SGW-62570
Revision 0

Evaluation and Recommendation of Alternative Coagulants for the 200 West Pump and Treat

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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APPROVED
By Lynn M. Ayers at 11:26 am, Oct 10, 2018

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Terms

AMT	aerated membrane tank
FBR	fluidized bed reactor
MBR	membrane bioreactor
MCL	maximum contaminant level
P&T	pump and treat
SDS	safety data sheet

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1 Introduction

The purpose of this document is to provide a recommendation to replace ferric chloride, which is used as a coagulant in the membrane bioreactors (MBRs). The ferric chloride ($FeCl_3$) used at the 200 West Pump and Treat (P&T) contains impurities, such as manganese and aluminum. These metals act as nutrients for biological growth and have been found to accumulate in biomass pipe deposits in the injection distribution system and contribute to well fouling. An effort to reduce biological nutrients in the effluent water is ongoing at the 200 West P&T, and this report will investigate possible replacement coagulants. Based on this review, the 200 West P&T engineering staff recommends switching to a ferric sulfate coagulant to replace the existing ferric chloride.

1.1 Background

The biosolids coagulant at the 200 West P&T, ferric chloride, is added upstream of the MBRs. It aids the solids ability to form flocs, removes trace nutrients from the feed stream, and reduces fouling of the membranes. The ferric chloride also helps in the filterability and dewatering in the downstream sludge removal process. The process used to make the ferric chloride introduces impurities, such as manganese, which contribute to well fouling in the injection system. Changing to an alternative coagulant may help reduce the amount of manganese or other contaminants that are dosed to the process water, and help to mitigate the well fouling issue. There are several standard coagulants used in MBR systems for water treatment, which include ferric sulfate [$Fe_2(SO_4)_3$], aluminum chlorohydrate [$Al_2Cl(OH)_5$], aluminum sulfate [$Al_2(SO_4)_3$], and poly aluminum chlorides with proprietary formulations. Polymer-based coagulants have been used selectively in MBR systems, but should be considered a last resort due to the limited information on fouling control as well as the higher cost compared to traditional coagulants.

1.2 Requirements

It is preferable to replace ferric chloride with a chemical that is compatible with the existing feed system. If switching to an aluminum-based coagulant, the lines and pumping skid would likely need to be completely cleaned. Ferric sulfate, on the other hand, is interchangeable with ferric chloride, and the piping and pumps would not need to be flushed prior to the change of coagulant. The dose of coagulant should be similar to that of ferric chloride so the existing pumping skid and piping could be reused. The conventional coagulants, both iron and aluminum based, have similar dosing requirements to ferric chloride.

2 Evaluation

In order to find a replacement for ferric chloride, the 200 West P&T engineering team reviewed relevant literature and product documents to find coagulants that are effective for MBR operation. The areas of interest were approximate dose, compatibility with the existing equipment, and the inherent chemical impurities. A study by Gkotsis, et al., 2017, “Fouling Control in a Lab Scale MBR System: Comparison of Several Commercially Applied Coagulants,” found that all the traditional iron- and aluminum-based coagulants work well as a coagulation and flocculation technique for an MBR system. The authors also stated that by comparing the common fouling indices, such as transmembrane pressure, the iron-based coagulants played the most important role in membrane fouling control. In addition, iron-based coagulants are effective in a wider pH band than the aluminum-based coagulants. The 200 West engineering team selected ferric sulfate for further review as a replacement coagulant over the aluminum-based chemicals because of the better process performance and compatibility with the existing system.

The coagulant examined for this review is a ferric sulfate product from Kemira called Kemira PIX-312 (see Appendix A). The ferric sulfate product from Kemira is approximately 44% ferric sulfate by weight, whereas the ferric chloride product currently in use is around 40% ferric chloride by weight.

2.1 Initial Screening

Table 1 presents the screening level comparison of alternative coagulants. The key differentiators are as follows:

- The aluminum-based coagulants would require testing to determine the final dose.
- The aluminum-based coagulants would require complete flushing of the feed system.
- The aluminum-based coagulants may require changes to the feed pumps depending on the dose requirements.

Table 1. Initial Screening Parameters for Coagulants

Criteria	Ferric Sulfate	Aluminum Sulfate	Polyaluminum Chloride	Aluminum Chlorohydrate	Ferric Chloride (Current Chemical)
SDS Summary hazards (health, fire, and reactivity)	Severe health hazard, avoid skin and eye contact	Moderate health hazard, avoid skin and eye contact	Severe health hazard, avoid skin and eye contact	Moderate health hazard, avoid skin and eye contact	Severe health hazard, avoid skin and eye contact
Impacts on groundwater and wells	Potential to increase sulfate and iron	Potential to increase sulfate and aluminum	Potential to increase aluminum	Potential to increase aluminum	Increased iron, chromium, and manganese
Chemical quantities	Similar to ferric chloride (15 to 30 mg/L)	Testing required to determine dose	Testing required to determine dose	Testing required to determine dose	15 to 30 mg/L
Compatibility and plant modifications	Materials compatible and feed pump capacities sufficient	Complete flushing of system required. uncertain whether existing feed pump capacity is sufficient.	Complete flushing of system required. uncertain whether existing feed pump capacity is sufficient.	Complete flushing of system required. uncertain whether existing feed pump capacity is sufficient.	Compatible
Compatibility with membranes	Compatible	Compatible	Compatible	Compatible	Compatible
Compatibility with chemicals at facility	Not compatible with sodium hypochlorite or	Not compatible with sodium hypochlorite or	Not compatible with sodium hypochlorite or	Not compatible with sodium hypochlorite or	Not compatible with sodium hypochlorite or

Table 1. Initial Screening Parameters for Coagulants

Criteria	Ferric Sulfate	Aluminum Sulfate	Polyaluminum Chloride	Aluminum Chlorohydrate	Ferric Chloride (Current Chemical)
	sodium hydroxide	sodium hydroxide	sodium hydroxide	sodium hydroxide	sodium hydroxide
Effectiveness as coagulant	Good effectiveness pH 5.0 to 8.5. Typically, pH 7.5 is optimum. pH in AMT is 7.0 to 7.6	Good effectiveness pH 5.5 to 7.5. Typically, pH 6.8 is optimum. pH in AMT is 7.0 to 7.6	Good effectiveness pH 5.0 to 8.0. Typically, pH 7.3 is optimum. pH in AMT is 7.0 to 7.6	Good effectiveness pH 6.5 to 8.0. Typically, pH 7.5 is optimum. pH in AMT is 7.0 to 7.6	Good effectiveness pH 5.0 to 8.5. Typically, pH 7.5 is optimum. pH in AMT is 7.0 to 7.6
Solids production	20 to 30 mg/L solids	20 to 30 mg/L solids	20 to 30 mg/L solids	20 to 30 mg/L solids	20 to 30 mg/L solids
Handling and storage	Corrosive and produces visible rust colored stains when spilled or leaked	Corrosive and does not stain when spilled or leaked	Less corrosive and does not stain	Less corrosive and does not stain	Corrosive and produces visible rust colored stains when spilled or leaked

AMT = aerated membrane tank

SDS = safety data sheet

Based on the known performance of iron-based coagulants and to avoid the need to flush the entire system and the downtime it might cause, ferric sulfate was considered the best alternative to pursue. The following chapters provide an in-depth evaluation of ferric sulfate as an alternative to ferric chloride.

