Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

MONITORING AND RESEARCH DEPARTMENT

REPORT NO. 14-42

STICKNEY PHOSPHORUS TASK FORCE

TECHNICAL MEMORANDUM NO. 5

STICKNEY BIO-P INFLUENT CHANNEL AND MIXED LIQUOR FERMENTATION SUMMARY

October 2014

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FORWARD

The Metropolitan Water Reclamation District of Greater Chicago (MWRD) recognizes the value of phosphorus as a non-renewable resource. In an effort to optimize the sustainable removal of phosphorus from its wastewater influents and the subsequent recovery of phosphorus in various forms suitable for use as an agronomic fertilizer, the MWRD initiated a Phosphorus Removal and Recovery Task Force in 2012. The Task Force initiated a study phase at several of the MWRD's Water Reclamation Plants (WRPs) to evaluate the feasibility of implementing enhanced biological phosphorus removal and to develop operational guidelines for optimizing its effectiveness. The Task Force has created WRP specific study workgroups that are focused on each of the WRPs that have been identified to participate in this initiative. As the workgroups complete various phases of their studies and evaluations they are documenting their findings and recommendations in technical memoranda. These memoranda are written by the WRP specific workgroups and vetted by the Task Force before being published. Their purpose is to capture the state of knowledge and study findings and to make recommendations for implementation of enhanced biological phosphorus removal as they are understood at the time the memoranda are published.

DISCLAIMER

The contents of this technical memorandum constitute the state of knowledge and recommendations developed by the MWRD's Phosphorus Task Force at the time of publication, and are subject to change as additional studies are completed and experience is attained, and as the full context of the MWRD's operating environment is considered.

Stickney Bio-P Influent Channel and Laboratory Mixed Liquor Fermentation Summary

Technical Memorandum 5

Date: June 4, 2014

To: Phosphorus Task Force & Advisory Committee

From: Phosphorus Study/Planning Team

Subject: Stickney Bio-P Influent Channel and Laboratory Mixed Liquor Fermentation Summary

1.0. Background

Volatile fatty acids (VFAs) are required as the precursor for enhanced biological phosphorus (P) removal (EBPR). There are a number of ways to generate VFAs internally for plants with relatively low influent VFAs, e.g. return activated sludge (RAS) fermentation and primary sludge fermentation. An emerging process for producing VFAs is mixed liquor (ML) fermentation, referred to as influent channel fermentation herein. Influent channel fermentation is an unmixed inline fermentation process. The fermentation of readily biodegradable chemical oxygen demand (rbCOD) in the ML to VFAs may produce the needed carbon (C) source for phosphate-accumulating organisms (PAOs) to grow and survive.

To encourage inline fermentation, the aeration and mixing in the activated sludge influent channel was stopped to encourage the ML to settle and a sludge blanket to accumulate and ferment on the channel bottom. The air to the channel was turned on for 5 to 15 minutes periodically to resuspend solids, prevent compaction of solids in the zone, and replace a portion of the sludge blanket for turnover of active solids.

2.0. Methods and Experiments

2.1. Inline Fermentation

At the beginning of the study, M&O staff fully opened all of the air valves in the east-west (EW) influent channel in Battery D, then turned off all the air mains to the influent channel.

On a routine basis at 10:00 a.m., air mains were turned on for approximately 5-15 minutes to resuspend a portion of the sludge blanket. Routine air blow-outs continued throughout the study.

M&R staff collected ML samples from the mixing channel corner (MCC) (beginning of the EW influent channel) and mixing channel (MC) (middle of the EW influent channel) at 9:30 a.m. (before blow-out) and 10:30 a.m. (right after blow-out) twice per week, weather permitting. The samples were measured for pH, temperature, TSS, ORP, VSS, sol COD, NH_3-N, NO_3-N, and ortho-P. This provided a recording of the change in nitrogen, C, and P levels in the influent channel. In order to identify the hydrolyzation and fermentation potential, attempts were made to grab a sample of the sludge blanket from the middle of the influent channel with a ponar sampler. These samples were scheduled to be analyzed for sol COD and VFA concentrations two times per week. Different blow-out schedules were tested, i.e. daily for three weeks, Monday and Friday for four weeks, and lastly Monday only for four weeks.

