california water technologies LLC

8851 Dice Road Santa Fe Springs, CA 90670   866-337-7427

Technical Bulletin

Drinking Water Treatment with Ferric Chloride

Before the 1800's finding sanitary drinking water in the cities of the world was a risky enterprise. The separation of drinking water and human waste was not assured and illness and death due to water borne diseases was very common. In the mid-1800's the connection was made between water purity and public health. Once that connection was made, a concerted effort began to develop water treatment processes that would guaranty the safety of the populace. Over the next century, progress in water treatment methods in the United States, Canada and Northern Europe, came to produce drinking water unequalled in quality and it was reasonable that these largely successful methods should become standardized.

In 1974, the Safe Drinking Water Act was passed by the United States Congress. In 1986 amendments to this act were passed that have radically changed the face of drinking water standards and the processes used to produce potable water in the United States. Water producers soon discovered that the old "tried and true" treatment processes were now inadequate to meet today's requirements. These new requirements made it necessary to re-evaluate the total water plant operation. One of the outcomes of this re-evaluation has been a focus on determining the correct coagulant to meet these new requirements. Ferric chloride has often been central to this discussion.

Ferric chloride is not new to the drinking water treatment industry and has been commercially available in the United States since the1930's. However, it has only been in the past 15 years that a trend towards increased acceptance of ferric chloride for drinking water treatment has evolved. This is due in large part to significant improvements in product economics, quality and availability. Since 1986 there has been a ground swell in interest in ferric chloride not only for the treatment of turbidity but additionally for the removal of color, natural organic materials and arsenic from raw waters. California Water Technologies has been instrumental in helping Water Treatment Plants understand the extensive capabilities of this coagulant.

Ferric chloride is an interesting compound. It is produced as a solution from the oxidation of ferrous chloride with chlorine and it has the unusual distinction of being one of the purest and most concentrated forms of iron commercially available for water treatment. However, what is truly unusual is its chemistry is that ferric chloride not only functions as a reactant to remove water impurities but it also functions as both a coagulant and a flocculant. Its versatility is enormous.

The reactions of ferric chloride in water include an ability to form precipitates with hydrogen sulfide (H_2S), phosphate (PO_4), arsenic as arsenate (AsO_4) and hydroxide alkalinity (OH).

In drinking water treatment, however, understanding ferric chloride's reaction with hydroxide alkalinity is the primary key to understanding its effectiveness as a coagulant/ flocculant.

Ferric chloride reacts in water with hydroxide alkalinity to form various hydrolysis products that incorporate $Fe(OH)_3$. These compounds possess high cationic charge which allows them to neutralize the electrostatic charges found on colloidal compounds and also to bind to negatively charged particles, including the ferric hydroxide itself. This ability to bind to itself is the mechanism for the formation of floc aggregates and the basis for ferric chloride's flocculation abilities.

The hydrolysis products from ferric chloride, nominally ferric hydroxide, are different from those of sulfate based ferric sulfate and aluminum sulfate (alum). The aggregates or floc particles of ferric hydroxide are physically more discrete and dense and have a higher cationic charge density. In contrast, the floc aggregates of ferric sulfate and aluminum sulfate tend to be less discrete and "fluffy" or cloud like, this apparently due to differences in the types of bonding of the hydrolysis products. These differences translate into characteristics and abilities for ferric chloride that set it far apart from the sulfate based coagulants. In typical plant situations one can expect to use about 30% less ferric chloride than aluminum sulfate (on a dry weight basis) to achieve similar results.

Ferric Chloride forms a more discrete and dense floc that promotes faster sedimentation in general and specifically, better sedimentation in cold water. This dense floc has more available cationic charge that allows higher reactivity with colloidal solids. The high ratio of cationic charge to total mass also makes the ferric chloride hydrolysis products more reactive and adsorptive with emulsified and semi-emulsified organic matter; such as oils, fats, and other natural and synthetic organic matter. This would explain the ability of ferric chloride to remove TOC and other disinfection by product precursors (DBP's).

The high density of the ferric hydroxide floc leads to another important benefit for the treatment plant. The settled sludge volume of the ferric (chloride) hydroxide ranges typically from 1/3 to 2/3 that of sulfate based coagulants. Additionally, the sludge developed through the use of ferric chloride is generally much more dewaterable. So, although the ferric hydroxide molecule itself is heavier than the aluminum hydroxide molecule, this does not translate into more sludge to be disposed of. Instead, because sludge is disposed of on a wet basis rather than on a dry basis, the use of ferric chloride produces fewer wet tons of sludge and yields significant solids handling and disposal savings.