2.2 Ferric Chloride versus Ferric Sulfate Dose

The typical dose for ferric chloride is 25.0 mg/L. The first calculation in Appendix B shows the volumetric dose for ferric chloride when the plant forward feed is at 2,300 gpm. The volumetric dose of ferric chloride for this plant flowrate is 6.12 gal/hr. To convert this to an equivalent dose for ferric sulfate, the dose of iron should be the same. Calculation 2 (Appendix B) shows that for an equivalent iron dose, the ferric sulfate required is 30.8 mg/L.

The volumetric dose for ferric sulfate at these conditions is 6.18 gal/hr (calculation 3, Appendix B), which is just slightly higher than the volumetric dose from ferric chloride. The similar volumetric dose needed from ferric sulfate means that there does not need to be any changes in pump size to replace the ferric chloride.

2.3 Impurities Introduced with Coagulant

The 200 West P&T staff has investigated the conditions that led to the fouling of the injection wells. Several solid samples have been taken from the effluent pipe as well as from a filter pack on an injection well. The results of the samples are described in SGW-61398, *Nature of Injection Well Foulant and Recommendations to Limit Injection Well Fouling at 200 West Pump & Treat*. The data show that a significant portion of the solids found on effluent piping and on the filters is a biofilm, which contains metals such as manganese. As biofilm grows, it concentrates metals and over time, will shear off from the piping and move downstream to clog wells. Reducing the amount of metals introduced to the process should help limit the bacterial growth in the effluent piping.

2.3.1 Manganese Addition

Manganese is intentionally added with the micronutrient feed to the fluidized bed reactors (FBRs) as a necessary constituent for biological health. In the micronutrient feed, the manganese dose has varied from 12 µg/L to 80 µg/L over the past year with an average of 49 µg/L. The low end of the range is most recent, as the micronutrient dose has been systematically decreased while maintaining the microorganism health. Downstream of the FBRs, manganese is introduced to the process water in the MBRs as a byproduct in the ferric chloride feed. Table 2 shows the amount of manganese added to the system from ferric chloride and the dose that is expected by switching to ferric sulfate.

Table 2. Manganese Addition with Ferric Chloride Coagulant

Coagulant	Manganese in Tote (mg/L)	Manganese Added with Dose (µg/L) [a]
Ferric chloride [b]	253 to 720	11.2 to 31.9
Ferric sulfate	57.8	2.59

a. Dose calculated at 25 mg/L ferric chloride dose rate and 30.8 mg/L ferric sulfate dose rate.

b. Manganese concentration data is from January 2018 through June 2018.

The manganese concentration contributed from the ferric chloride dose varies between 11.2 and 31.9 µg/L, depending on the concentration in the tote. With an equivalent iron dose, the ferric sulfate is calculated to only contribute 2.59 µg/L of manganese. The lower manganese dose from the ferric sulfate is expected to decrease the amount of manganese in the injection water. The 200 West P&T team is working toward a goal of ≤15 µg/L in the plant effluent.

2.3.2 Chemical Impurity from Coagulant

This chapter compares the chemical impurities introduced with either the ferric chloride or ferric sulfate coagulant. Due to the nature of how these coagulants are manufactured, there are metal impurities present that will be introduced to the process flow. Every batch of ferric chloride is tested by the chemical supplier at a certified laboratory as part of a quality control check. A sample from the ferric sulfate coagulant from Kemira was tested at the same laboratory to compare the metals concentration between the two coagulants. Table 3 presents a comparison of chemical impurity.

Table 3. Chemical Impurity Comparison

Contaminants	Concentration in Coagulant (mg/L)	
	Existing Ferric Chloride [a]	Ferric Sulfate [b]
Aluminum	172	401
Antimony	3.90	3.24
Arsenic	ND	ND
Barium	0.50	0.13
Bismuth	ND	ND
Cadmium	ND	ND
Chromium (total)	135	201
Copper	8.80	ND
Lead	3.40	3.56
Manganese	464	57.8
Mercury	ND	ND
Nickel	10.1	27.3
Selenium	ND	ND
Zinc	20.8	12.1

a. Metals concentration data is average from January 2018 through June 2018.

b. Metals concentration data is from Kemira sample analyzed on July 18, 2018.

ND = not detected

Many of the metals are present in the ferric sulfate at similar levels as the ferric chloride. Manganese is much lower in the ferric sulfate, as discussed in the previous chapter. Aluminum, on the other hand, was more than double the average concentration found in the ferric chloride. Although aluminum does play a role in the biofilm growth in the injection piping, the risk of increased fouling is low when switching to ferric sulfate. The plant effluent tank samples show that aluminum is typically below detection limits, which suggests that aluminum added with the coagulant precipitates and is removed with the waste-activated sludge. Figure 1 is a solubility chart for aluminum, which shows that the solubility is very low at the pH present in the MBRs (pH 6.5 to 7.5). The low solubility supports the idea that aluminum in the MBRs precipitates and is removed with the waste-activated sludge.

Chromium (total) is a measure of the two primary chromium oxidation states, chromium (III) and chromium (VI). The form of chromium found in the ferric chloride or sulfate is chromium (III), which is much less toxic and less mobile of the two forms. When introduced to the process with the coagulant, chromium (III) forms insoluble compounds with ferric hydroxide and is contained in the solids portion of the MBRs. The chromium added with the coagulant is removed with the waste-activated sludge and is not expected to impact the chromium treatment goal for the 200 West P&T.

