible need for pH adjustment.



FLOC REUSE: RECOVERING TREATMENT VALUE [16]

Research on recycled ferrate-derived Fe(III) flocs demonstrated additional flocculation and ferrate activation, with improved mammalian-cell toxicity endpoints under tested conditions. This reuses reaction-derived flocs; it does not mean that active Fe(VI) is indefinitely recycled. Confirm contaminant accumulation, solids purging, reagent demand and residuals handling before scale-up.



ENGINEERING VERIFICATION

Pair chemical analysis with fit-for-purpose bioassays. Track parent compounds, transformation products, microbial endpoints, residual oxidants, iron, pH and solids capture. Oxidant disappearance, antibiotic transformation, ARG removal and toxicity reduction are different endpoints. Define acceptance criteria and compare the complete treatment train with established alternatives.



TARGET CONTAMINANTS. MEASURE THE BIOLOGICAL RESPONSE.

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