

Field Trials of the BOD-BART system™ for the Rapid Determination of Biochemical Oxygen Demand in Secondary and Tertiary Effluents

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Introduction

Traditionally referred to as the biochemical oxygen demand (BOD) test, this test evaluates the potential demand for oxygen that would be created by the degradable organics in an effluent. This is likely to be generated as these organics are biochemically degraded primarily by biological respiratory processes. The BOD test has become a standard regulated procedure that is applied to determine the potential oxygen demand that would be created by discharging liquid effluents into natural water systems. Of the various BOD test procedures, it is the 5-day BOD test that has become recognized as the standard test to generate a BOD₅ estimation of the total biochemical oxygen demand. In this test the weaknesses relate primarily to the long length of the test (5 days) that renders responsive management difficult to achieve, the needs to dilute the sample in an experiential manner to achieve a partial removal of oxygen from the sample in the five day incubation period, intrinsic and operator-induced variability in the BOD₅, and the marginalized incubation temperature that is applied. These concerns are all addressed in detail in section six below.

The major differences between the generation of a BOD₅ and a patented BOD_{BART} is that the former employs dilution to achieve the “correct” value for the oxygen demand (through a partial depletion from oxygen saturated state in the test) while the latter does not dilute the test sample but evaluates the demand for oxygen by the time that it takes the indigenous organisms to create a reductive condition primarily as a result of the respiration (and removal of) of the saturated oxygen present in the sample at the beginning of the test. It is therefore claimed that the BOD_{BART} is generated in a more scientifically defensible manner than the BOD₅ for the evaluation of the intrinsic oxygen demand inherent in the sample.

The main objective in the patented BOD-BART system therefore is to provide an easy and rapid alternative testing system for the determination of BOD₅ in municipal aerated lagoon and activated sludge treated municipal wastewaters. This would be generated as a BOD_{BART} number generated in seconds that would have a similar precision to, and be faster and more convenient than the BOD₅ test.

Biochemical Oxygen Demand (BOD) is the measure of potential maximal oxygen consumption that may be present in given water due to the intrinsic biochemical oxidation of organic matter. It is commonly understood that these biochemical processes leading to an oxygen demand are primarily propelled by biologically-induced respiratory processes in which microorganisms are a significant component.

Presently, BOD₅ is measured by using a standard five-day test procedure based on dilution techniques that achieve precision by determining the diluent that has partial oxygen consumption in five days. The decrease in oxygen in this diluent is used to generate the BOD₅. In a simple comparison, the BOD-BART system provides an easy and rapid (<20-hour or <72,000 seconds) measurement of the BOD based on enhanced respiration activity of the indigenous heterotrophic aerobic bacteria (HAB) inhabiting the sample.

Historically the BOD test has presented many challenges due to the heterogeneous nature of the material summarized in section 5-2 of 5210 in the Standard Methods for the Analysis of Water and Wastewater as:

“A number of factors, for example, soluble versus particulate organics, settleable and floatable solids, oxidation of reduced iron and sulfur compounds, or lack of mixing may affect the accuracy and precision of BOD measurement. Presently, there is no way to include adjustments or corrections to account for the effect of these factors”.

Methodology

The idea for developing the BART™ biodetector (now referred to as testers) was established in 1986 and moved into the commercial stage with sales in 1989. In this development the main force of developing this idea was concern over the probability that the standard agar spread plate techniques used to enumerate bacterial numbers in waters tended to underestimate and generate false negatives (Hattori, 1988). Unacceptable failures to detect nuisance bacteria in natural surface and ground waters were well known due to the inability of many of these bacteria to grow on the surfaces of various enrichment and selective agar media. To overcome this, the BART™ test was developed and patented (Cullimore and Alford, 1990). The concept differed from the agar spread plate enumeration technique in that a more conducive environment was applied to encourage the selected nuisance bacteria to become aggressive (by showing a reaction or a recognizable growth activity). This was done by using 15 ml of natural water sample placed in a vial where the aspect ratio (air contact surface area, cm²: volume, cm³) was adjusted to 1:40 by inserting a floating device that restricted oxygen entry from the head space into the water sample. This restriction caused a redox gradient to form as a result of the intrinsic microbial respiration that was oxidative at the air interface (where there was a constant influx of headspace oxygen) and reductive in the base of the test vial (where the oxygen was utilized faster than the arrival of diffusing oxygen from the headspace above). This thus provided the various aerobic and anaerobic bacteria an opportunity to become aggressive at different sites within the BOD-BART.