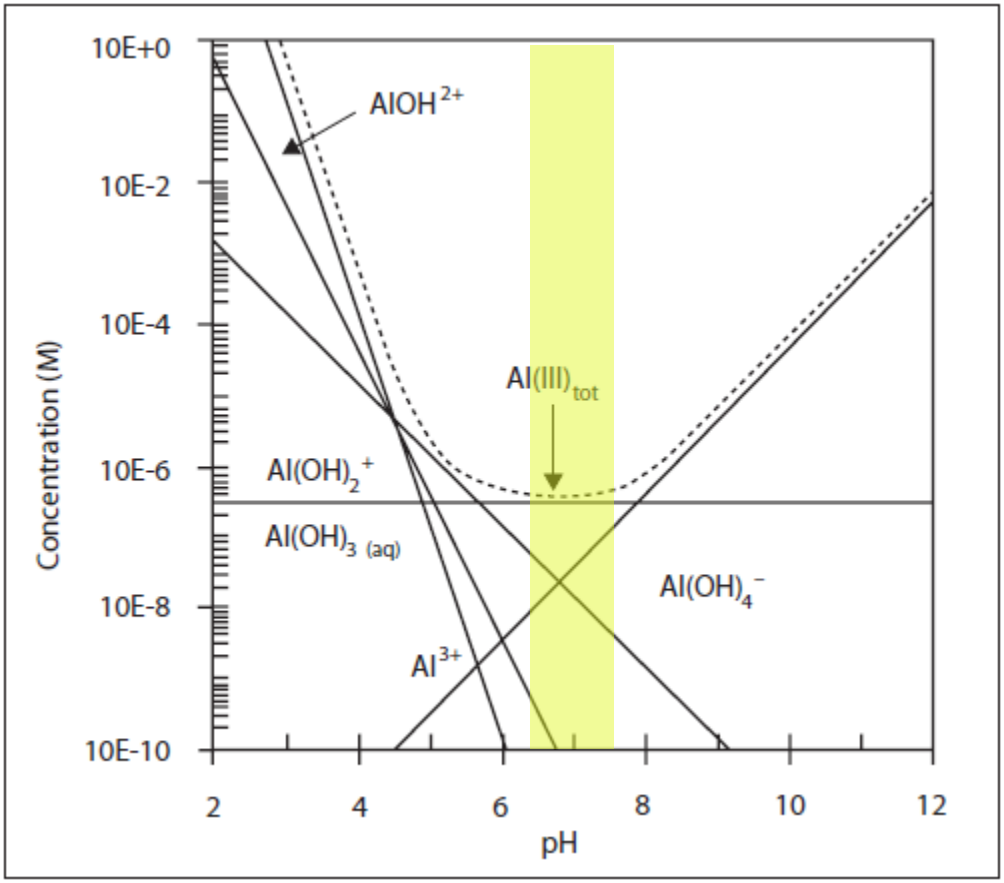

Figure 1. Solubility of Aluminum

2.4 Sulfate Addition From Ferric Sulfate

The switch to ferric sulfate introduces the issue of an increase in sulfate to the treatment system. At elevated levels, sulfate can cause scale buildup in pipes and cause taste and odor issues in water. There is a secondary maximum contaminant level (MCL) for sulfate at 250 mg/L. At a typical flow of 2,300 gpm, the ferric sulfate will increase the sulfate concentration in the process stream by 22.2 mg/L (Appendix B). Table 4 shows typical sulfate concentrations through the 200 West P&T.

Table 4. Sulfate Profile in Plant

Location	Sulfate Concentration (mg/L)
FBR Influent	47 to 67 (average of 57)
FBR Effluent	48 to 71 (average of 59)
Plant effluent	80 to 110 (average of 97)

Note: The sulfate concentration data is from January 2017 to April 2018.

FBR = fluidized bed reactors

In the FBR influent and effluent, the average sulfate concertation is 57 and 59 mg/L, respectively. In the plant effluent, the sulfate concentration is higher with an average around 97 mg/L. The higher levels in the effluent are from the addition of sulfuric acid for pH balance in the effluent tank. If all the sulfate passes through to the MBRs and Air Strippers to the effluent tank, the sulfate addition of about 22 mg/L from ferric sulfate will bring the average effluent concentration to nearly 120 mg/L, which is still well below the MCL of 250 mg/L.

3 Conclusion

It is recommended to switch coagulants from ferric chloride to the ferric sulfate product from Kemira. Ferric sulfate is compatible with the current chemical dosing system, and no equipment changes or flushing of lines is needed. The amount of manganese introduced by the coagulant will decrease by switching to ferric sulfate, which is important for controlling biofilm growth in the effluent piping and well system.

4 Recommendation

Ferric sulfate is recommended to replace ferric chloride. The following steps are recommended:

- Ensure the chemical safety data sheet (SDS) has been entered into the Hanford SDS system
- Ensure chemical review is complete
  - Industrial Health Hazard Assessment
  - Fire Protection
  - Emergency Preparedness Hazard Assessment
- Ensure operating procedures are updated to include new chemical
- Order chemical
- Receive new chemical and verify connection is compatible
- Stop feeding ferric chloride and place ferric sulfate on scale
- Set dose rate for ferric sulfate and begin new chemical feed
- After 1 week, verify feed rate by comparing theoretical tote weight change versus measured
- Monitor plant performance and adjust dose accordingly

5 References

Gkotsis, P.K., E.L Batsari, E.N. Peleka, A.K. Tolkou, and A.I. Zouboulis, 2017, "Fouling Control in a Lab Scale MBR System: Comparison of Several Commercially Applied Coagulants," *Journal of Environmental Management* 203:838-846.

SGW-61398, 2018, *Nature of Injection Well Foulant and Recommendations to Limit Injection Well Fouling at 200 West Pump & Treat*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0066757H.

Appendix A

Product Information: Safety Data Sheets and Product Data Sheets

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kemira
Where water meets chemistry™

Technical Data Sheet
(Ref: KWS-PIX-312)
May 2017

Kemira PIX-312

Ferric Sulfate Solution, 12% Fe

KEMIRA PIX-312 is an effective liquid ferric sulfate coagulant based on trivalent iron (Fe^{3+}). The product is manufactured using a patented process reacting high purity iron ore with sulfuric acid. KEMIRA PIX-312 functions very well for both potable and wastewater clarification and can be used for turbidity removal, color removal, phosphate removal, heavy metal removal, in lime softening applications as well as for sludge conditioning. KEMIRA PIX-312 can also effectively be used in hydrogen sulfide control applications to reduce odor and corrosion.

Typical Properties

Appearance	Dark brown liquid
Specific Gravity (20°C/68°F)	1.52 – 1.58
Fe_{TOT}	12.0 – 12.8 wt.%
Fe (III)	12.0 – 12.5 wt.%
Fe (II)	≤ 0.3 wt.%
pH (20°C/68°F)	< 1
Free Acid (H_2SO_4)	≤ 0.5 wt.%
Water-Insoluble Matter	≤ 0.1 wt.%
Freezing Point	-50°C/-58°F

This TDS is a general representation of the product. Detailed product specification/ analysis is available upon request.

Certification / Approval

KEMIRA PIX-312 meets or exceeds all the requirements of the current AWWA Standard B406 for liquid ferric sulfate and is NSF/ANSI Standard 60 certified for use in potable water treatment up to 600 mg/L.

Dosing

KEMIRA PIX-312 should be fed straight. No dilution or preparation is required. A diaphragm-metering pump of non-corrosive material is suitable.

Storage

Storage tanks and piping should be constructed of suitable material such as stainless steel, fiberglass, or cross-linked polyethylene. KEMIRA PIX-312 has a recommended shelf life of twelve (12) months. With this product, inspect the storage tank yearly, clean if necessary.

Handling / Safety

The handling of any chemical requires care. Anyone responsible for using or handling KEMIRA PIX-312 should familiarize themselves with the Safety Data Sheet.

Delivery

Shipping Instructions: UN 3264, CORROSIVE LIQUID, ACIDIC, INORGANIC, N.O.S. (Ferric Sulfate), 8, III,

Kemira makes this information available as an accomodation to its customers and it is intended to be solely a guide in customer's evaluation of the products. You must test our products, to determine if they are suitable for your intended uses and applications, as well as from the health, safety and environmental standpoint. You must also instruct employees, agents, contractors, customers or any third party which may be exposed to the products about all applicable precautions. All information and technical assistance is given without warranty or guarantee and is subject to change without notice. You assume full liability and responsibility for compliance with all information and precautions, and with all laws and statutes, ordinances and regulations of any governmental authority applicable to the processing, transportation, delivery, unloading, discharge, storage, handling, sale and use of each product. Nothing herein shall be construed as a recommendation to use any product in conflict with patents covering any material or its use.

Kemira

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SAFETY DATA SHEET

KEMIRA PIX-312

Ref. /US/EN

Revision Date: 11/03/2016 Previous date: 12/04/2015 Print Date:05/17/2018

1. IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

Product information

Product name
KEMIRA PIX-312 Chemical name: ferric sulfate

Recommended use of the chemical and restrictions on use

Use of the Substance/Mixture

Water treatment chemical
Recommended restrictions on use
There are no uses advised against.

