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Correlation of BOD_5 and COD for Specific Mill Operations

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Abstract:

The study conducted here was done to test the validity of a study conducted twenty years ago, which found that the ratio between COD and BOD_5 was 1.6 for different pulp and paper mill wastewater effluents. This study was conducted by first treating three different pulping operation wastewaters. BOD and COD tests were then conducted on the treated wastewater samples. The results from these BOD and COD tests were found to be invalid due to problems encounter during the experiment. Due to the results being invalid, it was impossible to compare results found by this study and those found by the past study. Although the study was found to be invalid, many important lessons can be learned from conducting an experiment like this one.

Introduction:

When looking at effluents from pulp and paper mill operations, one of the most important items to look for is the amount of dissolved oxygen that is present in the wastewater stream. Dissoloved oxygen is an important aspect of a water stream because it helps maintain the aquatic life present in that stream. Effluent from pulp and paper mill operations contain organic matter, which uses dissolved oxygen. It is important to find the amount of organic matter present in a waste stream, this can be used to determine the effect the organic matter will have on the dissolved oxygen supply. Two tests used to determine the amount of organic matter present in a water stream are BOD_5 (biochemical oxygen demand) and COD (chemical oxygen demand). The importance of knowing the amount of organic matter present in a water stream comes when determining whether this organic matter will use dissolved oxygen to a level where aquatic life in the water stream suffers.

With new mills operating many different processes at one facility, it is important to determine which of these processes is creating the most organic matter. R. Van Soest did a study which looked at COD and BOD correlation for many different pulping operations. Van Soest's study consisted of gathering BOD and COD data from these many different pulping operations, plotting them against each other, and developing ratios of COD to BOD for the different pulping operations. The idea proposed by this thesis is to test the validity of the study conducted by Van Soest. This was done by taking a step back in the wastewater treatment process. What this means is that this study first collected wastewater samples, then treated these wastewater samples with mixed liquor, and finally BOD and COD tests were run to see if the results derived by Van Soest are, in fact, true.

The experiment was run using wastewaters from three different pulping operations. These samples came from a bleached kraft plant, a semi-chemical plant, and a deinking facility. These samples were obtained from operations in the Kalamazoo area. The samples were tested separately to determine BOD_5 and COD. The testing was conducted in the National Council for Air and Stream Improvement (NCASI) lab. The equipment that was used included: a DO meter, COD testing vials, BOD test bottles, and other general equipment. With the use of this equipment and the samples collected, the results from this experiment can hopefully be beneficial to the pulp and paper industry.

Problem Statement:

The experiment that was performed for this thesis looked at trying to correlate treated BOD_5 results to treatable COD results. This was done to test the validity of results obtained from a study conducted by Van Soest, which stated that in all the waste streams he studied the ratio of COD to BOD was 1.6 (5). The difference between the study conducted by Van Soest and the study which was conducted here, is that this study took wastewater samples directly from the pulp mill, treated them, and developed the ratios from data collected from these samples, where as Van Soest used a large number of data points collected from the individual pulp mills, plotted them and developed ratios from these plots. It is also the intention of this study to make it possible to estimate the amount of BOD_5 present in the sample from COD results, which can also cut the time for determining the amount of BOD_5 from five days to about three hours. The results also make it possible to look at final mill effluents and determine which process the organic matter is coming from.

Background Information on BOD and COD:

This section will begin by defining the main terms to be discussed in this study which are BOD_5 (biochemical oxygen demand) and COD (chemical oxygen demand).

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen used by microorganisms in the biochemical oxidation of organic matter (1). BOD is determined in a laboratory based on the premise that all the biodegradable organic matter contained in a water sample will be oxidized to CO_2 and H_2O by microorganisms using molecular oxygen (2). The following general equation shows what occurs when degrading wastes biochemically (3).

$$C_aH_bO_c + O_2 + \text{nutrients} \xrightarrow{\text{bugs}} CO_2 + H_2O + \text{sludge} + \text{energy}$$

The BOD test is conducted by first testing the sample for initial dissolved oxygen (DO), then placing the samples in a temperature controlled environment for five days, then testing for final DO, and finally a simple calculation to determine the BOD_5 level.

There are some limitations associated with the BOD test. These include: a high concentration of active, acclimated seed bacteria is required, pretreatment is needed when dealing with toxic wastes, and the effects of nitrifying organisms must be reduced, only the biodegradable organics are measured, and the long period of time that is required to obtain the results (1).