Selectivity for the microorganisms that are common in waste waters, this was achieved by placing a dried enrichment medium on the floor of the test vial. Once the water/wastewater sample had been added, the crystallized medium would dissolve and diffuse upwards. This would then allow selective growth creating activity and reaction of the microorganisms in the sample and able to be aggressive. Through comparisons with the agar spread plate techniques, it was found that the time lag (generally registered in days) could be linked to the population loading for those particular nuisance bacteria (Cullimore, 1993, 1999, 2000).

Accurate determination of the respiration rate of intrinsic population of HAB (i.e. the rate of the free oxygen uptake) in terms of time to positive reaction or time lag (TL) is the essence of the rapid determination of BOD_{BART}. This is used to determine the concentration of biodegradable respirable organic matter present within the sample that could create the oxygen demand. HAB are able to biodegrade or consume organic matter in water bodies as their source of energy using the available oxygen as an electron acceptor (by respiratory functions).

The BOD-BART system is restricted in its claims to the examination of the secondary and tertiary effluents generated by either the aerated lagoon or the activated sludge process when it is applied to municipal waste waters only. This system when applied generates at 28±1.0°C a time lag (TL) measurement that is given in seconds (from the time the BOB-BART tester is first charged with the sample and placed in the incubator reader with the sample in a oxygen saturated state to the time when the microbial consumption of oxygen through respiration is completed within a selected zone of the sample. This is detected by the methylene blue moving from the blue oxidized states to a transparent reduction state.

To do this the sample to be tested needs to be less than four hours old and has been collected following the procedures stipulated in the standard methods for the 5-day BOD test. The sample should be retained at room temperature and aerated prior to the dispensing of the sample into the BOD-BART testers. Samples should not be refrigerated in an attempt to extend the storage life of the sample prior to testing. Also samples may not be diluted under any circumstances since the indigenous microorganisms could become subjected to any undue stress.

The BOD-BART incubator reader used in the generation of the BOD_{BART} (TL) will only function with an acceptable precision if the average room temperature is at least 4°C below the normal operating temperature of the isothermal incubator block in the reader that is set at 28 ± 1.0 °C. In events where the reader is operating in a room where the temperature commonly can exceed 24 °C then the reader should be placed under refrigerated conditions operating within the range of 4 to 10 °C.

The acceptable range within which the BOD-BART reader generated precision is in suitable treated influents and effluents that have a BOD_5 ranging from 60 down to 8 mg/L. TL for the BOD_{BART} to detect the range of BOD_5 can function over a range of 20,000 to 60,000 seconds with an inverted correlation is inverted and the TL goes up as the BOD_5 declines.

It is recommended that all BOD-BART testing be done in triplicate and the BOD-BART reader is designed to allow the testing of these tests within a common set of three pod channels. A pod channel is the name given to a single channel set within the readers' isothermal incubator block within which a single tester can be monitored. Testing should be performed one sample at a time with the three replicated test samples set up as quickly as possible for insertion into the BOD-BART reader. Undertaking a set-up sequence involving more than one sample and the subsequent replicates can cause errors to be generated in the BOD_{BART} data generated. This is due to the fact that the test begins as soon as the tester has been inverted and agitated to saturate the sample with headspace oxygen. Delays on even two minutes may cause the final BOD_{BART} to vary by 120 seconds.

The BOD-BART system is capable of generating precision in the determination of the biochemical oxygen demand where the restrictions as outlined in section one are observed. Defined protocol may be defined within three major areas of concern. These are: (1) set-up procedure for a single BOD-BART tester; (2) application of the BOD-BART reader to determine the BOD_{BART} in seconds; and (3) generating an effective chain of custody to assure all aspects of the accuracy of the test.

