MEMORANDUM

To: Dr. Valerie Budig-Markin
From: Caleb Dedmore
Subject: BOD Analysis of AWWTP Post-Oxidation Pond
Date: September 26, 2019

Introduction:
The Arcata Wastewater Treatment Plant (AWWTP) aims to bring water to standard quality before discharging into Humboldt Bay. The objective of this lab was to conduct an evaluation of the effectiveness of the AWWTP treatment train through a BOD analysis. My lab group conducted a BOD_5 test using Post-Oxidation Ponds samples at three different dilutions. Other lab groups measured Post-Treatment Wetlands and Post-Enhancement Wetlands, with a goal of comparing the amount of organic matter found at different stages along the AWWTP treatment train.

Methodology:
A water sample was collected Post-Oxidation Ponds of the AWWTP on Sept 10, 2019 in a jug and transported to the HSU campus.The BOD tests were begun on Sept 11, 2019 and completed at 1:00PM on Sept 16, 2019. After shaking to aggregate, samples were poured at different calculated dilutions to conduct a BOD_5 test followed in accordance with *Standard Methods* procedure 5210B (APHA 2005).The dilutions were based on hitting the high, medium, and low concentration range of the BOD_5 values expected after the oxidation ponds in the AWWTP treatment train. The expected range can be found in the Appendix. The samples were mostly evenly mixed other than for a small number of freshwater invertebrates spread throughout the diluted samples

Results:
The average BOD_5 Post-Oxidation Ponds of the AWWTP and the standard deviation of the measurements are presented in Table 1.The results of the BOD_5 test for the three different dilutions are also displayed. A notable trend can be suggested in that the BOD_5 measurement for each sample came out lower than the expected BOD_5 value for that respective dilution. Raw data for the BOD test can be found in the Appendix.

Table 1: Final results for the BOD_5 test Post-Oxidation Pond of the AWWTP at three different sample dilutions and their average.

BOD Level	Undiluted Sample Vol (mL)	Expected BOD (mg/L)	BOD5 (mg/L)	BOD5 Average (mg/L)	Standard Deviation (mg/L)
L	40.0	30	26.25	31.36	4.81
M	26.7	45	30.04		
H	20.0	60	37.80		
Control	0.0	0.0	0.52	--	--

Discussion:
The average BOD_5 for the Post-Oxidation Pond location along the AWWTP treatment train was 31.36 mg/L with a standard deviation of 4.81 mg/L. Each of the three dilutions had a lower BOD_5 measurement than the expected respective values. This indicates that the oxidation ponds are effective at removing organic matter from wastewater, and have done so at the upper expectation of efficiency.

The objective of this lab was to assess the effectiveness of the AWWTP treatment train via a BOD analysis. While the Post-Oxidation Pond location showed lower BOD_5 measurements than expected, the average BOD_5 was still within the lower range of expected values for the level of organic matter at the site location. The average BOD_5 for the Post-Treatment Wetlands also fell within the lower range of expected BOD_5 concentrations. The average BOD_5 for the Post-Effluent Wetlands was inconclusive. Four samples had less than a 2 mg/L change in DO and so were considered under-depleted. One of the two remaining PEW samples was over-depleted with an ending DO concentration of less than 1 mg/L. The last of the six PEW samples did not have a sufficient initial DO, most likely due to a failure to aggregate the sample before use. Group data of the three test sites along the AWWTP treatment train can be found in the Appendix.

Typical BOD limits for wastewater are monthly averages of 30 mg/L and weekly averages of 45 mg/L (Davis and Masten, 2004). Consistent testing would need to be done to monitor for spikes and dips in BOD levels within the treatment plant. Amongst the valid data recorded by the group, the BOD_5 values along the treatment plant were at the lower end of the expected values. The PEW value was consistently invalid, indicating that it may not have been user error. It's likely that the levels of organic matter at the PEW location of the treatment train are so low that it is difficult to get an accurate BOD reading. If true, this would indicate that the AWWTP is more than effective at lowering the amount of organic matter during wastewater treatment before discharging effluent into the bay.

Conclusion:
The average BOD_5 value Post-Oxidation Pond in the AWWTP was shown to be within 1.4 mg/L of the lowest expected BOD_5 value, indicating that the oxidation ponds are effective at removing organic matter from the wastewater. Low BOD_5 averages were also observed for the Post-Treatment Wetlands, and results for the Post-Effluent Wetlands were inconclusive. The goal of this lab was to assess the AWWTP treatment train, and both the POX and PTW sites were successfully effective. While the PEW BOD_5 measurements were inconclusive, it is likely that this was due to very low BOD levels that were difficult to measure accurately. If so, this would show that the AWWTP is very effective at removing organic matter from wastewater during wastewater treatment. The data that is viable shows that the AWWTP is at an acceptable concentration of organic matter at the sites tested within the treatment train.

