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CH2M Hill Plateau Remediation Company - Hanford

Evaluation Report of Fluidized Bed Reactors

March 7th to March 9th, 2017

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JUN 13 2017
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Envirogen Technologies, Inc. personnel (Mr. Jeff Lambeth and Mr. Sam Wong) performed site visits on March 7th to March 9th to meet with the CH2M Hill Plateau Remediation Company (CHPRC) Engineering team and Operation team on the FBR's performance. This document summarizes site activities, documents observations, and provides recommendations as part of the performance evaluation report.

Current System Operation:

The FBR system (FBR-A and FBR-B) is currently the primary nitrate treatment unit process at the water treatment plant. The FBRs use granular activated carbon (GAC) as media. The FBRs are followed by individual media separators. The FBRs are currently treating a total of 2,000 gpm (1,000 gpm each) of feed flow, with dissolved oxygen (D.O.) at approximately 9 mg/L and nitrate as nitrogen (NO_X-N) at approximately 25 mg/L. The extraction wells are adjusted to maintain a mass-loading rate of 600 lbs/day of NO_3-N to the FBRs. Effluent NO_X-N concentration has been staying at approximately 5 mg/L during the last few months during normal operation.

In addition to the continuous feed water from the wells, periodic recycled water from the downstream solids-handling systems combines to the feed flow to the FBRs, at an average 0.5% of the plant feed flow. COD, coagulant and polymer are present in the recycled stream.

The electron donor being used at the site is MicroCG with phosphoric acid as the nutrient. Although pH adjustment pumps are installed, and they are not being used. Desired COD residual level is below 20 mg/L, and recent COD residual levels have been maintained at approximately 10 mg/L under normal operation. Target orthophosphate-P (Ortho-P) residual level is below 0.40 mg/L, and recent Ortho-P residual levels have been maintained at approximately 0.20 mg/L. A customized blend of micronutrient (Metsource) from Riverbend is being used.

The biomass separators are removed from the FBRs. With the FBRs' closed top configuration, access to the biomass separators was difficult and it prohibited the operators from maintaining the biomass

separators. The in-bed eductors are also removed due to water leakage at the connection points. The biomass separators and the in-bed eductors are replaced with a network of four eductors located at different quadrant and elevation levels in the FBRs. Five eductors are installed at 10-feet, 16-feet, 18-feet, 20-feet, and 22-feet elevation from the bottom of the FBRs.

The bed level measurement devices have been removed from the FBRs due to perceived inaccuracies in level indication. The bed levels are measured using inspection cameras that also record videos of the media while measuring the bed levels. The bed levels are measured four days a week (Monday to Thursday). There have been occasions when the beds were not measured for long periods of time due to safety concerns caused by weather conditions. Current FBR bed levels are at approximately 18 feet.

On-line nitrate analyzers have also been removed from the system due to inaccurate measurements and pluggage in the sample tubing resulting from biological growth. The influent feed nitrate analyzer also experienced similar pluggage issue, possibly due to the recycled stream that was returned to the upstream of the FBRs. Effluent NO_X-N is measured using the on-site HACH test kits for four days a week (Monday to Thursday).

The carbon separator return lines operate continuously.

Discussions:

Design Parameters

The designed loading of the FBRs was 1,200 lbs/day of NO_3-N (2500 gpm of feed flow at roughly 40 mg/L of NO_3-N). The current loading of the FBRs is 600 lbs/day. An attempt was made in 2015 to increase the mass loading to the FBRs, and the effort was stopped at approximately 792 lbs/day, due to difficulties in controlling the rapid bed expansion resulting from the increasing load.

COD and Ortho-P Residual

The MicroCG and Ortho-P dosage rates are being monitored closely by the operators to prevent elevated COD residual levels at the FBR effluent. The COD and Ortho-P concentrations have been causing undesirable biological growth of bacteria at the downstream injection wells. The plant effluent COD concentration limits the excess COD and Ortho-P in the FBRs. Limiting excess COD concentrations may lead to under-dosing condition, and it may stress the microorganisms in the FBR. The stressful condition

may result in undesirable effects such as incomplete denitrification, excessive off-gassing, and formation of extracellular polymeric substance (EPS) in the FBR. These topics are further discussed below.

Nitrate vs Nitrite

Monthly nitrite (NO_2-N) samples shows that the NO_2-N would range from ND to 10% of NO_X-N at the FBR effluent. With the excess COD level being limited due to concerns relating to fouling at the downstream injection wells, variations in the feed water may cause incomplete denitrification to occur and NO_2-N can be present in the FBR effluent water. Under normal operating conditions, elevated NO_2-N concentrations can be used as indicator that a system upset has occurred in the FBRs.

FBR Bed Measurement and Controls

The FBR beds are measured once every Monday, Tuesday, Wednesday, and Thursday. An automated system to measure the FBR beds is highly desirable. A bubbler system that Envirogen has implemented in other FBR systems may be used to send an alarm/notification to the operators.