This is the set-up procedure used for a single BOD-BART tester from a municipal aerated lagoon waste water sample:

1. Remove BOD-BART tester from the protective foil pouch and protective foam block. Note that the standard BOD-BART system calls for three testers to be employed on any given sample to assure statistical precision in the data. The remaining steps listed below relate to an individual tester (one of the triplicate of test to be performed).
2. Using a permanent black marker, label the top of the test vial cap with the date and sample origin.
3. Unscrew the cap from test vial. Set cap down directly onto a clean surface. To avoid contamination, do not invert cap. Note that it is very important not to directly touch or in any way contaminate the inside of the tester or the cap during this procedure.
4. Using a 10 or 20ml pipette fill the BOD-BART tester with 15ml of the sample to be tested. The fluid level should now have reached the fill line set at 15ml.
5. Carefully place the cap back onto the same tester and screw it down tightly.
6. Turn the tester upside down on a clean dry flat surface for 30 seconds. This allows enough time for the methylene blue dried inside the cap of the tester to dissolve into the waste water sample.
7. Grasp three testers in the palm of the hand and agitate using a wrist action to gently fully invert tester containing sample five times making sure that the ball inside the tester moves the

full length of the tube each way. This action repeated five times will saturate the sample with headspace oxygen and also evenly dissolve the methylene blue indicator into the sample. The sample in the tester should now have an even blue color. In the event that there is still unevenness in the distribution of the blue color due to the colloidal nature of the water being tested then repeat the inversion five more times.

8. When all three of the replicates have been inverted then each of the testers in to each of the three pod channels in a BOD-BART reader assigned to a single sample. Each tester should be firmly pressed into the appropriate channel so that the lower rim of the cap is touching the black plastic upper rim of the pod channel. When all three testers are in position in either channel 1, 2 and 3 or 4, 5 and 6 then the start button for that row should be pressed to start the test.

9. When the start button is pressed then there would be a notation that the test are running which would take the form of the letter “R” besides each of the three numbered channels used.

10. Testing now continues for up to 24 hours (86,400 seconds) with the testers being incubated by the isothermal block at 28 ± 1.0 °C. This testing consists of routinely determining the sorption of a red light being pulsed at two positions through the tester. Initially these pulses of red light are absorbed by the methylene blue but once reductive conditions are generated by microbial respiration then the methylene blue moves into a reductive state and light passes through the tester. The time lag to this event becomes the BOD_{BART} . If light passes through the upper channel first then a down reaction (signaled by the appearance of a “D” after the channel number). However if light passes through the lower channel first then the reaction is deemed to be an up reaction and the letter “U” appears after the channel number. At the same time as one of these letters appears then the BOD_{BART} appears opposite the channel that has been declared positive. When all three pod channels are declared positive then the average and percentage of the standard deviation around the mean are displayed alternately to indicate the precision of the test.

11. After the testing is complete (all three replicates are now positive or 24 hours has passed and the test remains negative) it is important to record all of the data in a secure manner including the nature of the reaction (U or D). It is then important to safely dispose of the BOD-BART testers using the recommended microbiological disposal techniques.

It should be noted that the BOD-BART reader has the capacity to undertake three replicated tests from two samples at the same time. To assure that the isothermal incubation block is up to temperature before beginning a BOD-BART test the reader should have been turned on at least 60 minutes before the testers are scheduled to be inserted to start a test. If the reader is being maintained in refrigerated conditions then at least four hours should elapse after the reader has been turned on. Turning on the reader involves plugging in the reader to the power supply first making sure that the power switch on the back of the reader is off. Place reader on a horizontal, non-metallic or plastic coated surface that is clean and dry away from direct sunlight and any strong sources of artificial lighting. Plug UPS Uninterrupted Power Supply into any standard 120VAC outlet. Failure to use a UPS could mean all of the data would be lost in the event of a power outage. Connect the power supply to the back of the BOD-BART reader. Turn on power to the reader using the switch mounted on the back of the reader. Once power has been initiated, the BOD-BART reader will display a start up screen.