Supplier's details

Kemira Water Solutions, Inc.
1000 Parkwood Circle, Suite 500
30339 Atlanta USA
Telephone+17704361542, Telefax. +17704363432

HEAD OFFICE
Kemira Oyj
P.O. Box 330
00101 HELSINKI
FINLAND
Telephone +358108611 Telefax +358108621124

Emergency telephone number

Carechem 24 International: +44 (0) 1235 239 670
CHEMTREC: 1-800-424-9300

2. HAZARDS IDENTIFICATION

Classification of the substance or mixture

Corrosive to metals; Category 1; May be corrosive to metals.;
Acute toxicity (Oral); Category 4; Harmful if swallowed.;
Skin corrosion/irritation; Category 2; Causes skin irritation.;
Serious eye damage; Category 1; Causes serious eye damage.;

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KEMIRA PIX-312

Ref. /US/EN

Revision Date: 11/03/2016 Previous date: 12/04/2015 Print Date:05/17/2018

GHS-Labelling

Hazard pictograms :

Signal word : Danger

Hazard statements : **Hazard statements:**

H290	May be corrosive to metals.
H302	Harmful if swallowed.
H315	Causes skin irritation.
H318	Causes serious eye damage.

Precautionary statements : **Prevention:**

P234	Keep only in original container.
P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash face, hands and any exposed skin thoroughly after handling.
P270	Do not eat, drink or smoke when using this product.
P271	Use only outdoors or in a well-ventilated area.
P280	Wear protective gloves/ protective clothing/ eye protection/ face protection.

Response:

P390	Absorb spillage to prevent material damage.
P301 + P312	IF SWALLOWED: Call a POISON CENTER or doctor/ physician if you feel unwell.
P330	Rinse mouth.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P321	Specific treatment (see supplemental first aid instructions on this label).
P332 + P313	If skin irritation occurs: Get medical advice/ attention.
P362	Take off contaminated clothing and wash before reuse.
P305 + P351 + P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.

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P310	Immediately call a POISON CENTER or doctor/ physician.
Storage:	
P405	Store locked up.
P406	Store in corrosive resistant container with a resistant inner liner.
Disposal:	
P501	Dispose of contents/container as special waste in compliance with local and national regulations.

Hazardous components which must be listed on the label:

- 10028-22-5 Diiron tris(sulphate)

Other hazards which do not result in classification

3. COMPOSITION/INFORMATION ON INGREDIENTS

Substances /Mixtures

Hazardous components

Chemical Name	CAS-No.	Concentration[%]
Diiron tris(sulphate)	10028-22-5	30 - 50 %

Further information

This material is hazardous under the criteria of the Federal OSHA Hazard Communication Standard 29CFR 1910.1200.

Diiron tris(sulphate) CAS #10028-22-5 is Ferric Sulphate - Fe2(SO4)3

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4. FIRST AID MEASURES

Description of first aid measures

Inhalation

If breathing is difficult, remove to fresh air and provide oxygen. If not breathing, give artificial respiration. Seek medical attention if cough or other symptoms develop.

Skin contact

Wash off immediately with soap and plenty of water while removing all contaminated clothes and shoes. Get medical attention if irritation develops and persists.

Eye contact

Flush eyes with water at least 15 minutes. Get medical attention if eye irritation develops or persists.

Ingestion

Never give anything by mouth to an unconscious person. Do NOT induce vomiting. Drink 1 or 2 glasses of water. Obtain medical attention.

Most important symptoms and effects, both acute and delayed

5. FIREFIGHTING MEASURES

Suitable extinguishing media

Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.

Special hazards arising from the substance or mixture

Not combustible. Thermal decomposition products:
Sulphur oxides, hydrogen sulfide

Special protective actions for fire-fighters

Use NIOSH/MSHA approved respiratory protection.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment and emergency procedures

Wear personal protective equipment.

Environmental precautions

Should not be released into the soil, surface water or ground water system. Must be disposed of in accordance with local and national regulations.

Methods and materials for containment and cleaning up

Small amounts:

Absorb with materials such as; Clay. Neutralize with lime or soda.

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Large amounts:

In case of large spillage, contain by damming up. Absorb with materials such as; Clay. Dilute residues with water and then neutralize with lime or limestone powder.

7. HANDLING AND STORAGE

Precautions for safe handling

Wear personal protective equipment. Wash contact areas after handling. Prevent eye and skin contact.

Conditions for safe storage, including any incompatibilities

Keep at temperatures between 10 - 30 °C.
Keep containers tightly closed in a cool, well-ventilated place.

Materials for packaging
Suitable material: butyl-rubber, plastic, Stainless steel
Unsuitable material: Metals

Materials to avoid:
Carbon steel, brass, mineral acids, Bases

Storage stability:

Storage period 12 Months

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Components with workplace control parameters

Components	CAS-No.	Value	Form of exposure	Control parameters	Update	Basis
Sulphuric acid	7664-93-9	TWA	Thoracic fraction	0.2 mg/m³	2007-01-01	ACGIH
		TWA		1 mg/m³	2013-10-08	NIOSH REL
Diiron tris(sulphate)	10028-22-5			1 mg/m³		
				1 mg/m³		
		TWA		0.1 mg/m³		

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SAFETY DATA SHEET

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Appropriate engineering controls

Ensure adequate ventilation. Ensure that eyewash stations and safety showers are close to the workstation location.
Handle in accordance with good industrial hygiene and safety practice.

When using do not eat, drink or smoke.

Individual protection measures, such as personal protective equipment
Respiratory protection

Where exposures are below the established exposure limit, no respiratory protection is required. Where exposures exceed the established exposure limits, use respiratory protection recommended for the material and level of exposure. Under conditions of misting or contact with head gases, respiratory protection may be needed. Consider respirator warning properties before use.
With limited contact use an appropriate chemical cartridge respirator with acid gas cartridges. When cleaning, decontaminating or preforming maintenance on tanks, containers, piping systems and accessories, and in any other situations where airborne contaminants and/or dust could be generated, use protective equipment to protect against ingestion or inhalation. HEPA or air supplied respirator, full protective coveralls with head cover, gloves, and boots or chemical suits, and boots are suggested.

Hand protection

Glove material: Neoprene, Wear protective gloves.

Skin and body protection

Wear as appropriate: Protective clothing. Boots. Lab coat

Eye protection

Tightly fitting safety goggles or face-shield.

9. PHYSICAL AND CHEMICAL PROPERTIES

Information on basic physical and chemical properties

Physical state	, liquid
Colour	red, brown
Odour	acidic
Odour Threshold	not determined
pH	< 2
Freezing point :	> -38 °C

Initial boiling point and boiling range	No data available
Flash point	No data available
Evaporation rate	No data available
Explosive properties:	
Lower explosion limit	No data available
Upper explosion limit	No data available
Vapour pressure	No data available
Relative vapour density	No data available
Density	No data available
Relative density	No data available
Bulk density	No data available
Solubility(ies):	
Water solubility	soluble
Partition coefficient: n-octanol/water	No data available
Auto-ignition temperature	No data available
Decomposition temperature	No data available
Viscosity:	
Viscosity, dynamic	No data available
Viscosity, kinematic	No data available
Volatile organic content (VOC)	Not applicable

10. STABILITY AND REACTIVITY

Reactivity

Chemical stability

Possibility of hazardous reactions

Hazardous reactions: Hazardous polymerisation does not occur.

Stable under recommended storage conditions.

Conditions to avoid

Conditions to avoid: Avoid freezing.

Avoid storage at high temperatures.