The chemical oxygen demand (COD) test is used to calculate the oxygen equivalent of the organic matter that can be oxidized by a strong oxidizing agent, usually potassium dichromate, in an acid medium (2). The test is used in the pulp and paper industry to measure the organic matter that contain compounds that are toxic to biological life (1). The COD test, which requires a catalyst (silver sulfate) to aid in the oxidation of certain classes of organic compounds, must be performed at an elevated temperature (1). The general chemical reaction, which occurs during the COD test when using potassium dichromate, is as follows:

$$C_aH_bO_c + CrO_7(-2) + H(+) \xrightarrow[\text{catalyst}]{\text{heat}} Cr(+3) + CO_2 + H_2O$$

The amount of organic matter present, in a wastewater sample, is determined by measuring the amount of potassium dichromate used to oxidize the organic matter (3).

There are advantages and disadvantages that come along with running the COD test. The main advantage of the COD test is that the results can be obtained in approximately three hours. A disadvantage of the COD test is that it cannot be used to differentiate between biologically oxidizable organic matter and non-biological oxidizable organic matter, Also, the test provides no information concerning the rate at which organic matter is being oxidized. The test can also be affected by inorganic constituents. One such constituent could be chloride. For this reason, such constituents must be removed before COD can be determined (4).

When looking at data calculated from running the BOD_5 test and the COD test, it has been found that the COD data of a sample must always be higher than BOD_5 data for the same sample size. This is true because more compounds can be oxidized chemically than can be oxidized biologically, and because BOD_5 does not equal ultimate BOD (2).

Literature Review:

There has been past research conducted on the same principle that was tested for this thesis. The difference between past studies and the study that was executed is that this study looked at specific pulp mill operations, the other studies looked at ratios pertaining to pulp and paper mills in general. Three of these studies were conducted using data collected from different pulp mills after treatment was completed, which is different because this study took the raw wastewater and treated it in the lab and generated data from this treated wastewater. The other study took treated wastewater from both a pulp and paper mill, conducted BOD_5 and COD tests on the treated wastewater, and calculated BOD_5/COD ratios from those results.

A study conducted by R. Van Soest was one of the first studies that examined BOD_5/COD ratios in the pulp mill industry. Van Soest used data collected from seven different pulp and paper mills to conduct his study. In his study, he points out that the key to correlating the two tests is data accuracy. For the data he collected, he found that 40% of the data points were inaccurate. He assumed that this was due to different methods used to test the wastewater at the different mills. After disregarding the inaccurate data, Van Soest found that correlations could be made between BOD_5 results and COD test results. The study showed, after all the data were plotted, that the ratio of COD to BOD_5 was 1.6 (5). One problem found with Van Soest's study was the use of the "eyeball" to place the ratio line in the dense portion of the data points.

Two studies were conducted overseas on BOD_5/COD ratios. One of these studies looked at ratios at a kraft pulp mill in Siberia. Timofeva found, by using data collected at the pulp mill, that BOD_5/COD ratios were in the range of 0.6 and 0.7 for a kraft pulp mill effluent (6). In a similar study conducted in Germany, the BOD_5/COD ratio, for a sulfite pulp mill, was found to be 0.3 (7). When reading these two studies it was found that the main purpose for examining this question was to find a quicker way for obtaining BOD_5 results.

The final past study related to the topic being examined here, is one conducted using treated wastewater from an integrated pulp and paper mill facility. The study looked at BOD_5/COD ratios from the pulp mill effluent, the paper mill effluent, and a combination of the pulp and paper mill effluent. Tuskan found that the effluent from the pulp mill had a BOD_5/COD ratio of 0.12, the paper mill effluent had a ratio of 0.86, and the combined effluents had a BOD_5/COD ratio of 0.24 (4).

Establishment of constant relationships among the various measures of organic matter content depends on the type of wastewater and the source of this wastewater. For the sake of comparison, it was found that for typical untreated domestic wastes the BOD_5/COD ratio varies from 0.4 to 0.8 (1)

One purpose for conducting this experiment was to look at specific pulp mill operations and see what amount of organic matter each pulping process will contribute to the final effluent. When researching this subject, it was common place to find studies conducted on products or operations used to reduce BOD_5 and COD in specific operations. One such operation used alkali and alum to reduce COD in hardwood kraft pulping processes. It was found when using alum, with precipitation and flocculation, the COD in the effluent streams was reduced up to 45% (8). Another study looked at the effects that chlorination would have on BOD and COD of secondary effluents, This study found that BOD and COD response is a function of the chlorine dosage. In all cases, as the chlorine dosage was increased the BOD and COD levels increased (9).

