TECHNICAL BULLETIN: Wastewater

Comparing Ferric Sulfate with Ferrous Sulfate for Wastewater Treatment

Ferric Sulfate and Ferrous Sulfate are both commonly used for municipal and industrial wastewater treatment. These salts are used as coagulants or flocculants, for odor control to minimize hydrogen sulfide release, for phosphorus removal, and as a sludge thickening, conditioning and dewatering agent.

Liquid ferric sulfate is a red-brown aqueous solution that is typically sold at 50% and 60% strengths, on a dry basis. The ferric iron (Fe^{+3}) concentration of the two solutions is 10% and 12% respectively.

Liquid ferrous sulfate is a clear, blue-green aqueous solution that is typically sold at 25% strength on a dry basis. The ferrous ion concentration (Fe^{+2}) is typically 5-7% by weight.

Typical addition points differ for the two chemicals. Ferric sulfate can be added in the wastewater collection system or at the treatment plant headworks, where it also provides benefits in the subsequent treatment processes. Ferrous sulfate is primarily added in the collection system and is less effective when added in the plant.

Applications in Wastewater Treatment

Ferric sulfate enhances clarification by forming a rapidly settling floc, whereas ferrous sulfate does not form a floc suitable for clarification.

Ferric sulfate controls hydrogen sulfide (H_2S) by binding three sulfide ions with every two ions of iron. Stoichiometrically, this can be expressed as:

$$2\ Fe^{+3} + 3\ HS^{-} \leftrightarrow Fe_2S_{3\ (solid)} + 3\ H^{+}$$

Ferrous sulfate controls hydrogen sulfide by binding one sulfide ion with each single ion of iron. Stoichiometrically, this can be expressed as:

$$Fe^{+2} + HS^{-} \leftrightarrow FeS_{\ (solid)} + H^{+}$$

Theoretically, ferric sulfate consumes 3 ppm of HS^{-} for every 2 ppm of ferric metal, while ferrous sulfate consumes 1 ppm of HS^{-} for every 1 ppm of ferrous metal.

Phosphorus control is an important function of wastewater treatment. Theoretically, ferric sulfate consumes 1 ppm of orthophosphate (PO_4^{+3}) for every 1 ppm of ferric metal, while ferrous sulfate consumes 2 ppm of PO_4^{+3} for every 3 ppm of ferrous metal. Stoichiometrically, these reactions are expressed as:

$$Fe^{+3} + PO_4^{+3} \rightarrow Fe\ PO_4 \text{ for ferric, and}$$

$$3\ Fe^{+2} + 2\ PO_4^{+3} \rightarrow Fe_3(PO_4)_2 \text{ for ferrous.}$$

Fats, oils and greases (FOG) commonly build up in collection system pipes and drains. Both ferric sulfate and ferrous sulfate have proven effective in reducing FOG build-up. Also, adding ferric sulfate at the wastewater treatment plant headworks minimizes FOG scum on clarifiers.

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Struvite (magnesium ammonium phosphate hexahydrate) causes scaling issues within wastewater plants. Ferric sulfate and ferrous sulfate both inhibit struvite formation by reducing the proportion of phosphate. As shown above, ferric sulfate more efficiently precipitates phosphorus.

Manufacturing and handling are important considerations when choosing iron-based coagulants. Ferric sulfate is made from virgin iron ore containing low levels of trace metal contaminants. It is moderately corrosive, but compatible with most commonly used plastics and rubbers, 316 Stainless Steel, ceramics, glass, Hastelloy C-276 and Alloy 20.

Ferrous sulfate is made as a by-product of titanium dioxide production or from scrap iron, possibly containing undesirable levels of heavy metal contaminants. It is mildly corrosive and compatible with most commonly used plastics and rubbers, steel, alloys, ceramics and glass.

Ferric sulfate and ferrous sulfate are both versatile chemicals that have many benefits for wastewater treatment. More-detailed descriptions of some of these benefits, such as phosphorus reduction, H_2S control and struvite reduction, are presented in other General Chemical technical bulletins.

Typical Chemical Properties	50% Ferric Sulfate	16% Ferrous Sulfate ($FeSO_4$) or 28% Ferrous Sulfate Heptahydrate ($FeSO_4 \bullet 7H_2O$)
Soluble Ferric Iron (Fe^{+3})	10%	NA
Soluble Ferrous Iron (Fe^{+2})	Less than 0.2%	5% (approx.)
Free Sulfuric Acid (as H_2SO_4)	Less than 3%	Less than 6%
Water Insolubles	Less than 0.1%	Less than 0.5%
Product Density	11.97 lbs./US gallon	10.09 lbs./US gallon
pH, as is	1.0 (approx.)	1.5 - 4.5 (approx., depending on source)
pH, 1% Solution	4.8 (approx.)	NA
Specific Gravity (at 15.6°C)	1.435	1.15
Freezing Temperatures	Less than -50°C	-2°C (approx.); will crystallize below 10°C
Boiling Temperatures	100°C (approx.)	105 - 110°C

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