

**OGMCOAL - Crandall Water Treatment**

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**From:** Steve Christensen  
**To:** OGMCOAL  
**Date:** 2/25/2010 8:21 AM  
**Subject:** Crandall Water Treatment

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>>> "Means, Brent P." <bmeans@osmre.gov> 2/25/2010 7:57 AM >>>

Kevin,

First off, I'm so sorry for not getting back to you. That is not my usual MO. I had an untimely death in the family which caused an emergency leave of absence for 1.5 weeks. Anyway, I will be in the office all day today (Thursday 2/25 and all day Next Monday). I will be out next Tues through Friday. Feel free to call me anytime today until 5:30 EST. I'd be happy to speak to you regarding the data you sent and the treatment test.

I reviewed the water quality you sent and it helped me understand the situation a little better. The iron data is contradictory in my eyes, which is unfortunate, but not unusual. At this pH, if the "dissolved" iron is .9 mg/L, I'd suspect that the dissolved ferrous iron concentration is very close to .9 mg/L. I'm assuming that dissolved iron was defined by sample water that passed through a .45 micron filter. The other type of iron, ferric iron, can only exist in very low concentrations in the **dissolved** state at this pH. At this pH, the majority of the ferric iron in the water would be in the suspended (solid form) state. I would interpret the data as Total Iron - Dissolved iron = Suspended Iron and Dissolved iron = Ferrous Iron. While there is some soluble ferric iron in the water, it is at concentrations so low that it is not a concern to us. So the water has a physical treatment problem (settling the suspended iron) and a chemical treatment problem (forcing the removal of dissolved ferrous iron). The two main solubility controls (the amount of ferrous iron that can be dissolved in solution) on ferrous iron is pH and Eh. Ferrous iron can be removed as Ferrous Hydroxide by simple pH adjustment to pH 8.0 to 8.5. Ferrous iron can also be removed from solution by adjusting Eh (using an oxidant, like atmospheric O<sub>2</sub> or hydrogen peroxide) which will force ferrous iron to oxidize to dissolved ferric iron. As I just stated, at this pH the water can't hold much dissolved ferric iron so it will immediately precipitate as "yellow boy (Fe(OH)<sub>3</sub>)." Because of the low concentrations of iron in general, I would not recommend using an oxidant.... I'd try pH adjustment, like we discussed. Because the iron concentration is so low, the pH of the water may only have to be adjusted to 7.6 to 8.0. I'd run the test by adjusting the sodium hydroxide feed rate to ~ pH 8.0. Make sure the sodium hydroxide (NaOH or caustic soda) is being added BEFORE the pond. NaOH is heavier than water and will "sink" to the bottom of the pond and not provide treatment throughout the pond. The specific gravity of 20% (w/w) NaOH is about 1.125 (if I remember correctly) and water is 1.0...so it is heavier. You probably only need 20 ft of ditch or channel to thoroughly mix the NaOH with the AMD, as NaOH is very fast reacting and very soluble in mine drainage. You would even add it to the Maelstrom unit and use it as the mixing vessel. If you do this, add the NaOH towards the middle or back of the unit. I would not add it to the beginning "cells" of the unit. This strategy should help to conserve NaOH since the beginning of the unit would be used as a pre aeration device that would serve to exsolve dissolved CO<sub>2</sub> from this water. This water is loaded with CO<sub>2</sub> acidity and we don't want to spend unnecessary chemical on treating an acid that can be easily outgassed to the atmosphere. NaOH is very soluble and you probably only need 10 seconds of reaction time to force the iron out of solution.