Experimental Plan and Procedure:

This study looked at the correlation of BOD_5 and COD in three pulping operations. The three different pulping operations that were chosen to be researched included: a semi-chemical process, a bleached kraft process, and a deinking process.

The semi-chemical wastewater sample was collected from Menasha Corporation in Otsego, Michigan. This pulp mill produces unbleached hardwood pulp using 320 ton continuous digesters, from which 830 tons per day of semi-chemical corrugating medium is produced in the paper mill. The wastewater treatment system, at Menasha, consists of primary and secondary treatment system with an aeration pond (10).

The bleached kraft wastewater sample was obtained through S.D. Warren in Muskegon, Michigan. The pulp mill in Muskegon produces 250 tons per day of bleached hardwood and bleached softwood. Wastewater treatment at S.D. Warren consists of primary and secondary treatment (10)

The deinked pulp wastewater sample was collected from an operation which chose to stay anonymous. The pulp produced at this facility is used to produce 400 tons per day of bond, offset, label, coated and recycled grades. Water treatment at this facility consists of primary treatment, clarifiers,and a joint municipal system (10).

Each of the wastewater samples discussed above were collected in five gallon buckets and transported to Western Michigan University where they were stored in the lower level refrigerator in McCracken Hall. The sample size collected at each facility was approximately 3.5 to 4 gallons.

The experiment that was run also used a sample of mixed liquor to treat the wastewater samples. This mixed liquor was gathered from Simpson Paper

Company in Plainwell, Michigan. The sample size collected was about three gallons. This sample was placed in the lab with aerators and fed daily to keep the microorganisms alive.

The experiment was run in the National Council for Air and Stream Improvement laboratory located in McCracken Hall. The experiment consisted of first running preliminary tests to determine the amount of time it will take to reach 90% treatment of BOD. The samples where then placed, with the mixed liquor, in five gallon buckets to be treated for the predetermined amount of time. After the treatment was completed, the samples were the tested for BOD_5 and COD. The results of these tests were then used to develop ratios of treated BOD_5 to treatable COD. These results were then used to evaluate the study conducted by Van Soest. The ratios can also be used to estimate BOD_5 levels by calculating COD levels. The results can also be used to determine which process, at a complex mill facility, is creating the most organic matter. With this information, it will be easier to identify that process and work to decrease the organic matter created.

The equipment that was needed to run this experiment is a dissolved oxygen (DO) meter, five gallon buckets, BOD bottles, COD vials (discussed later), COD temperature control, and pipettes.

The first operation that was conducted, for running this experiment, was to make nutrients for the BOD_5 test. The nutrients were made following the instructions described in Standard Methods. The nutrients that were used, consisted of a phosphate buffer solution, magnesium sulfate solution, calcium chloride solution, and ferric chloride solution (11). Once the nutrients were taken care of, the following procedure was followed to perform the BOD_5 test (11).

1. Aeration, of a determined amount, of distilled water for about a half hour. This is done to add as much oxygen to the distilled water as possible.
2. The addition of the pre-made nutrients to the aerated distilled water.
3. Calibration of the DO meter using the Winkler Titration method, as described in Standard Methods.
4. Two bottles are then filled with the aerated dilution water. The initial dissolved oxygen is verified and the bottles are stoppered. These are going to be used as the unseeded blanks, which are used to test the quality of the dilution water. The depletion of dissolved oxygen should be no greater than 0.2 mg/L.
5. Microorganisms are then added to the dilution water.
6. Two bottles are then filled with this seeded solution. The initial dissolved oxygen is tested and recorded, the bottles are stoppered. These seeded blanks will be used to calculate the BOD of the samples.
7. The treated effluent is then added to each BOD bottle. The amount of effluent, to be added to each bottle has not yet been determined. The bottles are then filled with dilution water, checked for initial BOD, and finally stoppered.
8. The bottles will then be placed in a controlled environment, which consists of total darkness and a temperature of 20° C, for a period of five days.
9. After five days, the bottles will be removed and tested for the amount of final dissolved oxygen.