Start up Screen: Droycon Bioconcepts Inc.

Plug reader in at least 60 minutes prior to beginning tests to allow time for the incubator block to get up to temperature (28 ± 1.0 °C). The temperature of the block will be displayed on-screen. Once the incubation temperature is in range, the reader is now ready to begin testing.

The primary claim is therefore that the BOD_{BART} recorded in seconds and generated by the BOD-BART system from secondary and tertiary effluents of sanitary municipal waste water

treated through either the aerated lagoon or the activated sludge processes would have precision at least equal to that of the standard regulated 5-day BOD test that generates a BOD₅ given in mg/L or parts per million (ppm). Precision, for the purposes of this verification, is defined statistically in terms of the variability generated when the test is replicated twelve times on a sample and a comparison is made between the BOD₅ and the BOD_{BART} for each comparison that is made. It should be noted that the BOD₅ will use an estimated scale based on the theoretical milligrams per liter of oxygen demand that has been assessed for each specific sample while the BOD_{BART} will be given as the number of seconds generated by the time delay to the point when each sample tested was found to have gone reductive by either an UP or a DO reaction. It is proposed not to convert the BOD_{BART} into a theoretical concentration scale equivalent to the BOD₅ but to generate a table for direct comparison and an equation that would be relevant to effluent samples from secondary and tertiary treatment processes.

$$\% \text{ Variability} = ((\text{S.D.}) / (\text{mean})) \times 100$$

Where S.D. is the computed standard deviation derived from the data set for a particular set of sample replicates and the mean is the average for the data set. This generates a factorial which is converted to a percentile by multiplying by 100.

In the developmental studies for the aerated treatment lagoon effluents it was found that in the majority of cases the percentile variability for the BOD_{BART} was superior (less variability) than the BOD₅. In general the variability for the BOD_{BART} rarely exceeded 5% while the BOD₅ was larger but rarely exceeded 9%.

For the aerated treatment lagoon effluents and tertiary treatment influents in the initial studies it was found that that the BOD_{BART} data (presented in seconds) provided a 17,500 second “window” (35,000 to 52,500) where the BOD₅ falls from 25 to less than 8 (a data window of 17). This would mean by direct linear correlation that every unit of BOD₅ measured in mg/L would be equivalent to approximately 1,000 seconds. The use of the BOD_{BART} in increments of seconds would give a greater potential for precision than relying on the traditional BOD₅ (recorded in mg/L or ppm) as the first level of recording. The major components in the BOD-BART system are listed below:

BOD - BART™ is the trademark applied to the patented concept for the determination of the biochemical oxygen demand (BOD) for effluents from waste water that has been treated by an aerated method such as the lagoon or activated sludge process. The claims for the effectiveness of the test are restricted to these processes only. Where the BOD-BART test is applied to other samples the data gathered may not be effectively interpreted using the standard technique described in this manual.

BOD-BART tester™ is the trademark applied to the patented concepts employed in the BART test apparatus that allows a 15ml sample of effluent to be used and a time lag obtained that relates directly to the BOD of that sample. The time lag is measured in seconds to the confirmation of a reaction that is detected when the BART test vial becomes reductive. Here it is claimed that the shorter the time lag then the greater would be the BOD value in the sample being tested.

BOD-BART reader™ is an electronic device that allows the detection of the time lags for up to six BOD-BART testers. The positive results are displayed on-screen in seconds that may be converted from a standard table to BOD. It is recommended that, in order to achieve acceptable precision, triplicates should be performed for each effluent sample to be tested. Note that the reader is set up to encourage triplicate testing by the testing channels being set up as two lateral rows of three test pods into which the testers are placed. The reader operates on 120 volts AC that should be supplied using an uninterrupted power supply to assure the data is still gathered during any power outage of moderate duration. To improve precision the reader

incorporates an incubator that maintains the testers at 28°C.