Incompatible materials

Materials to avoid: Carbon steel
brass
mineral acids
Bases

Hazardous decomposition products

Hazardous decomposition products: Thermal decomposition products:
Sulphur oxides

Thermal decomposition: Note: No data available

11. TOXICOLOGICAL INFORMATION

Information on toxicological effects

Acute oral toxicity

Diiron tris(sulphate):
/OECD Test Guideline 423Remarks: Calculated as Fe
/Rat/220 mg/kg/LD50

Acute inhalation toxicity

Diiron tris(sulphate):
LC50
Remarks: No data available, Not applicable

Acute dermal toxicity

Diiron tris(sulphate):
LD50/Rat/>
/3,154 mg/kg/OECD Test Guideline 402
Remarks: Read-across (Analogy), CAS-No., 7758-94-3

Diiron tris(sulphate):
LD50/Rat/>
/881 mg/kg/OECD Test Guideline 402
Remarks: Calculated as Fe

Skin corrosion/irritation	**Diiron tris(sulphate):** Rabbit Result: No skin irritation /OECD Test Guideline 404 Conclusion: Moistened solid is expected to be irritant as a consequence of low pH.
Serious eye damage/eye irritation	**Diiron tris(sulphate):** Rabbit Result: Causes serious eye damage. /OECD Test Guideline 405 Remarks: Read-across (Analogy), 7758-94-3, dry substance

Respiratory or skin sensitisation

Skin sensitisation	**Diiron tris(sulphate):** Conclusion: According to experience sensitization is not expected.

Germ cell mutagenicity

Genotoxicity in vivo	**Diiron tris(sulphate):** Result: negative

Carcinogenicity

Carcinogenicity	**Diiron tris(sulphate):** /Rat/Oral/2 years Remarks:Information given is based on data obtained from similar substances. Not believed to be a carcinogen. Long-term test

Reproductive toxicity

Toxicity for reproduction	**Diiron tris(sulphate):** Reproductive effects/Rat/>/500 mg/kg Remarks: Read-across (Analogy) **Diiron tris(sulphate):** Developmental toxicity test/Rat/>/1,000 mg/kg Remarks: Read-across (Analogy) Conclusion: In animal studies, did not interfere with reproduction.
Teratogenicity	**Diiron tris(sulphate):** Rat/Oral/>/1,000 mg/kg Conclusion: Did not show teratogenic effects in animal experiments., Information given is based on data obtained from similar substances.

kemira

SAFETY DATA SHEET

KEMIRA PIX-312

Ref. /US/EN

Revision Date: 11/03/2016 Previous date: 12/04/2015 Print Date:05/17/2018

12. ECOLOGICAL INFORMATION

Ecotoxicity effects

Aquatic toxicity
LC50/24 h/Gambusia affinis (Mosquito fish): 37.2 mg/l
LC50/96 h/Gambusia affinis (Mosquito fish): 37.2 mg/l
/7 d/Green algae (Selenastrum capricornutum): 10 mg/l

Diiron tris(sulphate):
LC50/96 h/Oncorhynchus mykiss (rainbow trout): > 100 mg/l
NOEC/90 d/Oncorhynchus kisutch (Coho salmon): > 1 mg/l
EC50/48 h/Daphnia (water flea): 82.8 mg/l
NOEC/21 d/Daphnia magna (Water flea): > 1 mg/l

The compound is considered to have no long term effects in aquatic systems due to the rapid formation of insoluble hydroxides.

Toxicity to other organisms

Persistence and degradability

Biological degradability:
Diiron tris(sulphate):
The methods for determining the biological degradability are not applicable to inorganic substances.

Bioaccumulative potential

Partition coefficient: n-octanol/water: No data available

Diiron tris(sulphate):

Does not bioaccumulate.
Partition coefficient: n-octanol/water: Not applicable, inorganic compound

Mobility in soil

Water solubility: soluble

Other adverse effects

May lower the pH of water and thus be harmful to aquatic organisms.

kemira

SAFETY DATA SHEET

KEMIRA PIX-312

Ref. /US/EN

Revision Date: 11/03/2016 Previous date: 12/04/2015 Print Date:05/17/2018

13. DISPOSAL CONSIDERATIONS

Product	Must be disposed of as hazardous waste.
Contaminated packaging	Must be disposed of in accordance with local and national regulations.

14. TRANSPORT INFORMATION

UN number	3264
Land transport	
DOT:	
Description of the goods:	UN3264, CORROSIVE LIQUID, ACIDIC, INORGANIC, N.O.S. (Ferric sulfate)
Proper shipping name	
Class:	8
Packaging group:	III
DOT-Labels	8
Reportable quantity	Ferric sulfate
Sea transport	
IMDG:	
Description of the goods:	
UN proper shipping name	UN3264, CORROSIVE LIQUID, ACIDIC, INORGANIC, N.O.S. (FERRIC SULFATE)
Class:	8
Packaging group:	III
IMDG-Labels:	8
Air transport	
ICAO/IATA:	
Description of the goods:	
UN proper shipping name	UN3264, Corrosive liquid, acidic, inorganic, n.o.s. (Ferric sulfate)
Class:	8
Packaging group:	III
ICAO-Labels:	8
Special precautions for user	

15. REGULATORY INFORMATION

Safety, health and environmental regulations/legislation specific for the substance or mixture

SARA Title III Section 311 Categories

Immediate (Acute) Health Effects: Yes;

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SAFETY DATA SHEET

KEMIRA PIX-312

Ref. /US/EN

Revision Date: 11/03/2016 Previous date: 12/04/2015 Print Date:05/17/2018

Delayed (Chronic) Health Effects: No;
Fire Hazard: No;
Sudden Release Of Pressure Hazard: No;
Reactivity Hazard: No;

SARA 313 - Specific Toxic Chemical Listings

Sulfuric acid (7664-93-9)
OSHA a. United States Occupational Safety and Health Administration substances, 29 CFR 1910.1000, Sub Part Z.

CERCLA Hazardous substance (Reportable Quantities)

CERCLA Hazardous substance (Reportable Quantities)

Diiron tris(sulphate) (10028-22-5)
1,000 lb

Sulfuric acid (7664-93-9)
1,000 lb

Diiron tris(sulphate) (10028-22-5)

California Proposition 65

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.
None Present ()
Remarks: This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

Other regulations : No restrictions identified other than those already covered in regulations.

: None

Notification status

: All components of this product are included in the United States TSCA Chemical Inventory or are not required to be listed on the United States TSCA Chemical Inventory.
: All components of this product are included in the Canada Domestic Substance List (DSL) or are not required to be listed on the Canada Domestic Substance List (DSL).

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SAFETY DATA SHEET

KEMIRA PIX-312

Ref. /US/EN

Revision Date: 11/03/2016 Previous date: 12/04/2015 Print Date:05/17/2018

: All components of this product are included in the Australian Inventory of Chemical Substances (AICS) or are not required to be listed on the Australian Inventory of Chemical Substances (AICS).
: All components of this product are included on the Chinese inventory or are not required to be listed on the Chinese inventory.
: All components of this product are included in the Korean (ECL) inventory or are not required to be listed on the Korean (ECL) inventory.
: All components of this product are included on the Philippine (PICCS) inventory or are not required to be listed on the Philippine (PICCS) inventory.
: All components of this product are included on the Japanese (ENCS) inventory or are not required to be listed on the Japanese (ENCS) inventory.
: All components of this product are included in the European Inventory of Existing Chemical Substances (EINECS) or are not required to be listed on EINECS.
: All components of this product are included in the New Zealand inventory (NZIoC) or are not required to be listed on the New Zealand inventory(NZIoC).