BOD_5 is then calculated in the following way [1]:

$$BOD_5\ (mg/L) = \frac{(D_1 - D_2) - (B_1 - B_2)\,f}{P}$$

D_1 = dissolved oxygen of diluted sample immediately after preparation, (mg/L)

D_2 = dissolved oxygen of diluted sample after 5 d incubation at 20°C, (mg/L)

P = decimal volumetric fraction of sample used

B_1 = dissolved oxygen of seed control before incubation, (mg/L)

B_2 = dissolved oxygen of seed control after incubation, (mg/L)

f = ratio of seed in sample to seed in control

There are different methods used to determine the COD of a sample. The one which was used for this study was the closed reflux digestion method, which is described in Standard Methods. This method uses prepared vials containing potassium dichromate, silver sulfate, sulfuric acid, and mercuric sulfate. The potassium dichromate in the sample is used as the oxidizing agent, while the silver sulfate is used as a catalyst. The sulfuric acid, in the vials, is used to control the pH of the sample and the mercuric sulfate in the vial to complex halides, so they will not interfere with the test (11). Ferrous ammonium sulfate, of known molarity, must be prepared to titrate the remaining potassium dichromate in the sample vials. The following is the procedure used to conduct the closed reflux COD test (11).

1. Two digestion vials are prepared as blanks by adding 2 ml of distilled water. These are used to tell how much potassium dichromate is present.
2. Effluents are then added to vials in predetermined amounts, which have not yet been determined.
3. The sample vials are then placed in a heating chamber, which is set at 150°C, for two hours.
4. The samples are then removed and titrated with ferrous ammonium sulfate (FAS) to determine the amount of potassium dichromate that was consumed.

COD is then calculated like this (11):

$$COD\ (mg/L) = \frac{(A - B) * M * 8000 * \text{dilution factor}}{\text{ml of sample}}$$

A = ml of FAS used for the blank

B = ml of FAS used for the sample

M = molarity of FAS

Problems occurred during the procedure discussed above. These complications have made the results found by this experiment invalid. It was determined that the results from the BOD tests were invalid because the DO meter, used to conduct the BOD tests, had a faulty probe. This caused the results of the preliminary and final BOD_5 tests to be invalid. It is yet undetermined what went wrong with COD test. The results, which will be discussed later, were found to have impossible trends. For these reasons, averages of BOD_5 and COD were calculated for each wastewater sample, these averages were then used and compared to the results found by Van Soest.

After the BOD_5 and COD values were calculated, the results were tabulated and averaged. The average COD value was then divided by the average BOD_5. This calculation gave a ratio to correlate COD and BOD_5 for specific pulping operations. These ratios were then compared to the ratios which Van Soest developed. This was done to see if the results obtained by Van Soest are true, but as stated above the results from this study were found to be invalid, so the comparison of results would also be invalid.

Results:

The BOD_5 and the COD test results generated by this experiment have been found to be invaiid. Complications occurred during the running of the experiment, which made the results, almost impossible to achieve. This was determined by other tests conducted in different studies. The complications included: trouble with the DO meter used, and trends for BOD_5 and COD that were unheard of. For these reasons, the results that will now be discussed were found to be invalid.

The experiment conducted first required preliminary tests to determine whether the mixed liquor solution treated the wastewater to a desired 90%+ removal of BOD. The results of the preliminary tests did, in fact show that for two of the three samples at least 90% removal of BOD did occur.

The first sample treated with the mixed liquor was the sample from the bleached kraft operation. The BOD was first tested on the wastewater sample. The sample was then placed in a beaker with 10 ml of the mixed liquor solution for a time period of 24 hours. The sample was then filtered and the BOD was again tested on the treated sample. The results of these tests showed that there was 91.3% removal of BOD in the sample after treatment. The other samples were tested in the same way. The deinking operation wastewater had 92.5% removal of BOD after a treatment time of 24 hours.

The problem that occurred, with the treatment, was with the semi-chemical wastewater sample. The tests were conducted in the same manner as the other two wastewater samples, but the results were not what was expected. The results of the first treatment period showed that the percent of BOD removed was 83.4%. Since this did not meet the standards of the experiment, the tests were run again this time using a new sample of mixed liquor solution, from the same source as the other sample. This was done because it was thought that the microorganisms used in the first sample were old and possibly dead. The results of the second treatment showed an increase in BOD removal, but still not the amount of removal that the experiment demanded. The removal of BOD in the second treatment was 86.4%. For this reason, the results from this wastewater same were hard to compare to the results of Van Soest's study.