2.2. Laboratory Mixed Liquor Fermentation

ML samples were collected from the MC in Battery D on 2/24/14, 3/3/14, and 3/10/14. The ML samples were then placed in 5-gallon buckets. The test bucket for summer fermentation tests was placed in the pilot room at room temperature ranging from 19°C to 23°C with the lights off. The test bucket for winter fermentation tests was placed in the environmental room at 10°C on 2/24/14 and 4°C on 3/3/14 and 3/10/14 with the lights off. Grab samples were taken from the test buckets at time intervals of 3, 27, 51, and 75 hours, respectively. The ML samples were mixed gently before each grab sample. The collected samples were measured for pH, temperature, TSS, ORP, VSS, sol COD, NH_3-N, NO_3-N, and ortho P.

3.0. Results and Discussion

Table 1 summarizes the sol COD results of ML samples collected for the full-scale inline fermentation study with different blow-out schedules, i.e. daily for three weeks, Monday and Friday for four weeks, and lastly Monday only for four weeks. The average sol COD level shows no difference before and after blow-out regardless of the different blow-out schedules. It may due to the fact that fermented soluble C was consumed so quickly upon production that the ML sampling performed could not catch the release. Similarly, the average ORP in the test channel before and after the blow-out during the study period showed no change as well. The average changes before and after blow-out for NH_3-N, NO_3-N and ortho-P concentrations in the test channel were 0.101 mg/L, 0.009 mg/L and -0.007 mg/L, respectively, during the whole study period, i.e. essentially no change

In order to determine if a sludge blanket accumulated on the bottom of influent channel, an effort was made to collect a sludge sample with a ponar sampler. However, even after the longest blow-out schedule (once per week, Monday only), no sludge sample could be collected. This indicates that little to no sludge blanket was formed during the study period, which may be due to the relatively fast velocity (~1.7 feet per second) in the test channel.

Table 2 summarizes the sol COD results of the laboratory ML fermentation tests. With the ML sitting in the buckets, sol COD concentration increased up to 413 mg/L after three days' solids retention time (SRT) at room temperature. The ratios of sol COD to MLVSS in the tested ML shown in Table 3 ranged from 7.85 percent to 14.86 percent after three days SRT for summer fermentation tests. Due to a broken environmental room, only one ML winter fermentation was tested at 10°C; the other two tests were conducted in the sample storage room at 4°C. The average ending sol COD concentration for winter ML fermentation was 82 mg/L; this number would likely be higher if the tests were done at 10°C (please note two ML winter fermentations were tested at 4°C due to environmental room problems on 3/3/14 and 3/10/14). The ratios of sol COD to MLVSS ranged from 1.62 percent to 3.92 percent after three days SRT for winter fermentation tests.

Figure 1 shows the sol COD profile of Stickney ML laboratory fermentation in simulated summer and winter conditions. For both summer and winter ML fermentation tests, sol COD increased after one day of fermentation. A correlation between ORP and released sol COD concentration was graphed in Figure 2. An ORP value of about -125 mV or lower corresponds to a sol COD concentration of 100 mg/L or higher. Figure 3a shows all the test parameters against sampling time on 2/24/2014. Please note the winter fermentation on 2/24/2014 was conducted at 10°C. MLSS on 2/24/2014 was 4,400 mg/L, and MLVSS was 3,360 mg/L. It can be seen that sol COD was produced two to three times higher in the summer temperature than at the winter temperatures. However, ortho P release was only little different between summer or winter fermentation. Figures 3b and 3c show all the test parameters against time from the 3/3/14 and 3/10/14 fermentation tests in which winter fermentation was tested at 4°C (staff did not take an ORP reading at 75 hrs on 3/10/2014); therefore sol COD concentrations were much lower compared to sol COD from the 2/24/14 tests at 10°C.

In summary, a sludge blanket cannot be built up in the EW influent channel due to the high velocity without adding a baffle or some other device. Laboratory ML fermentation tests indicate that if we are able to generate a sludge blanket, a fair amount of sol COD can be produced at an SRT of three days depending on temperature.