16. OTHER INFORMATION

HMIS Rating

Health: 3
Flammability: 0
Reactivity: 0

NFPA Rating

Health: 3
Fire: 0
Reactivity: 0

Training advice

Read the safety data sheet before using the product.

Further information

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to

the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

Sources of key data used to compile the Safety Data Sheet

Regulations, databases, literature, own tests.

Additions, Deletions, Revisions

Relevant changes have been marked with vertical lines.

Two Rivers Terminal

PO Box 2327 - Pasco, WA 99302 - Ph: (509) 547-7776
www.tworiversterminal.com

Ferric Chloride

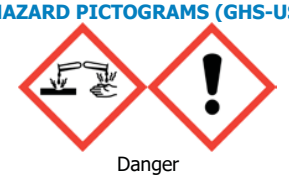
38 – 42% Ferric Chloride Solution

Typical Analysis

Ferric Chloride ($FeCl_3$)	**38.00-42.00 %**
Fe (III)	**13.10-14.50 %**

Specific Gravity: 1.41 at 68º F
Weight: 11.76 lbs/gallon at 68º F
pH ≅ 1.8 to 3.0

HAZARD PICTOGRAMS (GHS-US)



Danger

HAZARD STATEMENTS (GHS-US)

May be corrosive to metals
Harmful if swallowed
Causes severs skin burns and eye damage

PRECAUTIONARY STATEMENT (GHS-US): Wash Skin thoroughly after handling. Do not eat, drink or smoke when using this product. Avoid release to the environment. Wear eye protection, face protection, protective clothing, protective gloves. Do not breathe mist spray or vapors. If swallowed: Do NOT induce vomiting. Clean mouth with water. Immediately call a poison center. Causes serious eye damage. If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a poison center. If on skin (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower. If inhaled: Remove person to fresh air and keep comfortable for breathing. Immediately call a poison center. Collect spillage. Dispose of contents/container to an authorized waste collection point.

CAS NUMBER: 7705-08-0
24 Hour Emergency HAZMAT Response: (800) 229-5252
EPA National Response Center (800) 424-8802

NOTICE OF WARRANTY

Two Rivers Terminal, LLC warrants that this product conforms to the chemical description on the label thereof and is reasonably fit for the purposes stated on such label only when used in accordance with the directions under normal use. It is impossible to eliminate all risks inherently associated with the use of this product. Plant injury, ineffectiveness, or other unintended consequences may result because of such factors as weather conditions, presence of other materials or the manner of use or application, all of which are beyond the control of Two Rivers Terminal, LLC products. In no case shall Two Rivers Terminal, LLC products be liable for consequential, special or indirect damages resulting from the use or handling of the product. All such risks shall be assumed by the buyer. Except as expressly provided herein, Two Rivers Terminal products makes no warranties, guarantees, or representations of any kind, either expressed or implied, or by usage of trade, statutory or otherwise, with regard to the product sold, including, but not limited to merchantability, fitness for a particular purpose, use of eligibility of the product for any particular trade usage.

TWO RIVERS TERMINAL, LLC

NET CONTENTS: _____

Distributed By:	**Two Rivers Terminal, LLC** **PO Box 2327** **Pasco, WA 99302** **Ph: (509) 547-7776**

MATERIAL SAFETY DATA SHEET FERRIC CHLORIDE SOLUTION

HANFORD MSDS#070951

Section 1 – CHEMICAL PRODUCT AND COMPANY INFORMATION

MANUFACTURED FOR:
Two Rivers Terminal, LLC
PO Box 2327
Pasco, WA 99302

EMERGENCY TELEPHONE NO.:
DAYS: (509) 547-7776
24 Hour Emergency HAZMAT Response: (800) 229-5252
EPA National Response Center: (800) 424-8802

PRODUCT NAME: Ferric Chloride Solution
PRODUCT SYNONYMS: Iron Chloride Solution
CHEMICAL NAME/CLASS: Inorganic Acid Salt
CHEMICAL FORMULA: $FeCl_3 + FeCl_2 + H_2O$
PRODUCT USE: Various Industrial and Agricultural Applications

Section 2 - -COMPOSITION/INFORMATION ON INGREDIENTS

INGREDIENT NAME	CAS REGISTRY NUMBER	TYPICAL WT %
Ferric chloride	7705-08-0	25-45%
Ferrous chloride	7758-94-3	0-3%
Hydrochloric Acid	7647-01-0	0-3%
Water	7732-18-5	Balance

Section 3 – HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

APPEARANCE: Dark Orange-Brown
ODOR: Mild Metallic Chloride Odor
PHYSICAL FORM: Liquid
SIGNAL WORD: Caution!

EMERGENCY OVERVIEW: Caution! Corrosive. May cause severe eye and skin irritation with severe burns. Product may react violently with water and alkalis.

	OSHA PEL (1989)	NIOSH (PEL)	ACGIH (TLV)
Iron (Fe	N/A	N/A	1 mg/m^3
Hydrochloric Acid	7 mg/m^3	7 mg/m^3	7.5 mg/m^3 (ceiling)

SYMPTOMS OF OVEREXPOSURE BY ROUTE OF EXPOSURE: The primary routes of overexposure for this material are via inhalation and contact with skin and eyes. The following paragraphs describe the symptoms of overexposure to this material.

INHALATION: Not a normal route of entry. May irritate upper respiratory passages and cause coughing.

CONTACT WITH SKIN: May cause irritation with discomfort or rash, skin burns, or ulcerations.

CONTACT WITH EYES: May be slight to severe! Causes discoloration, irritation, pain, tearing, edema, corneal ulceration

INGESTION: Get immediate medical attention. May cause corrosion to the gastrointestinal tract In high does may lead to abnormal liver function with nausea or vomiting, reduce appetite, abdominal pain, lethargy, diarrhea, fast and weak pulse, hypertension, dehydration acidosis and coma. Repeated sub-lethal doses may lead to excessive deposition in the tissues accompanied by pancreatic and liver damage.

CHRONIC: Dermatitis may form from repeated skin contact. Repeated ingestion may lead to build up in organ of the body and eventual organ failure.

HEALTH: 2 REACTIVITY: 1 FLAMMABILITY: 0 ENVIRONMENT:

(0=Insignificant 1=Slight 2=Moderate 3=High 4=Extreme)

Section 4 – FIRST AID MEASURES

SKIN EXPOSURE: Flush contaminated area with soap and clean water for 15 minutes. Remove contaminated clothing. If irritation persists, get Medical Attention immediately.

EYE EXPOSURE: Immediately flush eyes with running water for a minimum of 15 minutes. Hold eyelids open during flushing. If irritation persists, repeat flushing. Obtain medical attention IMMEDIATELY.

INHALATION: Move victim to fresh air. Give artificial respiration ONLY if breathing has stopped. If breathing is difficult, give oxygen. Obtain medical attention IMMEDIATELY.

MATERIAL SAFETY DATA SHEET FERRIC CHLORIDE SOLUTION

HANFORD MSDS#070951

INGESTION: If swallowed., DO NOT INDUCE VOMITING. Wash mouth with large amounts of water and then give 1 or 2 glasses of water to dilute, followed by an antacid. Never give anything by mouth to an unconscious person. Get immediate Medical Attention

Section 5 – FIRE FIGHTING MEASURES

FLASH POINT: Not Applicable. Product is non-flammable

AUTOIGNITION TEMPERATURE: Not Applicable.