The FBRs were designed with FBR bed level controls. The biomass separators (removed) were used to remove biomass from the GAC media with largest biological attachment. Majority of the GAC would be retained in the FBR after the biomass was removed. The biomass separators were removed from the FBR and replaced with eductors at the upper portion of the expanded FBR beds. An alternative FBR bed level control strategy that Envirogen has used was to remove the biomass by agitating the with pneumatic diaphragm pumps. The pumps should be properly selected to handle GAC and should equipped with flush water connection to prevent plugging.

Another biomass control was the in-bed eductor system located at the lower elevation of the FBR bed. The in-bed eductors should be operated when high biological growth occurred at the lower portion of the FBR bed. Due to water leakage, the side insertion in-bed eductors assembly were replaced with top insertion in-bed eductors.

Nitrogen gas generation is expected to occur in the FBR as the product of denitrification. Nitrogen gas can lift some GAC media above the FBR bed to the FBR effluent pipe. The media separator is designed to retain and to return the GAC media back to the corresponding FBR. The media separator should also retain a small amount of GAC with high biological attachment if it were to exit the FBR.

GAC Carry-Over and GAC Specifications

The operators constantly notice GAC carry-over from the FBR system. A portion of the GAC can usually be recovered from a downstream flow splitter structure, with the remaining portion processed through the solids-handling system. The average GAC loss is approximately 35 cubic feet for every 2 months.

The cause of GAC carry-over can either be a continuous outflow due high biological attachment, a periodic exit of GAC caused by upset condition, out-of-spec GAC media being flushed out of the FBRs, or a combination of these factors. Increasing mass loading rate or EPS formation can result in high biological attachment and can overwhelm the existing FBR bed level control at the top of the FBR beds. EPS can further decrease the effectiveness of the top FBR bed level control since the biomass tends to be "sticky". The media separators are expected to retain and to return the GAC under normal operating conditions.

When a periodic upset occurs in the FBR system, such as insufficient COD dosage rate, nutrient deficiency, high or low pH, etc., the FBR can produce excessive off-gassing when the microorganism is stressed. The off-gassing can cause the GAC to exit the FBR in a short period of time, and rate of GAC exit may exceed the rate of GAC return from the media separator, resulting in loss of GAC to the downstream processes.

The physical properties of the GAC in the FBR currently may be different than the original Envirogen specification. Abrasion could occur to the GAC when it is recovered from downstream processes, or the make-up GAC could have higher variability in terms of their sizes. GAC fines (small GAC) are more likely to flow out of the FBR.

The cause(s) of the GAC carry-over should be further investigated to determine if it was caused by system upset or excessive biological growth (i.e., periodic or continuous).

GAC vs Sand Media

Sand media has been used in other Envirogen's FBR systems instead of GAC. In general, a sand FBR can handle a higher loading rate when compare with a GAC FBR, but the effluent concentration level may not be as low or as consistent. The effluent concentration of NO_3-N at the site can be above non-detect level, therefore, replacing the GAC with sand media can increase the loading rate of the FBRs, assuming other limitations, such as COD residual levels, would not be implemented.

Biomass Quality

Recent videos of the GAC media throughout various depths of the FBRs were shown. For both FBRs, the biomass concentrations were higher at the upper portion of the FBR bed when compared with the lower portion. The biomass at the lower portions of the FBRs also looked very similar. At the upper portion of the FBRs, the volume of the attached biomass in FBR-B was much larger than the ones in FBR-A. The appearances were also different, with the biomass FBR-B having white color and with the biomass in FBR-A having gray color. The exact reason was not known.

Settled Bed Level

The settled bed levels of the FBRs are not measured on a routine basis. The settled bed level should be measured whenever the FBRs are shutdown during maintenance, as well as after any upset conditions that lead to excess GAC carry-over. The information could help determine how much carbon would need to be loaded.

Alternative Electron Donor

Alternative electron donor may be evaluated since it may provide other benefits, such as better cost or lower biomass yield.

Recommendations:

- The physical properties of the recovered GAC, make-up GAC, and the GAC currently in the FBR should be tested and compared with original specifications.
- Alternative FBR bed control strategy utilizing properly selected pneumatic diaphragm pump should be tested and implemented if applicable.
- The cause(s) and types of GAC carry-over should be further investigated (i.e., continuous outflow of GAC or periodic) and it may help to refine process parameters.
- FBR bed level transmitter (bubbler) system that sends alarms to operators should be tested and implemented if applicable.
- The residual Ortho-P level should be increased to between 0.5 to 1.0 mg/L.
- The NO_2-N concentrations at FBR effluent should be routinely monitored as an indicator for upset condition.

- If possible, a lower dosage of sodium hypochlorite at the plant effluent may be injected at the plant effluent stream to inhibit biological growth at the injection well.
- Currently, the residual COD level at the FBR effluent is limited due to concerns relating to fouling at the downstream injection wells. If possible, the residual COD level may be maintained at or above 10 mg/L to ensure excess COD is available for the microbes.
- Alternative electron donors may be evaluated.