One of the other characteristics of ferric chloride is its ability to form floc over a very wide pH range as is demonstrated in the accompanying charts. The charts also show the very low solubility of ferric hydroxide compared to aluminum hydroxide. The combination of these properties allow ferric chloride to function over a very wide pH range with little fear of carry over into down stream processes due to post precipitation. This ends up being very important for operations looking to flocculate at higher pH's and alkalinity's while controlling

corrosivity factors in the water. Additionally, the low end of the pH range becomes especially important to enhanced coagulation processes.
Although there is little formal data regarding the use of ferric chloride as a filtration aid there is much operational data that speaks to its ability to greatly enhance turbidity removal with both slow and rapid sand filter filtration. Additionally there are more recent reports that speak to the use of iron coated sand in the removal of manganese.

Potable Water Treatment Applications

- Turbidity removal
- Enhanced Coagulation
- NOM, DBP precursor removal
- Color removal
- Arsenic reduction
- Softening Solids Sedimentation Aid
- Filtration Aid

Summary of benefits

- Very effective in the removal of high and low turbidity
- Extremely effective in removal of color, NOM and DBP precursors
- Works over a wide pH range
- Lower dosage requirements than other sulfate based coagulants
- Low cost
- Makes a heavier floc that settles faster and works better in cold water
- Produces higher sludge concentrations **=** Lower sludge disposal costs
- High iron content sludge is not considered hazardous to the environment and is compatible and beneficial with many land application residuals programs

Handling Ferric Chloride- **Read and understand the Ferric Chloride Material Safety Data Sheet**

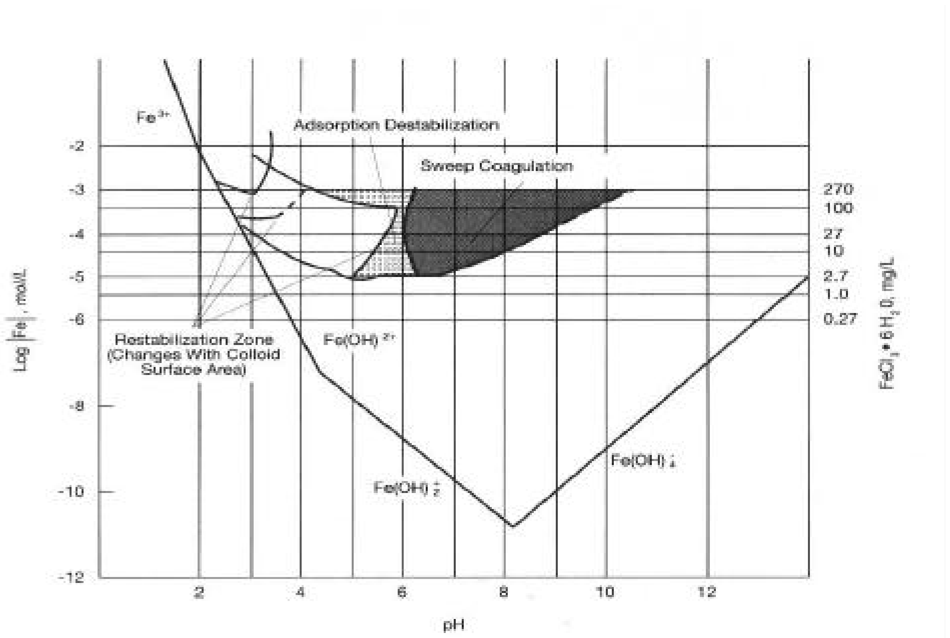
It is extremely important that we handle Ferric Chloride and all chemicals with respect and in a safe manner. Always wear personal protective safety equipment and practice good housekeeping. For more information contact your PVS Technologies representative or resource the material safety data sheet.

Treatment Methods

Our experience has taught us that each water treatment facility must be approached individually. Differences in raw quality, treatment requirements, facility capabilities and staff expertise require solutions to treatment that are custom designed for the facility. Contact your California Water Technologies representative for knowledgeable assistance in developing solid solutions to your treatment needs.

Ferric Chloride Solubility Chart

Source: Johnson P.N. & Amirtharajah A. 1983. *Ferric Chloride and Alum as Single and Dual Coagualants* Jour. AWWA, 75:5:232.



Aluminum Sulfate Solubility Chart

Source: Amirtharajah A. & Mills, K.M. 1992 *Rapid-Mix Design for Mechanisms of Alum Coagulation* Jour. AWWA, 74:4:210.