The next portion of the experiment consisted of running a number of BOD and COD tests on the treated wastewater samples. Ten BOD and ten COD tests were run on each sample. The amount of sample in each BOD test ranged from 2 ml to 10 ml, and the amount of sample in each COD test ranged from 1 ml to 5 ml. The raw data for each wastewater sample is shown in Appendix A through C. By looking at the calculated BOD_5 values it can be seen that there are definite trends. The problem with these trends is that they are backwards, because as the amount of sample used in a test increased the BOD decreased. With the COD results, there should be no trends at all, but instead the results should be near the same for all the tests conducted, no matter what amount of sample used was, with each wastewater sample.

An average value was calculated, for each different wastewater sample, for all the BOD_5 and COD tests conducted. The COD average was divided by the BOD_5 average to give a ratio. These ratio were then compared to the ratios found by Van Soest. These results will now be discussed.

Discussion:

The study that was conducted encounter many problems along the way. The first problem, which was not discovered until late in the study, was a faulty DO meter, which was used. This meter caused the BOD results to be invalid. The second problem was the COD results, which were found to have backward trends, meaning as the amount of wastewater sample increased the

COD decreased. In fact, there should be no trends found in a COD test, instead the results from each COD test should be near the same as other COD results, for each given wastewater sample. The third problem discovered was that the mixed liquor, used in treatment, did not treat the semi-chemical wastewater sample to the level expected by this experiment. Even though it has been found that the results obtained by this experiment were invalid, ratios were developed to give the closest possible comparison to Van Soest's study.

Ratios were developed by finding the average of all the BOD_5 and COD results, for each wastewater sample used. Table 1. shows the results for the bleached kraft wastewater sample. The table shows the BOD_5 values and COD values, the average of different values, and finally the ratio developed from these averages. For the bleached kraft sample, the ratio of COD to BOD_5 was found to be 4.26, which is far from the 1.6 ratio Van Soest found in his study. Tables 2 &3 are set up in the same manner as Table 1. was set up, with the difference lying in the type of wastewater sample tested. Table 2. shows the results of the semi-chemical wastewater. The ratio found for this sample was 2.1, again not real close to Van Soest result. The final table shows the results found for the deinking operation. The ratio found for this operation was 3.0.

Since the results of the study have been found to be invalid, it is impossible to make valid comparisons between the ratios found by the study conducted here and the study conducted by Van Soest twenty years ago.

Conclusion:

Conclusions are difficult to discuss when results of a study are invalid. Valid comparisons could not be made between this study and the study conducted by Van Soest, which was the main question to be tested by this

Table 1.

Development of COD/BOD_5 Ratio for Bleached Kraft Operation

	BOD Data (mg/L)	COD Data (mg/L)
	159	530.82
	165	460.04
	99.75	406.96
	100.5	336.19
	78	389.27
	78	365.68
	65.25	362.73
	64.5	345
	54.9	361
	55.2	361
Averages:	92.01	391.87

Ratio of COD to BOD_5 = 391.87/92.01 = 4.26

Table 2.

Development of COD/BOD_5 Ratio for Semi-Chemical Operation

	BOD_5 (mg/L)	COD (mg/L)
	553.5	884.7
	558	813.92
	272.25	548.51
	274.5	548.51
	178	436.45
	176.5	412.86
	130.13	380.42
	130.88	415.81
	102.3	375.11
	101.4	389.26
Average:	247.75	520.55

Ratio of COD to BOD_5 = 520.55/247.75 = 2.1

Table 3.

Development of COD/BOD_5 Ratio for Deinking Operation

	BOD_5 (mg/L)	COD (mg/L)
	255	469.84
	255	536.96
	145.5	436.28
	142.5	402.72
	103.0	380.35
	102.5	380.35
	85.12	352.38
	83.62	335.6
	72.3	335.6
	72.0	322.18
Average:	131.65	395.23

Ratio of COD to BOD_5 = 395.23/131.65 = 3.0

study. Ratios were developed, but the validity of these ratios rest on the results that were found during the experiment, which means the ratios are invalid.

After conducting this experiment, it is believed the most accurate way to test the validity of Van Soest's study is to collect wastewater samples from a number of different pulp mills producing the same product and conduct the same type of experiment conducted here. With the results from many different mills, a ratio can be developed by plotting BOD and COD against each other and finding a linear relation between these results. This linear relation can then be used to develop a ratio by finding the slope of the linear relationship.

From the experience of conducting this study, the main conclusions derived were to be sure that all the equipment, that is to be used in a study, is functioning properly, and if there is place or person that can answer questions about results or testing procedure, consult this source frequently to keep a study proceeding properly.