FLAMMABLE LIMITS (in air by volume, %): Lower (LEL): Not applicable.
Upper (UEL): Not applicable.

FIRE EXTINGUISHING MATERIALS: Use extinguisher media appropriate for surrounding fire.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Move container if possible, cool with flooding amounts of water.

SPECIAL FIRE-FIGHTING PROCEDURES: In the event of a fire, wear full protective clothing and NIOSH-approved self contained breathing apparatus with full face-piece operated in the pressure demand or other positive pressure mode.

Section 6 – ACCIDENTAL RELEASE MEASURES

IN CASE OF SPILL OR LEAK: In case or release to the environment, report spills to the National Response Center 1-800-424-8802. RQ 1000 lbs. Stop the leak, if possible. Keep people away, Ventilate the space involved. Use appropriate personal protection equipment. Dike liquid spills with inert material (sand, earth, etc.). Prevent waterway contamination. Collect run-off and transfer to drums or tanks for later disposal. Consult with regulatory specialists to determine appropriate state or local reporting requirements, for assistance in waste characterization and/or hazardous waste disposal and other requirements listed in pertinent environmental permits.

Spills may be neutralized with lime, limestone or sodium carbonate and resultant product properly disposed.

Section 7 – HANDLING AND STORAGE

WORK PRACTICES AND HYGIENE PRACTICES: Wear appropriate Personal Protection Equipment. As with all chemicals, avoid getting this product on you or in you. Wash hands after handling this product. Do not eat, drink, smoke or apply cosmetics while handling this product. All work practices should minimize the generation of spills, splashes and aerosols. Remove contaminated clothing immediately. Avoid contact with incompatible substances

STORAGE AND HANDLING PRACTICES: All employees who handle this material must be trained to handle it safely. Avoid breathing dust or mists generated by this product. Caution is important in al phases of handling and storage. Do not store near metal powders, Containers of this product must be properly labeled. Empty containers may contain residual product, therefore, empty containers should be handled with care. Store, Keep container tightly closed when not in use. Inspect all incoming containers before storage, to ensure containers are properly labeled and not damaged.

PROTECTIVE PRACTICES DURING MAINTENANCE OF CONTAMINATED EQUIPMENT: Follow practices indicated in Section 6 (Accidental Release Measures). Collect all spills, residues, rinsates and dispose of according to applicable U.S. Federal, State, or local procedures, or the applicable Canadian standards.

Section 8 – EXPOSURE CONTROL, PERSONAL PROTECTION

VENTILATION AND ENGINEERING CONTROLS: Use adequate local or general ventilation where necessary to maintain the concentrations well below the recommended occupational exposure limits. Ensure the eyewash stations and safety showers are proximal to the work area.

RESPIRATORY PROTECTION: Can vary from none to Self-Contained breathing apparatus depending on operational risk. If ventilation is inadequate to maintain personal inhalation exposure below TLV (PEL), use appropriate MSHA/NIOSH approved respiratory protection for Acid.

EYE PROTECTION: Wear safety glasses with side shield. A face shield may also be worn, to prevent contact with this product. As a general rule, do not wear contact lenses when handling.

HAND PROTECTION: Wear appropriate rubber gloves for routine handling of the material to prevent contact.

BODY PROTECTION: Rubber gloves, rubber apron and rubber boots should be worn to prevent contact with skin.

OTHER:

Section 9 – PHYSICAL AND CHEMICAL PROPERTIES

VAPOR DENSITY: Not available
BULK DENSITY; Variabl with assay
SOLUBILITY IN WATER: Complete.(highly exothermic)
EVAPORATION RATE (n-BuAc = 1): Not Applicable.
MELTING POINT or RANGE: -12 C
BOILING POINT: 106 C

MATERIAL SAFETY DATA SHEET FERRIC CHLORIDE SOLUTION HANFORD MSDS#070951

VAPOR PRESSURE: 40 mm Hg @ 35C
ODOR THRESHOLD: Acrid
SPECIFIC GRAVITY: 1.2 -1.5

pH @ 15ºC (59ºF): <1
LOG WATER/OIL DISTRIBUTION COEFFICIENT: Not available

APPEARANCE AND COLOR: Orange Brown Liquid
HOW TO DETECT THIS SUBSTANCE (warning properties):

Section 10 – STABILITY AND REACTIVITY

STABILITY: Stable Under normal conditions:

DECOMPOSITION PRODUCTS: Will no Occur.

MATERIALS WITH WHICH SUBSTANCE IS INCOMPATIBLE: Rapidly corrodes most metals, may generate flammable hydrogen gas, Avoid contact with nylon, aluminum/aluminum alloys, carbon steel, stainless steel, and copper/copper alloys.

HAZARDOUS POLYMERIZATION: Will not occur.

CONDITIONS TO AVOID: Powdered metals.

Section 11 – TOXICOLOGICAL INFORMATION

Ingredient	Test	Result	Route(Time)	Species

SUMMARY: No Specific Toxicology data found

CARCINOGENICITY: Not listed.

REPRODUCTIVE EFFECTS: Not Available.

MUTAGENICITY: Not Available

TERATOGENICTY: Not Available

Section 12 – ECOLOGICAL INFORMATION

Ingredient	Species	Period	Result
No Data Found			

Products of Biodegradation: Inorganic and not subject to biodegradation

Toxicity of Products: May decrease pH of waterways and adversely affect aquatic life.

Section 13 – DISPOSAL CONSIDERATIONS

Consul with environmental engineer or professional to determine of neutralization is appropriate and for handling procedures for residual material. Note: Chemical additions to, processing of; or otherwise altering this material may make this waste management information incomplete, inaccurate, or otherwise inappropriate. Furthermore, state and local waste disposal requirements may be more restrictive or otherwise different from federal laws and regulation.

Section 14 – TRANSPORT INFORMATION

United States (Under DOT)

Shipping Name: Ferric Chloride Solution
Product Identification No. (PIN): UN2582
Packing Group: III
Hazard Class or Division: 8
Labels: Corrosive
Placards: Corrosive

Reportable Quantity (RQ): 1000

Canada (Under TC)

Same

MATERIAL SAFETY DATA SHEET FERRIC CHLORIDE SOLUTION HANFORD MSDS#070951

Section 15 – REGULATORY INFORMATION

UNITED STATES:

SARA TITLE III HAZARD CATEGORIES AND LISTS

Category		List	
Acute (Immediate) Health	Yes	Extremely Hazardous Substance (40CFR 355, SARA title III Section 302)	No
Chronic (Delayed) Health	No		
Fire	No	CERCLA Hazardous Substance (40CFR 302.4)	Yes
Reactivity	No		
Sudden Release of Pressure	No	Toxic Chemical (40CFR 372.65, SARA Title III Section 313)	No

Reportable Quantity (RQ): 1000

TSCA Inventory Status: Yes

Right-To-Know:

CALIFORNIA SAFE DRINKING WATER AND TOXIC ENFORCEMENT ACT (PROPOSITION 65): Yes (Hydrochloric Acid)

CANADIAN:

INGREDIENTS LISTED ON DSL……YES

WHMIS CLASSIFICTION……Corrosive

WHMIS HEALTH EFFECTS INDEX……, E

WHMIS Ingredient Disclosure List: ……..N/A

All information contained in this Material Safety Data Sheet is furnished free of charge and is intended for your evaluation. In our opinion the information is, as of the date of this Material Safety Data Sheet, reliable, however, it is your responsibility to determine the suitability of the information for your use. You are advised not to construe the information as absolutely complete since additional information may be necessary or desirable when particular, exceptional or variable conditions or circumstances exist or because of applicable laws or government regulations. Therefore, you should use this information only as a supplement to other information gathered by you, and you must make independent determinations of the suitability and completeness of the information from all sources to assure both proper use of the material described herein and the safety and health of employees. Accordingly, no guarantee is expressed or implied as to the results to be obtained based upon your use of the information.