References:

American Public Health Association (APHA), American Water Works Association (AWWA), Water Environment Federation (WEF). (2005). Standard methods for the examination of water and wastewater, 21st Ed., American Public Health Association, Washington DC, USA

Davis, M. and Masten, S. (2004). *Principles of environmental engineering and science*. 2nd ed. New York: McGraw-Hill.

Appendix:

A. Table 2 shows the expected BOD range and the undiluted sample volumes for each of the samples from the three sites where water was collected at the AWWTP. The dilution factor and undiluted sample volume calculations can be found in section E.

Table 2: The dilutions for each BOD sample is shown below, with a range of expected BOD_5 values for each location on the treatment train.

Component	Expected BOD5 (mg/L)	BOD Level	Undiluted Sample Volume (mL)	Dilution Factor
POX	60	H	20.0	0.067
	45	M	26.7	0.089
	30	L	40.0	0.133
PTW	50	H	24.0	0.080
	37.5	M	32.0	0.107
	25	L	48.0	0.160
PEW	15	H	80.0	0.267
	10	M	120.0	0.400
	4	L	300.0	1.000

B. Table 3 presents the raw data collected by my lab group Post-Oxidation Pond in the AWWTP treatment train.

Table 3: Raw data of measurements taken of the AWWTP Post-Oxidation Pond on Sept 11 and 16, 2019

BOD Level	Undiluted Sample Vol (mL)	BOD Water Vol (mL)	Expected BOD (mg/L)	DO initial (mg/L)	DO initial (%)	T initial (C)	DO final (mg/L)	DO final (%)	T final (℃)
L	40.0	260.0	30	8.58	97.8	21.84	4.56	50.1	19.95
M	26.7	273.3	45	8.75	99.8	21.84	5.56	61.2	19.97
H	20.0	280.0	60	8.79	99.9	21.68	5.75	63.2	19.98
Control	0.0	300.0	-	8.99	102.0	21.60	8.47	93.2	20.03

C. Table 4 presents the class data for the BOD_5 measurements of water samples from three different locations along the treatment train of the AWWTP.

Table 4: Two groups each measured the BOD_5 levels of three sites along the AWWTP. The average and standard deviation was calculated for each group, and inconclusive data due to measurement incontinuity was removed for the PEW groups

Sample Site	BOD5 Average (mg/L)	Std Dev (mg/L)
POX Group 1	31.27	2.84
POX Group 2	31.36	4.81
PTM Group 1	32.73	2.31
PTM Group 2	31.08	8.91
PEW Group 1	N/A	N/A
PEW Group 2	N/A	N/A

D. Below is the equation used for calculating the BOD_5 of the samples using the raw data recorded (raw data shown in Appendix Section B).

- Equation:

$$BOD_5\,(mg/L) = \frac{(D_i - D_f) - (B_i - B_f)}{P}$$

Where:

D_i = the initial DO of the sample (mg/L)
D_f = the DO of the sample on day 5, after incubation (mg/L)
B_i = the initial DO of the control (mg/L)
B_f = the DO of the control on day 5, after incubation (mg/L)
P = the volumetric fraction of the sample (dilution ratio)

- Sample Calculation using the 40 mL undiluted sample volume sample:

$$BOD_5\,(mg/L) = \frac{(8.58 - 4.56) - (8.99 - 8.47)}{0.133}$$

$$BOD_5 = 26.25\,\frac{mg}{L}$$

E. The derivation for the dilution factor for each BOD_5 test consisted of two equations. When combined this allowed for the calculation of the undiluted sample volume to use for each of the three BOD samples.

- Equations:

$$Dilution\,Factor = P = \frac{4\,(mg/L)}{Expected\,BOD_5}$$

and,

$$Dilution\,Factor = P = \frac{Volume\,undiluted\,sample}{Total\,volume}$$

When combined,

$$Volume\,undiluted\,sample\; = \frac{4\,(mg/L)}{Expected\,BOD_5} \times Total\,volume$$

- Sample Calculation using the low end expected BOD_5 value of 30 mg/L:

$$P\; = \frac{4}{30}(mg/L) = \frac{Undiluted\,sample\,volume}{300mL}$$

$$Undiluted\,sample\,volume = 300mL \times \left(\frac{4}{30}mg/L\right)$$

$$Undiluted\,sample\,volume = 40mL$$

F. Standard Deviation was calculated for each group's averaged BOD_5 results at the three locations in the AWWTP treatment train. This was done using the excel function *stdevpa(...)*, which uses the following equation to compute standard deviation:

- Equation:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x - x_{avg})^2}{n}}$$

- Sample Calculation solving for the standard deviation of the BOD_5 data:

$$\sigma = \sqrt{\frac{(26.25 - 31.36)^2 + (30.04 - 31.36)^2 + (37.80 - 31.36)^2}{3}}$$

$$\sigma = 4.81\,mg/L$$