APPENDIX A

BOD AND COD RAW DATA FOR BLEACHED KRAFT

BOD

ML OF SAMPLE	SEED RATIO	INITIAL D.O.	FINAL D.O.	DISSOLVED OXYGEN		BOD5 (MG/L)
2	1.0	9.05	6.09	2.96		159
2	1.0	9.03	6.03	3.00		165
4	1.0	9.08	5.85	3.23		99.75
4	1.0	9.11	5.87	3.24		100.5
6	1.0	9.07	5.61	3.46		78
6	1.0	9.05	5.59	3.46		78
8	1.0	9.09	5.45	3.64		65.25
8	1.0	9.11	5.49	3.62		64.5
10	1.0	9.06	5.33	3.73		54.9
10	1.0	9.04	5.30	3.74		55.2
SEED		9.03	7.17		AVERAGE	
SEED		9.06	7.12		1.9	

COD

ML OF SAMPLE	DILUTION FACTOR	INITIAL FAS	FINAL FAS	FAS USED		COD (MG/L)
1	1	0.0	3.0	3.0		530.82
1	1	3.0	6.1	3.1		460.04
2	1	6.1	8.7	2.6		406.96
2	1	8.7	11.5	2.8		336.19
3	1	11.5	13.6	2.1		389.27
3	1	13.6	15.8	2.2		365.68
4	1	15.8	17.5	1.7		362.73
4	1	17.5	19.3	1.8		345
5	1	19.3	20.5	1.2		361
5	1	20.5	21.7	1.2		361
BLANK		21.7	25.5	3.8	AVERAGE	
BLANK		25.5	29.2	3.7	3.75	

APPENDIX B

BOD AND COD RAW DATA FOR SEMI-CHEMICAL

BOD

ML OF SAMPLE	SEED RATIO	INITIAL D.O.	FINAL D.O.	DISSOLVED OXYGEN		BOD5 (MG/L)
2	1.0	9.03	3.44	5.59		553.5
2	1.0	9.08	3.46	5.62		558
4	1.0	9.06	3.53	5.53		272.25
4	1.0	9.11	3.55	5.56		274.5
6	1.0	9.07	3.61	5.46		178
6	1.0	9.03	3.60	5.43		176.5
8	1.0	9.06	3.69	5.37		130.13
8	1.0	9.08	3.69	5.39		130.88
10	1.0	9.05	3.74	5.31		102.3
10	1.0	9.05	3.77	5.28		101.4
SEED		9.03	7.17		AVERAGE	
SEED		9.06	7.12		1.9	

COD

ML OF SAMPLE	DILUTION FACTOR	FAS USED		COD (MG/L)
1	1	2.5		884.7
1	1	2.6		813.92
2	1	2.2		548.51
2	1	2.2		548.51
3	1	1.9		436.45
3	1	2.0		412.86
4	1	1.6		380.42
4	1	1.4		415.81
5	1	1.1		375.11
5	1	1.0		389.26
BLANK		3.8	AVERAGE	
BLANK		3.7	3.75	

APPENDIX C
BOD AND COD RAW DATA FOR DEINKINK OPERATION

BOD

ML OF SAMPLE	SEED RATIO	INITIAL D.O.	FINAL D.O.	DISSOLVED OXYGEN		BOD5 (MG/L)
2	1.0	9.02	5.52	3.50		255
2	1.0	9.00	5.50	3.50		255
4	1.0	9.05	5.31	3.74		145.5
4	1.0	9.06	5.36	3.70		142.5
6	1.0	9.03	5.17	3.86		103.0
6	1.0	9.04	5.19	3.85		102.5
8	1.0	9.08	5.01	4.07		85.12
8	1.0	9.02	4.99	4.03		83.62
10	1.0	9.04	4.83	4.21		72.3
10	1.0	9.06	4.81	4.25		72.00
SEED		9.00	7.17		AVERAGE	
SEED		9.03	7.26		1.8	

COD

ML OF SAMPLE	DILUTION FACTOR	FAS USED		COD (MG/L)
1	1	3.3		469.84
1	1	3.2		536.96
2	1	2.7		436.28
2	1	2.8		402.72
3	1	2.3		380.35
3	1	2.3		380.35
4	1	1.9		352.38
4	1	2.0		335.6
5	1	1.5		335.6
5	1	1.6		322.18
BLANK		4.0	AVERAGE	
BLANK		4.0	4.0	

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