United States Department of the Interior

OFFICE OF SURFACE MINING
RECLAMATION AND ENFORCEMENT

Technology Transfer Event at the Flight 93 Memorial Grounds
August 27, 2015

Stop 1: Venturi Site - Pumped Discharge

Need: clean glass beaker to show iron is dissolved in influent is clear

Easel 1: Mining Depiction and discharge characteristics Table that includes a water quality and quantity table

- Talking Points Easel 1
    1. Surface Mining Started here in 1967 and 5 seams were mined. Maximum highwall was 325 ft.
    2. In the early 1990s two underground mines (Diamond T mines) operated on the Middle and Lower Kittanning seams. In 1992, another mine was permitted on the property called the Longview UG mine. It's a Lower Kittanning mine that closed in 2004 (no discharge).
    3. By 2000, the Diamond T underground mines closed
    4. FLT 93 crashed on Sept. 11, 2001
    5. In 2003 a pumping well was installed into the Middle Kittanning mine pool to prevent an uncontrolled surface discharge below the Flight 93 impact site. Both mine pools are connected via a borehole.
    6. The well produces between 775 -1,200 gpm. The water is pH 6.7 and net alkaline by 140 mg/L as CaCO3. Fe = 50 mg/L, Mn = 10 mg/L, Al <0.3 mg/L and alkalinity = 226 mg/L.

Easel 2: Google Earth Image showing Pond/Wetland system overview and a poster of Iron Eh/pH Diagram

- Talking Points Easel 2
    1. At first, a hydrated lime treatment system was installed that was later converted to the passive pond-based system you currently see.
    2. The passive treatment system operates by pumping the chemically-reduced water to the surface and converting it to a highly-oxygenated water by having the water pass through a venturi system that outgasses carbon dioxide and

ingasses ~ 8 mg/L of dissolved oxygen which would satisfies the D.O. requirement for the oxidization of 50 mg/L of ferrous iron. (Collect raw water in a clear glass beaker to show the water is clear and the Fe is dissolved). Under highly-oxygenated atmospheric conditions, ferrous iron is unstable and will oxidize and precipitate to Ferric Hydroxide, which is also known as "yellow boy." The series of ponds at this treatment site serve two main functions. First they provide the retention time needed to allow the oxidization reaction to occur and they provide a retention time needed to settling the yellow boy precipitate and clarify the water for discharge.

3. The initial passive system contained 5 ponds, but the iron effluent quality as unacceptable so the water was routed through an additional 5 ponds. The 10 pond treatment system contained a theoretical retention time of 1 week.
4. Even with 10 ponds and a week's worth of retention time, the system discharged elevated concentration of suspended iron precipitate in the range of 1.6 to 7.0 mg/L..
5. In 2009, an evaluation team consisting of PADEP, OSM, SCCD, and citizens conducted a year-long sampling effort to investigate why the system discharged elevated iron. The team found the iron oxidized completely by the end of the second pond and over 50% of the iron settled by the second pond. They also found the poorest settling occurred in the winter months when cold temperatures increased the viscosity of the water, which decreased the velocity required for settling. After the 3rd pond, very little settling occurred throughout the remaining 7 ponds. The addition of pond curtains did not improve settling.
6. The Team recommended converting the 5th pond into a wetland to solve settling issue. The wetland was installed in 2013 and we will discuss the wetland later in the tour.

Stop 2: Outlet Pond 3/Inlet to Pond 4

Need: Clean glass beaker to show reddish water in pond 3 effluent. Show individual iron particles cannot be seen.

Easel 3: Flocculation Figure, Figure 2 (on handout) showing charge repulsion, Graph of surface charge on Iron Hydroxide particle

- Talking Points Easel 3
    1. The majority of the suspended iron is settled by the outlet of Pond 4, as can be witnessed by the difference in the depth of the reddish color between the 3rd and 4th pond.
    2. After the iron oxidizes, the iron hydroxide particles undergo flocculation in the first 3 ponds, a process where very small pieces of precipitated iron collide,

combine, and grow in size and mass. The process of flocculation depends on many factors including the number of suspended particles in solution and the pH of the water.