BOD-BART hub™ is an electronic hub that possesses eight input ports to allow up to eight readers to be connected with a single output port that may be connected directly to a computer supporting Windows 98 or better and will allow the direct storage and interpretation of the data on-screen with real-time graphs.

BOD-BART read™ is the software package written in Visual Basic™ that allows the information to be managed through the computer with the ability for a chain of custody that could include the printing out of all data at the moment a sample is declared positive for all three of the triplicates for that sample. Statistical analysis would include the calculation of the mean (average), the standard deviation and the percentile of the mean that is created by the standard deviation. The smaller the percentile displayed then the better is the precision between the three replicates under test from that sample. BOD-BART read also allows for the generation of e-mails to remote locations giving the data in either a simple .txt format or in adobe distiller™ that could also include graphical interpretation of the data generated during the tests.

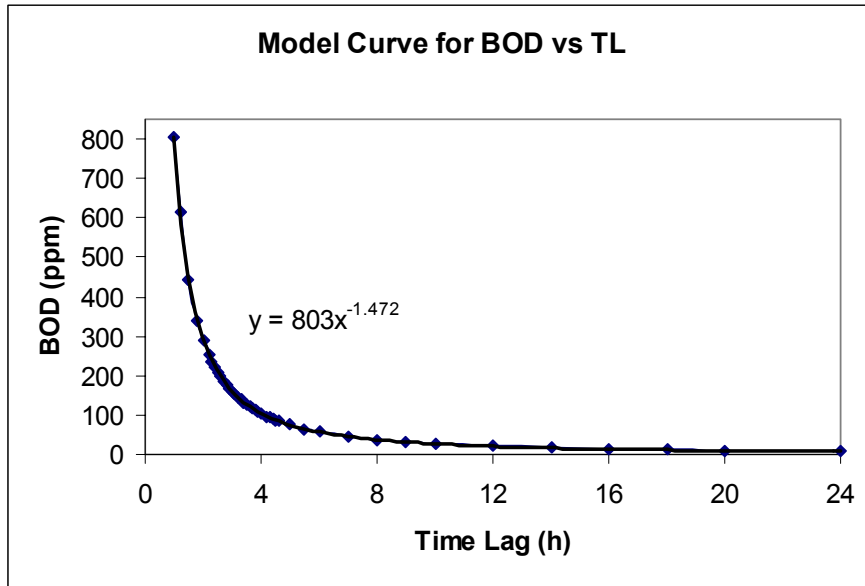
BOD-BART system™ refers to the total package for undertaking the determination of the BOD using at least the BOD-BART tester and reader in combination.

Results and Discussion

Historically, statistical validation by comparative studies with the standard 5-day BOD have been ongoing since 1997. Experiments were conducted routinely at the research laboratories of DBI in cooperation with the City of Regina Wastewater Treatment Plant (RWTP). This intensive study was continued for one year (December, 1998 to December, 1999) with continuing confirmatory studies following to the summer of 2002. This experimentation involved regular analysis for the BOD₅ by the RWTP using treated waste water samples using the same samples as used by DBI. This BOD₅ test followed the standard methods and was conducted by the City of Regina staff (APHA, AWWA and WEF, 1998) and by Droycon Bioconcepts Inc. staff using the BOD-BART™ system that was set up and operated at the City of Regina facility. Four different types of samples were used. These included: primary influent (raw municipal wastewater), primary effluent (after primary settling), tertiary influent (after secondary biological treatment), and tertiary effluent (final treated wastewater to be discharged into the creek. The standard BOD₅ test results ranged from 350 mg/L down to 8 mg/L and parallel tests of the samples were obtained from the municipal wastewater treatment plant to perform triplicate BOD-BART™ analyses. Over one hundred sample sets (one set consists of four samples in triplicate/duplicate) were compared. This amounted to more than four hundred samples and a total of one thousand comparisons including duplicate/triplicate data. These experiments were conducted to build a strong data base that could also be used to consider the importance of other potentially impacting factors (dilution effect, color, temperature, oxygen saturation, mixing etc.) and also fluctuations in the characteristics of the municipal wastewater. BOD-BART™ experiments were conducted at room temperature (22±1°C). To investigate the impact of variations in room temperature (commonly between 20 and 25°C) on the speed of the test and the consequent time lag obtained, an experimental series was conducted over a temperature range from 4 to 45°C. The influence of the incubation temperature on the TL for the BOD-BART™ test is defined in that study below.