TABLE 1: SOLUBLE CHEMICAL OXYGEN DEMAND RESULTS OF MIXED LIQUOR FROM INLINE FERMENTATION PILOT STUDY IN BATTERY D

	ST_D_MCC*		ST_D_MC**	
	Before	After	Before	After
Daily Blow Out (12/12/13 – 1/5/14)				
# of samples	3	3	3	3
Minimum	44	40	43	34
Maximum	102	117	87	104
Average	64	68	61	62
Monday & Friday Blow Out (1/6/14 – 3/9/14)				
# of samples	6	6	6	6
Minimum	37	39	37	37
Maximum	138	132	136	142
Average	65	63	61	61
Monday Blow Out (3/10/14 – 4/7/14)				
# of samples	5	5	5	5
Minimum	25	27	25	31
Maximum	126	94	149	214
Average	55	53	71	76

*Sampling point ST_D_MCC is in the corner of the NW and EW influent channels of Stickney Battery D.

**Sampling point ST_D_MC is in the EW influent channel of Stickney Battery D before entering aeration tank # 4.

TABLE 2: SOLUBLE CHEMICAL OXYGEN DEMAND RESULTS OF LABORATORY MIXED LIQUOR FERMENTATION TESTS*

	Summer				Winter			
	sol COD (mg/L)				sol COD (mg/L)			
Time	3 hr	27 hr	51 hr	75 hr	3 hr	27 hr	51 hr	75 hr
# of samples	3	3	3	3	3	3	3	3
Minimum	25	92	170	256	25	25	33	52
Average	28	127	193	342	28	38	63	82
Maximum	33	170	216	413	35	50	109	105

*Summer ML fermentation tests were conducted at room temperature; liquid temperatures ranged from 16°C to 23°C. Winter ML fermentation tests were conducted in an environmental room. Due to environmental room shut-down problems, one test (2/24/2014) was tested at 10°C and the other two were tested at 4°C; liquid temperatures ranged from 4°C to 13°C.

TABLE 3: SOLUBLE CHEMICAL OXYGEN DEMAND TO MIXED LIQUOR VOLATILE SUSPENDED SOLIDS RATIOS PERCENTAGE AT THREE-DAYS SOLIDS RETENTION TIME FOR LABORATORY MIXED LIQUOR FERMENTATION TESTS

Date	2/24/2014		3/3/2014		3/10/2014	
	Summer	Winter	Summer	Winter	Summer	Winter
Temperature (°C)	19–22	10	19–23	4	19–21	4
solCOD/MLVSS (%)	7.85	3.92	14.86	2.54	9.86	1.62

FIGURE 1: SOLUBLE CHEMICAL OXYGEN DEMAND PROFILE OF STICKNEY MIXED LIQUOR LABORATORY FERMENTATION TESTS UNDER SUMMER AND WINTER CONDITIONS (SOLID LINE FOR SUMMER FERMENTATION AND DASHED LINE FOR WINTER FERMENTATION)