3. The graph on the poster shows that metal hydroxide precipitates contain a surface charge. While the surface contains both negative and positively-charged sites, this graph shows at pH < 8 the iron particles contain more positively-charged sites than negative, thus the net charge is positive. When surface potentials are high, repulsion among particles is strong and particles don't collide, grow, and flocculate.
4. The graph shows at pH 8 the overall charge is net neutral (aka Zero Point of Charge) and charge repulsion is low. Flocculation can be strong and efficient in many active treatment systems treating for iron because the treatment pH is near the point of zero charge. Particles are free to collide without repulsion and grow in mass until gravity causes solid/liquid separation.
5. In treatment systems that contain a treatment pH that is not near the Zero Point of Charge or have high water velocities (like in clarifiers), polymers are often added to the water to induce flocculation. Polymers are long-chained molecules that can contain positive or negative-charge polymer sites. In the case of mine drainage treatment, anionic polymers are very effective at attracting positively-charged Iron Hydroxide particles to the negatively-charged sites. The polymer forms a "bridges" that holds the particles together and gain mass until gravity causes solid/liquid separation. The bridging can be weak, thus turbulent conditions must be avoided to break or "shear" the newly-formed floc.
6. Flocculation is more difficult in solutions containing low concentrations of suspended solids because of the decreased chance of particle collision and growth. And, repulsion can occur if the pH is less than the Zero Point of Charge.
7. As you can see in this beaker of water from the effluent of Pond 3 (hold a beaker of Pond 3 water to the group), the majority of the iron hydroxide settled in the first three pond as the water is just slightly reddish. Note the remaining suspended iron particulates causing the discoloration of the water cannot be individually seen. The particles did not flocculate or flocculate to a point where the particles grew to the size and mass necessary to be removed via gravitational settling. The lack of flocculation explains why the evaluation team found no additional settling occurs after the 3rd pond. The remaining particles are very small and their mass is insufficient to be settle via gravitational settling. The particles are effectively buoyant. Constructing additional ponds would not improve clarification and polymer addition is expensive.

Stop3: Inlet of Engineered Wetland

Easel 4: Figure 2 (on handout) showing charge repulsion, Wetland/Particle Figures Tiara created, Wetland Effluent Iron Graph, Wetland Facts (size, sizing).

- Talking Points Easel 4
  1. Notice how all of the rock and plant surfaces are covered in iron precipitate.
  2. Humic matter in the wetland contain and release carboxyl groups that are negatively charged. These attract the positively-charged iron particles and act as a natural polymer.
  3. Wetland constructed in Fall 2012 and planted into May 2013.
  4. Wetland is 1.2 acres
  5. Sized to remove 5 mg/L of Fe at 1,200 gpm
  6. Sizing Criteria was 7 g of Fe/m2/day
  7. Sizing included the effect of winter on plant growth and density.
  8. Key Points
     a. Flow distribution into and out of wetland
     b. Allow wetland plants to germinate and grow in saturated solid conditions with little or no standing water.
     c. Allow wetland plants to grow and become established before running water through the wetland (to avoid channeling of water).
     d. Use of water control structure to control water level in wetland (Agri-drain, riser & fernco couplers and emergency spillways)
     e. Increased Freeboard to accommodate iron and organic matter deposition to prolong maintenance events.
     f. Contains periodic rock baffles, level-lip spreaders, and outlet header pipes to prevent channeling and help to distribute flow
  9. As we walk from the inlet to the outlet of the wetland, take note how the water clarifies and how the organic matter and rocks are coated with iron hydroxide precipitate.