Appendix B

Calculations

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SGW-62769
Revision 0

CALCULATION FOR EVALUATION AND RECOMMENDATION OF ALTERNATIVE COAGULANTS FOR THE 200 WEST PUMP AND TREAT

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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SGW-62769
Revision 0

CALCULATION FOR EVALUATION AND RECOMMENDATION OF ALTERNATIVE COAGULANTS FOR THE 200 WEST PUMP AND TREAT

Date Published
October 2018

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company
P.O. Box 1600
Richland, Washington 99352

APPROVED
By Mary P. Curry at 5:23 pm, Oct 08, 2018

Release Approval Date

Approved for Public Release;
Further Dissemination Unlimited

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SGW-62769, REV. 0

CHPRC CALCULATION COVER SHEET

Selection: 1 Identification

1. Calculation Number	2. Revision	3. Title
SGW-62769	0	Calculation for Evaluation and Recommendation of Alternative Coagulants for the 200 West Pump and Treat.

4. Purpose
Supporting calculations for SGW-62570, Evaluation and Recommendation of Alternative Coagulants for the 200 West Pump and Treat.

5. Project/Program/Activity
S&GRP

Section 2: Approval

6. Author	7. Checker
SS Cartmell Sam Cartmell 10/8/2018	MA Carlson Mark Carlson 10/9/2018
Print /Signature/Date	Print /Signature/Date

8. Title	Print/Sign/Date	ADD ROW
Engineering Manager	Greg Bergquist Greg Bergquist	Date 10/8/18

Section 3: Summary of Revisions

9. Rev. No.	10. Description of Change	11. Affected Pages	12. Author	13. Checker ADD ROW
0	Initial issue into DMCS	All	SS Cartmell	MA Carlson
				☒
				☒
				☒
				☒
				☒
				☒
				☒

SGW-62769, REV. 0

CHPRC REVIEW CHECKLIST

Document Reviewed:
SGW-62769, Calculation for Evaluation and Recommendation of Alternative Coagulants for the 200 West Pump and Treat.

Scope of Review:
This review ensures the accuracy of the calculations done to support the evaluation of coagulants for 200 West Pump and Treat.

Yes	No	N/A		
☐	☐	☒	*	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
☒	☐	☐		Problem completely defined.
☐	☐	☒		Accident scenarios developed in a clear and logical manner.
☒	☐	☐		Necessary assumptions explicitly stated and supported.
☐	☐	☒		Computer codes and data files documented.
☒	☐	☐		Data used in calculations explicitly stated in document.
☒	☐	☐		Data checked for consistency with original source information as applicable.
☒	☐	☐		Mathematical derivation checked including dimensional consistency of results.
☐	☐	☒		Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐		Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
☐	☐	☒		Software input correct and consistent with document reviewed.
☐	☐	☒		Software output consistent with input and with results reported in document reviewed.
☐	☐	☒		Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
☐	☐	☒		Safety margins consistent with good engineering practices.
☒	☐	☐		Conclusions consistent with analytical results and applicable limits.
☒	☐	☐		Results and conclusions address all points required in the problem statement.
☐	☐	☒	*	Format consistent with appropriate NRC Regulatory Guide or other standards.
☒	☐	☐		Review calculations, comments, and/or notes are attached.
☐	☐	☒		For calculations in which codes/spreadsheets (e.g., RADIDOSE, GENII, etc) are used, is the latest revision used? Is the User Authorized?
☐	☐	☒		Hazard controls established are appropriate for the hazards including selection using the appropriate hierarchy (e.g., engineered over administrative).
☐	☐	☒		The preventive or mitigative credit assigned to hazard controls are appropriate, and the basis is documented.
☒	☐	☐		**Document approved.**

MA Carlson — 10/8/2018

Reviewer (Printed Name and Signature) — Date

*Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

Calculation Check

1) Determine volumetric dose for Ferric Chloride ($FeCl_3$)

Given: 25.0 mg/L ferric chloride dose

2300 gpm process flow

40% ferric chloride solution

11.76 $\frac{lb\ FeCl_3}{gal}$ density

$$\frac{25.0\ mg\ FeCl_3}{L\ water} \times \frac{2300\ gal}{min} \times \frac{solution}{0.40\ FeCl_3} \times \frac{3.785\ L}{gal} \times \frac{1\ g}{1000\ mg} \times \frac{gal}{11.76\ lb} \times \frac{lb}{453.6\ g} \times \frac{60\ min}{hr}$$

$$= \boxed{\frac{6.12\ gal\ FeCl_3}{hr}} \checkmark$$

2) Determine equivalent amount of ferric sulfate based on iron.

Given: 25.0 mg/L ferric chloride dose

$FeCl_3$

Fe = 55.85

Cl_3 = 35.45 x 3 = 106.35

Σ = 162.2 ✓

$Fe_2(SO_4)_3$

Fe_2 = 55.85 x 2 = 111.7

S = 32.06 x 3 = 96.18

O_4 = 16 x 4 x 3 = 192

Σ = 399.9

~400

$$25.0\ \frac{mg}{L} \times \frac{200}{162.2} = \boxed{\frac{30.8\ mg\ Fe_2(SO_4)_3}{L}} \checkmark$$

· divide by 2 (2 Fe)

= 200

3) Determine volumetric dose for ferric sulfate [$Fe_2(SO_4)_3$]

Given: 30.8 mg/L ferric sulfate

2300 gpm process flow

44.4% ferric sulfate solution

12.93 lb FeS/gal FeS = $Fe_2(SO_4)_3$

$$\frac{30.8\ mg\ FeS}{L} \times \frac{2300\ gal}{min} \times \frac{soln}{0.444\ FeS} \times \frac{3.785\ L}{gal} \times \frac{1\ g}{1000\ mg} \times \frac{gal}{12.93\ lb} \times \frac{lb}{453.6\ g} \times \frac{60\ min}{hr}$$

$$= \boxed{\frac{6.18\ gal\ FeS}{hr}} \checkmark$$

4) Determine sulfate addition with ferric sulfate

Given: 30.8 mg/L ferric sulfate dose

399.9 g/mol $Fe_2(SO_4)_3$ [= FeS] molecular weight

96.06 g/mol SO_4 molecular weight

$$\frac{30.8\ mg\ FeS}{L} \times \frac{1\ mol\ FeS}{399.9\ g\ FeS} \times \frac{3\ mol\ SO_4}{1\ mol\ FeS} \times \frac{96.06\ g\ SO_4}{1\ mol\ SO_4} = \boxed{\frac{22.2\ mg\ SO_4}{L\ water}} \checkmark$$

Calculation By: Sam Cartwell Sam Cartwell 8/6/2018

Check By: MARK CARLSON Mark Carlson 8/6/2018