Regression analyses were conducted to develop the nature of the relationship (based on best-fit line/curve) between the time lag obtained from BOD-BART™ analysis and the comparable standard BOD₅ test result. Besides regression analysis, statistical parameters such as standard deviation and mean were also evaluated. To minimize variations relating to storage the samples were all setup within a maximum of two hours after collection. BOD of wastewater samples depends upon their composition. Figure 1, 2 and 3 shows the graphic relationships between 5-day BOD and TL for this series.

Figure 1
Relationship between the Time Lag in hours (x axis) to the BOD₅ (y axis up to 800 mg/L) as Power Regression analyses.



Note that the time lag is entered as hour as the standard until the year 2000

Figure 2
Relationship between the Time Lag in hours (x axis) to the BOD₅ (y axis up to 250 mg/L) as Power Regression analyses.

Figure 4: Linearization of TL and 5-day projected BOD relationship

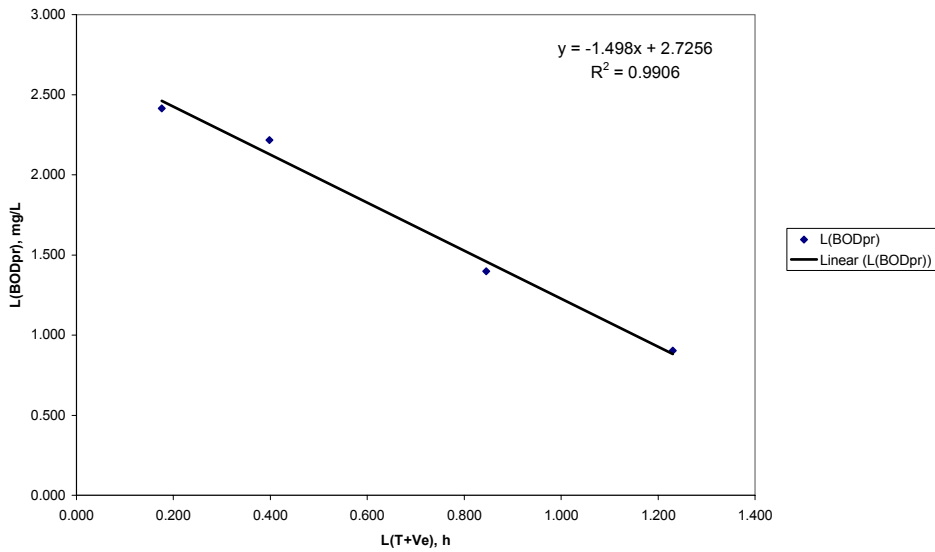
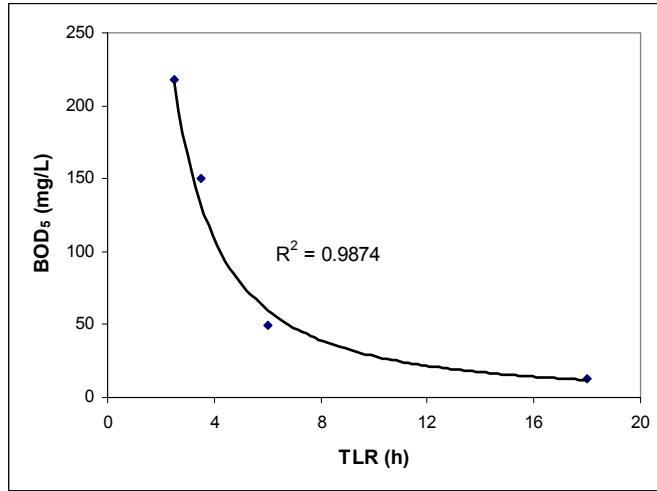


Figure 3
Log-log linear regression analysis of the data



Note that the graph in Figure 1 shows the correlation with the higher BOD samples (up to 800 mg/L) while Figure 3 shows the correlation at lower BOD (<250 mg/L) values. By the middle of 2001 there was a sufficient level of confidence to expand the independent evaluation of the BOD-BART system. A summary of these activities is included in Table 2.