I recommend "calibrating" the treatment system by first adjusting the NaOH feed rate (which is needle valve is commonly used to dispense the "drip" NaOH is mostly passively dispensed but some folks do use metering pumps connected to pH controllers (PIP)) until a pH of 8.0 is achieved near where the chemical is thoroughly mixed. Right before the water is discharged into the settling pond, field-filter a small amount water and dispense the water in to a HACH "color wheel" field iron test kit. I would also collect a dissolved lab sample to confirm the field test kit. This field test will inform you if the NaOH treatment pH is sufficient to remove the dissolved iron from .9 mg/L to the desired effluent standard. A field test kit is needed to calibrate the treatment system....it takes too much time to use lab samples to calibrate the system.... You need the flexibility to make quick adjustments to the NaOH feed rate and measure the corresponding effect on the dissolved iron concentration. If the dissolved iron is not low enough, upwards adjust the NaOH feed rate until pH of 8.5 it achieved and then perform another field dissolved iron test. To start, I would not recommend any pH lower than 8.0 until you see the quality of the final discharge. You may be able to have a lower treatment pH than 8.0 to remove the dissolved iron, but pH also has an effect on settling and, in general, the higher the pH, the better the settling. The reasons for this are complicated and beyond the scope of this email, but I'd be happy to discuss the reasons of the phone, if you want. The purpose of this is to make sure that all of the dissolved iron is transformed to suspended iron (precipitated) before the water enters the settling pond. We want to use the (small) pond completely for settling and not for further chemical treatment of iron. The Maelstrom unit made the pond both a chemical and physical treatment pond since the dissolved iron had to oxidize in the pond and settle. This reduces the retention time needed for settling. Make sure the settling pond is baffled and I would recommend using baffles to force the water up and down as it travels through the pond. The change in direction causes particles to lose momentum as direction is changed and allows gravity to "pull" the particles down to initiate settling. I would take a effluent pH from the pond outlet before you start the test and then use pH measurements after the test started to determine when the "NaOH" treatment has reached the outlet of the pond. You could also take samples at the inlet of the pond and the outlet of the pond and have them tested for dissolved Na. You know the pond will have "chemically equilibrated" when the sodium value at the beginning of the pond is roughly equal to the sodium value at the pond effluent. Obviously, the dissolved Na is from the dissolution of NaOH, so sodium (and pH) is good to use to determine when the effect of the NaOH has reached the outlet of the pond. Of course, I'm assuming the raw water doesn't contain high levels of Na. The sample you sent me doesn't contain Na, I recommend taking at least one sample to determine the raw sodium concentration. After you determine that the effect of the NaOH addition as reached the outlet of the pond, I'd recommend taking three water samples, the raw before treatment (total and dissolved), a sample right before the water is discharged into to the pond (dissolved and total), and at the pond outlet (dissolved and total). I would also record the NaOH drip rate and the discharge rate of the AMD. By the way, I also use the same HACH field iron test kit to determine "total" iron at the pond outlet. Hach would advise against this, but I've found it to work well. Again, you need some quick method to determine whether total iron is in compliance at the pond outlet so quick adjustments to the NaOH (and/or floc) can be made. This kit works well.

If the NaOH doesn't work (meaning the iron will not settle, because it will lower the dissolved iron to effluent standards), then I'd recommend trying a floc in conjunction with or without the NaOH. I don't know the site conditions to be able to recommend what is possible. If the floc doesn't work for settling, then pond clarification will not work (unless you can build bigger ponds) and a mechanical clarifier might have to be used. Sounds like an interesting site...lower concentrations of iron are always more difficult to treat compared to high concentrations... If I had direct knowledge of the site, I might be of more assistance.

By the way, the name of the consultant I told you about is Tiff Hilton of WV. He is extremely good with mine drainage treatment. He may be able to help out... He is one of the few folks that I think could help because he specializes in the treatment of mine drainage. He has a small consulting company (just him) called WOPEC. His contact information is [wopec@suddenlink.net](mailto:wopec@suddenlink.net) and (304) 667-1952.

The other person I worked with to try to settle ferric iron that as formed through mechanical aeration was Jim Eyth of Nalco (724-312-4168). Jim sells treatment chemicals (for coal prep plants, mine drainage treatment, etc) to many of the companies in the east. Jim and I worked on that problem where we used a mechanical aerator (like the Maelstrom but much cheaper) to oxidize ferrous iron at a pH of 7.0. As I was telling you, the type of iron particulate that is formed through "natural" oxidation is very small and hard to settle without the use of a polishing wetland (adsorbs to organic matter). We tried to settle this type of iron with a floc and couldn't achieve settling. We had the same situation as you... no room for wetland or large settling ponds... could use an aerator to oxidize all of the dissolved iron but couldn't achieve effluent standards for total iron since the iron wouldn't settle. NaOH-produced iron precipitate should be easier to settle, however, at the concentrations of iron you are dealing with no iron is easy to settle without adequate settling room. If the NaOH doesn't work, maybe some sort of floc, either alone or in combination with NaOH will work. I just haven't had much luck using a floc to settle naturally oxidized iron (using O<sub>2</sub> for the oxidant)..... I have had luck when a chemical oxidant is used (like H<sub>2</sub>O<sub>2</sub>) or when NaOH is used in conjunction with NaOH. However, most of the time, if the iron concentration is in the 10s of mg/L, NaOH will remove and settle the iron from solution by its self.

I recommend sampling the raw water for the following parameters to aid in developing a treatment strategy (both dissolved and total).

Aluminum, Calcium, Iron, Potassium, Sodium, Manganese, Magnesium, Silica, Sulfate, Chloride, Alkalinity, Hot Acidity (Standard Methods 2310), pH, TDS, Suspended solids.