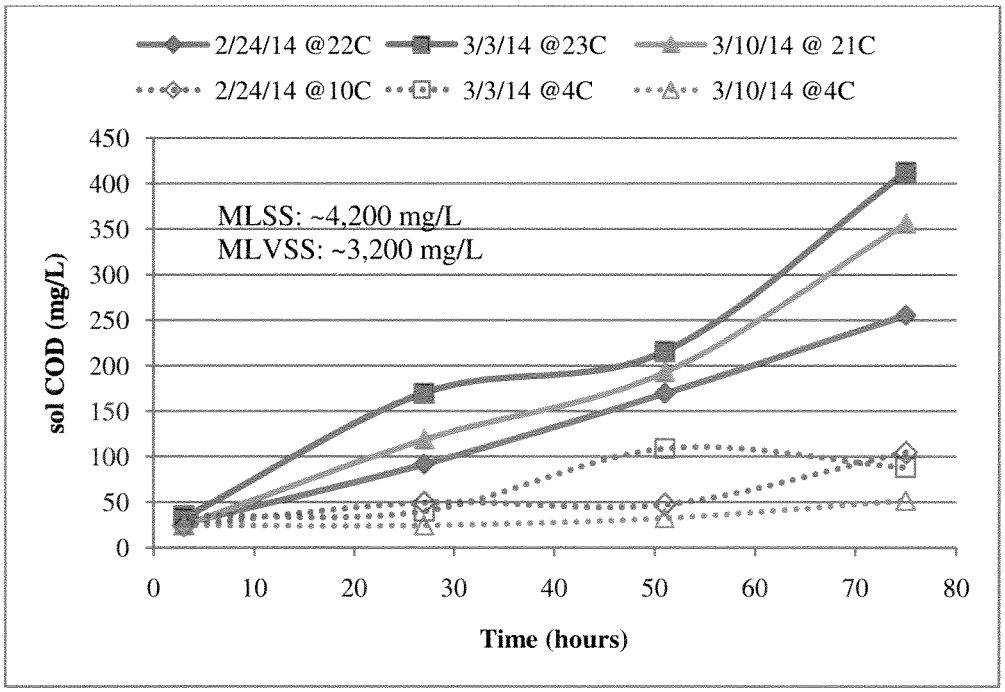

FIGURE 2: SOLUBLE CHEMICAL OXYGEN DEMAND AND OXIDATION-REDUCTION POTENTIAL RELATIONSHIP FROM THE LABORATORY MIXED LIQUOR FERMENTATION TESTS

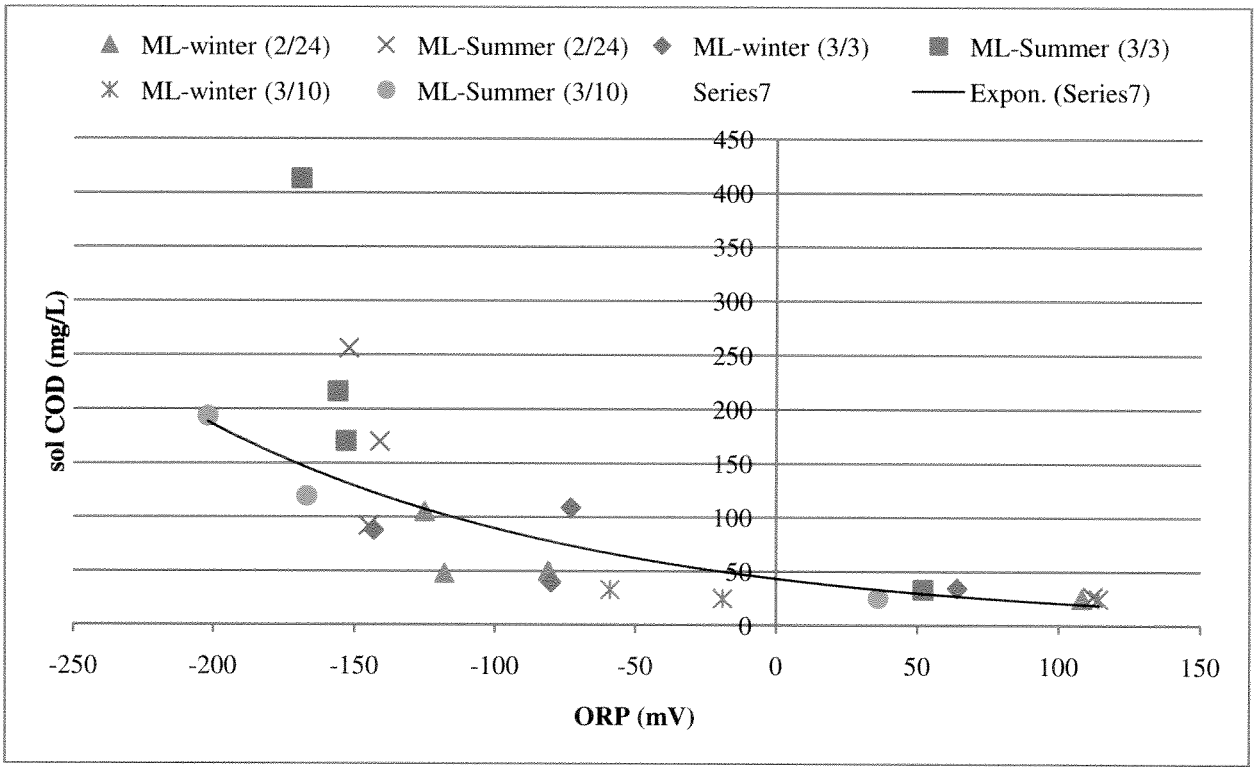

FIGURE 3: PROFILE OF ALL PARAMETERS FOR (a) 2/24/2014 FERMENTATION TEST (WINTER FERMENTATION TESTED AT 10 °C), (b) 3/3/2014 AND (c) 3/10/2014 FERMENTATION TESTS (WINTER FERMENTATION TESTED AT 4 °C)