Table 1
Sites of Comparative Trials for the BOD-BART system in 2002

Location	Length of trials (months)	Number of Samples
Moose Jaw, Sask	58	700*
Estevan, Sask	9	450
North Battleford, Sask	7	350
Prince Albert, Sask.	7	350
Vancouver, B.C.	4	180

* No comparative BOD₅ tests performed.

Tertiary effluent is the product being released from the POTW and has a relatively low BOD and a low bacterial aggressivity. Thus the TL are likely to be much longer than for upstream partially treated samples of municipal wastewater. One eight replicate trial was conducted (Table 2.). As with the previous trials using primary effluent samples there was less variability than had been experienced when using upstream samples.

From this experimental comparison there would appear to be a close comparison between the BOD₅ and the BOD_{BART} with a relatively small variability. For this experiment the variations were (in percentiles around the mean with the BOD₅ first): S.D., 4.7 % and 3.4%; minimum, -6.8% and -5.5%; and for the maximum, +5.5% and +1.8% respectively. The accuracy of the BOD_{BART} was underscored by six of the eight replicates giving precisely the same BOD_{BART} (57,383seconds). This level of accuracy would indicate that the BOD-BART through the BOD_{BART} can give a BOD determination with precise comparable to the BOD₅.

Table 2
Comparison of 5-day BOD and BOD_{BART} for eight replicates of tertiary effluent taken on November 24, 2000

Item	BOD ₅ (mg/L)	BOD _{BART} (seconds)
Replicate 1	7.6	57,383
Replicate 2	6.8	53,232
Replicate 3	7.6	53,232
Replicate 4	7.0	57,383
Replicate 5	7.2	57,383
Replicate 6	7.7	57,383
Replicate 7	7.5	57,383
Replicate 8	7.0	57,383
Average	7.3	56,345
S.D.	0.34 (4.7%)	1921 (3.4%)
Minimum	6.8 (-6.8%)	53,232 (-5.5%)
Maximum	7.7 (+5.5%)	57,383 (+1.8%)

Variability in the BOD_{BART} data sets from POTW influent and effluent samples in the summer, 2001 is shown in Table 3. From this data it would appear that the BOD_{BART} rose about 1,500 seconds between primary influent and effluent with poor precision (13.7 and 9.5% respectively). A sequential increase in the BOD_{BART} was evident between lagoon 2a and lagoon 3 with lagoons 2 and 1S in the middle of the range. Precision improved throughout these lagoons to average at between 2.7 and 5.9%. Tertiary influent and effluents has slightly less variability (2.6 and 3.3% respectively) and the final BOD_{BART} averaged at 43,516. In this study emphasis was placed on the reliability and statistical robustness of the BOD-BART system rather than on the comparative studies with the BOD₅. Previous studies reported elsewhere had already indicate an inverse but potentially valid link between the BOD_{BART} and the BOD₅ and this will be the topic of section 7.2.2 where comparative studies were undertaken between January and May 2002.

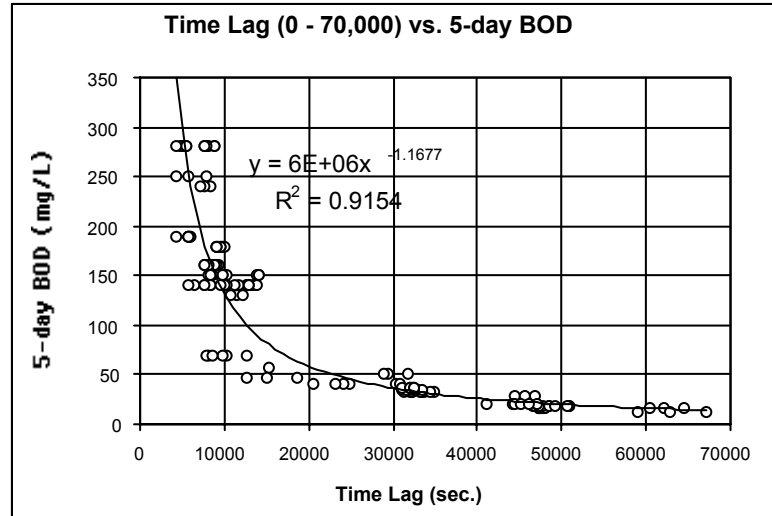
Table 3
Variability in the BOD_{BART} (seconds) for Samples from Different Stages in the Aerated Lagoon Treatment System