I also recommend always obtaining field pH and temp.....for waters like this I also perform a field alkalinity titration (from Hach).

I hope this helps. Let me know if I can be of further help or assistance. Brent

**Brent Means**  
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**From:** Kevin Lundmark [mailto:kevinlundmark@utah.gov]

**Sent:** Monday, February 22, 2010 11:19 AM  
**To:** Means, Brent P.  
**Cc:** Steve Christensen  
**Subject:** Fwd: RE: Crandall Water Treatment

Brent,

Thanks again for speaking with me week before last. The operator at Crandall Canyon will be running a trial with NaOH (without the Maelstrom unit) later this week. We have finally received some water quality data for the site, which is summarized in the attached spreadsheet. If you have a chance, I would like to discuss these data with you. I am concerned that the majority of the iron is already oxidized (prior to treatment by the Maelstrom unit) and that this may affect the results using NaOH. Are you available to discuss this later today or tomorrow?

Thank you,  
Kevin

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>>> "Shaver, Dave" <dshaver@coalsource.com> 2/19/2010 3:24 PM >>>

To all...based on this observation from DOGM, we are making preparation to do a test run on the Crandall water using NaOH to help settle the iron particles. The barrel should be here Monday afternoon, and the chemical injection system at the site should be operational then as well. Therefore we would like to do a test run on Tuesday. We will be set up to monitor the pH to keep the discharge within UPDES compliance of 9. The sodium should be covered under TDS (salinity) agreement. This will be a very small-scale test, but I wanted everyone's concurrence. The 7763 flocculent test is still pending for later in the week, but according to Nalco we can't do field titration testing on the polymer to ascertain the 1 mg/L limit. The sample has to be sent off to Naperville for analysis. This is going to make verification difficult and time-consuming. In the meantime, we have found another chemical that is NSF-60 rated up to 200 mg/L, but they have no aquatic toxicity info available, so they are scrambling to get us something. If the NaOH treatment works, then most of these issues would be greatly simplified. Fingers crossed!

Dave

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**From:** Kevin Lundmark [mailto:[kevinlundmark@utah.gov](mailto:kevinlundmark@utah.gov)]  
**Sent:** Tuesday, February 09, 2010 3:24 PM  
**To:** Shaver, Dave; Dale Harber; Thomas W Lloyd; Daron Haddock; Ingrid Wieser; Jeffrey Studenka; Steve Christensen  
**Cc:** bmeans@osmre.gov; OGMCOAL@utah.gov  
**Subject:** Crandall Water Treatment

Hello all:

Yesterday I spoke with Mr. Brent Means, who is OSM's water treatment expert in Pennsylvania. My reasons for contacting Mr. Means were to discuss whether he has experience with situations similar to Crandall Canyon, and to see if he had any recommendations. From our conversation, I've summarized Mr. Means main points of concern:

- Maelstrom oxidizer units can be very effective in producing iron precipitate, however, getting the iron precipitate to settle out can be very difficult.
- The iron precipitate formed as a result of treatment with the Maelstrom unit under conditions like we have at Crandall will be very difficult to settle. This is a result of the extremely fine particle size and the positively-charged particles which result from aeration treatment.
- A typical (minimum) design recommendation to settle the iron precipitate formed by the Maelstrom unit would be a 48-hour retention time, followed by a wetland. From a short-term/immediate view point, we're obviously well below a 48-hour retention time and do not have a polishing wetland. Can the addition of a flocculent compensate for a lack of adequate retention time? From a long-term/reclamation stand-point, this is definitely something that must be considered.
- Mr. Means indicated that wetlands have been more effective at removing positively-charged iron precipitate than pond-type clarifiers, and attempts to pond-clarify should be avoided for treating the relatively low concentrations of iron at Crandall. Again, this is a long-term/reclamation consideration at this point.
- Improved settling by coagulant / flocculant addition has been difficult to achieve; though these chemicals have been successful at some sites.
- Brent highly recommends treatment by addition a 20% solution of sodium hydroxide to raise the pH to 8.5 without oxidation. The resulting ferrous hydroxide precipitate settles more rapidly than the ferric hydroxide precipitate resulting from the Maelstrom unit.
- A complete water chemistry analysis (including typical cations and anions) should be completed ASAP to aid in the design of an effective treatment approach.

These points are good to consider during design of both the temporary and final reclamation treatment systems at Crandall. I would like to see the complete water chemistry analysis completed next time JBR is at the site collecting samples. I can provide a list of parameters.

Please feel free to contact me if you have any questions. I look forward to our call tomorrow.

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