

False High BOD Tests in Wastewater Lagoon Systems

The TSS and BOD Relationship Formula and when to make the switch to CBOD testing.



Background

In municipal wastewater lagoon systems in the United States, living algae comprises virtually all of the biochemical oxygen demand (BOD) material and total suspended solids (TSS) which is tested for regularly to ensure compliance with the city's National Pollution Discharge Elimination System (NPDES) permit.

Both the BOD and TSS test are basically measuring the same thing, algae. The relationship between BOD and TSS for lagoon systems is well known in the industry and can be expressed mathematically as:
$$\text{BOD} = (\text{TSS} \times 0.5) + 7$$

This relationship is the reason that the typical NPDES permit for municipal lagoon systems throughout the USA have a TSS limit of 45 mg/l and a BOD limit of 30 mg/l. The TSS and BOD Relationship Formula holds true for those limits:

$$\text{BOD} = (45 \text{ mg/l of TSS} \times 0.5) + 7 = 30 \text{ mg/l.}$$

The BOD testing problem with lagoon water

The standard BOD 5-day test is meant to be a test of carbon-based oxygen demand and for activated sludge systems, this standard works well; however, it was discovered in the 1980's that the BOD 5-day test does not work well for lagoon systems.

In lagoon systems, nitrifying bacteria are quite often present in samples and will exert a nitrogen-based (ammonia reduction) oxygen demand during the BOD test. Labeling the entire oxygen demand during the 5-day test as "BOD" (implying carbon-based demand) led to testing inaccuracies since some of the oxygen demand was actually nitrogen-based (thus giving a "false high BOD" result).

Step 1: Check the mathematical formula against the BOD and TSS test results

The mathematical relationship between BOD and TSS mentioned earlier can be used to determine if the BOD 5-day test is giving a "false high BOD".

The same formula can also be worked in reverse to determine if high TSS is being caused by detritus (dead) algae or silt (as shown in Example 4 on the next page).

TSS and BOD Relationship Formula

$$(TSS * 0.5) + 7 = BOD$$

Example 1

Water test results: 50 mg/l TSS and 34 mg/l BOD

To check these results, apply the formula above.

$(50 \text{ mg/l TSS} * 0.5) + 7 = 32 \text{ mg/l expected BOD}$

In this case the test result BOD was 34 mg/l. This is close enough to 32 mg/l so the BOD test appears valid and accurate and all the TSS was comprised of living algae.

Example 2

Water test results: 20 mg/l TSS and 43 mg/l BOD

Apply the formula from above.

$(20 \text{ mg/l TSS} * 0.5) + 7 = 17 \text{ mg/l expected BOD}$

The water test result is much higher than the formula predicted. This indicates nitrification occurred in the test using up the dissolved oxygen and giving a false high BOD reading. This double-check indicates the actual carbon based BOD was only 17 mg/l.

The city should consider switching to a CBOD test and a discharge limit of 25 mg/l instead of 30 mg/l as we will discuss later in this paper.

Example 3

Water test results: 16 mg/l TSS and 13 mg/l BOD

Apply the formula from above.

$(16 \text{ mg/l TSS} * 0.5) + 7 = 15 \text{ mg/l expected BOD}$

This BOD numbers are close enough. The test appears to be valid and indicates all BOD was living algae.

Example 4

Water test results: 76 mg/l TSS and 20 mg/l BOD

Apply the formula from above.

$(76 \text{ mg/l TSS} * 0.5) + 7 = 45 \text{ mg/l expected BOD}$

The BOD test result of 20 mg/l is far lower than what the formula predicted (expected 45 mg/l).

This indicates the TSS (which is always an accurate test number) was comprised of some non-oxygen consuming suspended solids. The suspended solids were not all living algae because if they had been, the BOD test result would have come in where the formula predicted. The "extra" TSS was most likely detritus (i.e. dead algae), silt or other solids stirred up from the bottom of the pond by high winds or regular lagoon turnovers. To find out how much of the TSS was detritus or silt, you can reverse the formula.

Making the assumption that the BOD test number is accurate, and working the formula backwards, the formula shows TSS associated with the living algae (TSSL).

Apply the Reversed Formula: $(BOD - 7) / 0.5 = TSSL$
 $20 \text{ mg/l BOD} - 7) / 0.5 = 26 \text{ mg/l TSSL}$

Of the 76 mg/l TSS, about 26 mg/l was associated with living algae indicating the other 50 mg/l was either detritus or silt.

To address this problem of excess TSS, the city should make sure discharge is taking place from a mid-depth in the pond (or at least 2 feet or more off the bottom) and if possible, try to avoid discharging during high wind turnover events.

The Next Steps

- Perform parallel CBOD testing
- Verify the problem
- Move toward a CBOD permit instead of a BOD permit

The "false high" issue for BOD testing of lagoon water shows up in many ways.

For instance, let's examine the following scenario. One larger water sample is split into three smaller subsamples. BOD testing is performed on each subsample with each giving a different BOD result of 10, 50 and 100 mg/l. This is because each BOD test results depend on exactly how many nitrifying bacteria each subsample contained.

Learning (cont'd)

It is also possible that the same water sample tested in two different labs can result in two significantly different BOD numbers.

In short, BOD data from lagoons do not provide a dependable comparison from day to day, month to month, year to year, or from one lab result to the next. This makes BOD testing a very poor indicator of system performance in lagoons.

However, with CBOD testing, the nitrifying bacteria are killed before the test is started so the 5-day test will give a true carbon-based BOD result.

In order to get true and dependable results for carbon-based BOD, the US EPA allows (and most States either require or allow) a city with a lagoon system to switch from BOD testing to CBOD testing with a limit 5 mg/l less than the previous BOD limit.

A good way to move toward a CBOD limit is to:

1. Inform the state permitting agency of your analysis of BOD and TSS testing results as described above.
2. Ask for permission to conduct regular CBOD testing in parallel with the required BOD testing for one year for comparative analysis (parallel testing usually doesn't add much cost).
3. If parallel testing proves that the BOD testing is inaccurate, request the NPDES permit be changed to CBOD testing with a limit of 5 mg/l less than the former BOD limit.

Summary and Further Reading

Wastewater lagoon systems can produce very high quality effluent but as discussed, standard BOD testing will often show false high readings. To avoid misleading BOD test results, all wastewater lagoon discharge permits should be based on CBOD testing instead. Finally, analyzing the relationship between BOD/CBOD/TSS can help better understand the cause of high TSS issues due to detritus and silt.

For further reading on this subject, please see the USEPA NPDES Permit Writer's Manual, Chapter 5, section 5.2.1 and section 5.2.2

This gives the federal statutory reference for issuing a lower NPDES CBOD limit to replace a BOD limit. As of January 2023, you can find this information at the following link.

https://www.epa.gov/sites/default/files/2015-09/documents/pwm_chapt_05.pdf

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