Stage	samples	Average BOD _{BART}	Standard deviation BOD _{BART}	% variability
PI-28	3	2,877	374	13.69%
PE-28	20	4,425	425	9.50%
2a	8	28,219	1,574	5.86%
2	8	33,035	890	2.73%
1S	8	32,264	1,221	3.77%
3	8	42,556	1,758	4.19%
TI-28	19	37,468	963	2.59%
TE-28	20	43,516	1,400	3.27%

Each sample was replicated eight times in this study and it should be noted that this study included 17 cases of lost data (LD) out of a total data set of 752 (2.2%). These LD arose primarily as a result of the prototype nature of the BOD-BART reader that was, at that time, only detecting sorption from a single light channel set to detect UP reactions primarily. At that time there were failures in the readers due to electrical static charge build up and this was one of the factors taken into account when designing the new BOD-BART reader that is now the standard.

Figure 4

Comparison between the BOD_{BART} (time lag in seconds) and the BOD₅ (mg/L) for the study on the Regina POTW treated waste water samples, Winter 2002



In fifty one triplicated samples were compared. Table 4 lists the number of triplicated trials for each type of wastewater and the range of BOD₅ and BOD_{BART} values observed.

**Table 4
Summary of BOD Comparison Sampling Protocol**

Sample	No. of Triplicate Samples	Range of BOD ₅ (mg/L)	Range of BOD _{BART} (seconds)
Primary Influent (PI)	8	190 - 280	4,400 – 8,800
Primary Effluent (PE)	19	70 - 180	5,700 – 12,900
Lagoon 1s (1s)	2	50 - 57	15,300 – 32,800
Lagoon 2a (2a)	2	46 - 70	7,800 – 18,600
Lagoon 3 (3)	3	28 - 41	20,500 – 44,400
Secondary Effluent (SE)	7	32 - 36	31,100 – 34,900
Tertiary Effluent (TE)	8	17 - 21	44,200 – 50,900
Creek – WAO	1	17	60,400 – 64,600
Creek – Lumsden	1	13	58,900 – 67,100
Total Range	51	13 - 280	4,300 – 67,100

This figure displays one of the two best fitting regression equations between TL (0-70,000) with the BOD₅. The power regression equation is $y = 6,000,000 x^{-1.167}$ and is the best fitting equation. It has a correlation coefficient (R²) of 0.9154, which indicates that there is a very strong relationship between BOD₅ and BOD_{BART} using this protocol.

Table 5
Comparison of BOD_{BART} and Percent Standard Deviation (% S.D.) around the mean.

BOD_{BART} Range (1000's of seconds)	Average % S.D.	Low % S.D.	High % S.D.
5,000 – 10,000	9.65	1.9	28.9
10,001 – 20,000	5.97	0.7	19.5
20,001 – 30,000	7.98	0.8	21.6
30,001 – 40,000	3.25	0.2	11.2
40,001 – 65,000+	2.90	0.3	6.5

Conclusions

The BOD-BART system has been evaluated as an alternative technique to the 5-day BOD standard technique for the determination of the biochemical oxygen demand in a treated aerated lagoon process and has been found to have equal or superior precision with the BOD₅ for secondary effluents and tertiary influents and effluents. Parallel investigations are now proceeding for activated sludge plants prior to the technology being proposed for environmental technology verification in both Canada and the U.S.A.

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