Stop 4: Wetland Outlet

Need: Hach Fe test kit, clean glass beaker to show iron removal in effluent

- Talking Points
  1. Use the Hack Kit to perform a total iron test on effluent.
  2. Note how the iron level is at or below detection. Notice the lack of iron staining anywhere at the end of the wetland. The lack of iron staining is highly unusal at the effluent of a treatment system and illustrates just how low the wetland is able to reduce the iron concentration.
  3. Note that 1-week of retention time couldn't clarify the iron the way the wetland did because gravity in settling ponds was the wrong removal mechanism.

4. Highlight the effluent water distribution system. It’s a perforated pipe at the bottom of the pond connected to an Agri-drain box. This system allows us to control the water level in the pond and the long lateral effluent pipe evenly “pulls” the water across the entire pond, enhancing the utilization of the pond and preventing short circuiting.

Stop 5: Manganese Removal Bed

Easel 5: Mn Eh/pH diagram and graph showing Mn-removal bed performance at effluent of system.

Need: Hach Fe test kit, clean glass beaker to show iron removal in effluent

- Talking Points
  1. Manganese is typically removed in active treatment systems by increasing the pH to between 9.5 and 10.0. Increasing the pH from 8.0 to 10 can double or triple treatment costs because of increased sludge production and chemical consumption caused by CO2 acidity, Mg acidity, and increased calcite ppt.
  2. The Eh/pH diagram shows, at chemical equilibrium, Manganese should precipitate at Pyrolusite in oxidizing conditions at pH > 3. However, the kinetics of this reaction is extremely slow and studies have shown that precipitation could take decades. However, this reaction is quite fast if facilitated by microbes, fungi, and algae. In the late 1990s, Dr. Jerry Vail, a professor at Frostburg State University in MD, developed a passive treatment system that provided a surface area and environment for microbes to grow and thrive. The treatment system consists of a shallow bed of Limestone, where the water elevation must be held below the surface of the limestone to ensure flow through the limestone. The limestone provides a surface area for microbe growth and manganese mineral precipitation. Dr. Vail cultivated select microbes in his lab and inoculate the limestone bed. However, beds are constructed and successfully operated without inoculation.
  3. Important features of this bed are:
     a. Mn-removal bed should only be placed on water with a pH>6 and net alkaline, unless you discuss the situation with a treatment specialist. These beds are placed at the end of a treatment system.
     b. Flow distribution in and out of the bed;
     c. Use of “fist-sized” clean limestone (ASSHTO # 1 or 3);
     d. Water elevation must be held below limestone surface;
     e. Ample dissolved oxygen is required for reaction completion (27 mg/L of Mn requires 8 mg/L of O2);
     f. A sizing criterion of 1 to 2 days of retention time is typically used, but it is recommended to use 2 days for sites with NPDES permits. The retention time

    volume is defined by the porosity of the bed and not the total excavation volume.
    g. Manganese removal beds have been successfully operating on discharges ranging from 1 gpm to > 1,000 gpm.
    h. Mn-removal beds are a biotic system and may take several months to become fully operational after initiating flow through the system.
4. Periodic maintenance includes using an excavator to break apart the mineral precipitate as it grows in sizes and decreases porosity (thus flow through the bed).
5. The precipitation of manganese minerals on the surface of the limestone is not a detriment, but rather will increase the rate of Mn removal in the bed.
6. The discharge contains 10 mg/L of dissolved manganese when it is pumped to the surface. This Mn-removal bed was designed to remove 10 mg/L at 60 gpm. The graph on the poster shows the influent Mn concentration decreased from 7.5 mg/L to 2.5 mg/L after the engineered wetland was installed in 2013. Like the Manganese removal bed, the wetland is a biologically-rich treatment system and the wetland removes ½ of the manganese. While the influent Mn concentration is not extremely elevated, the bed does reduce the Mn concentration to less than detection, which is < 0.04 mg/L. Beds have been successfully constructed on discharges containing over 100 mg/L of Mn.