# RECOMMENDATIONS OF THE BOD LOD TECHNICAL GROUP

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## SUMMARY

Department staff has expressed concern over permittees inconsistently reporting biochemical oxygen demand (BOD) and total suspended solids "less-than" results. Permit Standard Requirements allow permittees to assign any non-detected result a value of zero for purposes of compliance determinations, including averaging calculations. In cases where limits are low (10 mg/L or less), averaging zero values can have a significant effect on compliance determinations if detection limits are excessively high. If less-than results are reported for POTW influents, use of zeros in averaging skews the values used for future design and CMAR purposes.

The Bureau of Watershed convened a Technical Group to make recommendations on how to settle this issue. The Group consisted of Tom Mugan and Jim Schmidt of the Bureau of Watershed Management, Rick Mealy representing the Analytical and Statistical Sciences Section of the Bureau of ISS, Susan Watson of the Northern Region, Linda Vogen of Northeast Region and George Bowman of the State Laboratory of Hygiene. The group decided to document recommendations for Department staff and also to provide guidance for permittees, contract labs and consultants.

The Technical Group makes the following recommendations:

1. Reporting limits for BOD and total suspended solids are defined as the lowest concentration levels that can be reported when applying the minimum dissolved oxygen depletion requirement of the BOD Test Method* and the minimum residue requirement of the Total Suspended Solids Test Method*.

2. The desired reporting limit for effluent BOD is 2 mg/L. To obtain this reporting limit for the cleanest samples, the BOD Test Method* requires analysts to incubate undiluted sample and add nutrients directly to the BOD test bottle.

3. The desired reporting limit for effluent suspended solids is 2 mg/L or less. To obtain this reporting limit for the cleanest samples, the Total Suspended Solids Test Method* requires analysts to filter at least 500 milliliters of sample and accept as valid, filter weight gains as low as 1 milligram.

4. Test results not meeting minimum dissolved oxygen depletion or filter residue requirements of the BOD and Total Suspended Solids Test Methods* should be reported as < (less than) the value of the reporting limit.

5. Our default procedure (used except in unusual circumstances) for determining effluent limitation compliance for BOD and suspended solids should apply a value of zero to any result less than the reporting limit, similar to how we treat values below the limit of detection (LOD) for toxic pollutants.

6. We should consider values just above the reporting limits for BOD and suspended solids to be reliable, similar to how we treat values above the limit of quantitation (LOQ) for toxic pollutants.

7. Staff reviewing DMR effluent data should consider contacting permittees who routinely report less-than results using a reporting limit greater than 2. Our posture for these contacts should generally be one of cooperation and education.

8. For purposes of calculating influent averages, less-than results should be assigned a value equal to the reporting limit. In other words, the < symbol should be ignored.

9. We should communicate these positions by preparing articles for permittee newsletters and by enclosing information in the next mailing of Discharge Monitoring Reports.

**PROBLEM**

BOD

The BOD Test Method* measures the dissolved oxygen consumed in a sample incubated at 20°C for five days. The range of values that can be measured by the test is controlled by the concentration of dissolved oxygen in the sample before incubation and by some minimum measurable final concentration after incubation. The BOD Test Method* sets this minimum dissolved oxygen residual level at 1.0 mg/L. By diluting the sample, an analyst can push the upper end of the measurable range of concentration to any desired level. The disadvantage of dilution is that it also pulls up the minimum measurable level.

The lower range of measurement is determined by the ability to detect and quantify differences in dissolved oxygen concentrations. The BOD Test Method* specifies 2.0 mg/L as the minimum dissolved oxygen depletion needed for determining the BOD. It follows that the lowest reportable BOD is 2 mg/L when undiluted sample is incubated.

Since an analyst cannot know the final BOD until 5 days later, he or she normally sets up several different dilutions to make sure that at least one of them meets the 2.0 mg/L dissolved oxygen depletion requirement and also the minimum dissolved oxygen residual of 1.0 mg/L.

The BOD Test Method* also requires that certain trace nutrients be added to the samples tested. Historically, analysts most commonly added those nutrients to the dilution water. However, that procedure fails when the test water is straight sample (no dilution water). To account for this, it has become common practice to add small quantities of nutrient chemicals directly to the BOD test bottles when testing very clean effluents. To avoid the inconvenience of measuring very small quantities of nutrient chemicals, at least one lab chemical supply company sells small packets of pre-measured nutrient chemicals, each suitable for one BOD test.

Some analysts either are not aware of the availability of individual nutrient packets or are not motivated to obtain the lowest possible detection limit. As a result, permittees sometimes

report less-than results, when in fact the actual BOD may be greater than the 2 mg/L minimum achievable reporting limit.

For example, if an analyst employs a 3:1 dilution water to sample ratio as his or her lowest dilution, because of the 2.0 mg/L minimum depletion requirement, the lowest reportable BOD determined from that test is 6 mg/L. If the dissolved oxygen depleted on that day turns out to be less than 2 mg/L, the analyst should report, according to common reporting protocol, a value of < 6 mg/L. If that day's result is assigned a value of zero for determining compliance or calculating averages, the effect could be significant, particularly if the effluent limitation is 10 mg/L or lower.

Suspended Solids

The Total Suspended Solids Test Method* measures the weight gain of a glass fiber filter after passing a measured volume of sample and drying at 104°C. The range of measurement is determined by the optimum solids loading on the filter, which can be controlled by adjusting the volume of sample filtered.

The several references cited by the Total Suspended Solids Test Method* specify different restrictions on the minimum filter residue that must be collected and instructs analysts to adjust sample size to optimize the solids loading on the filter. The least restrictive reference, *EPA Methods for Chemical Analysis of Water and Wastes*, limits the minimum residue to 1 milligram.

As with the BOD test, there is a down side to increasing sample volume too much. As solids build up on the filter, they may form a mat, causing filtration time to become excessive. One of the test method references recommends a maximum solids-capture of 200 milligrams. However, sometimes that is too much residue since certain sized solids may penetrate the pores of the filter, causing the filter to capture smaller and smaller solids as filtration proceeds. This leads to inaccuracy.

## BACKGROUND

Regulatory Constraints

Reporting and sensitivity requirements for BOD and suspended solids testing are not contained in any regulations. Chapter NR 106 (Procedures for Calculating Water Quality Based Effluent Limitations for Toxic and Organoleptic Substances Discharged to Surface Waters) defines LOD and LOQ, requires permittees' labs to determine LODs and LOQs and use the most sensitive test methods, and specifies procedures for assessing compliance with a limit when the limit is less than the LOD or LOQ. However, chapter NR 106 clearly does not apply to BOD or suspended solids.

Use of the same or similar conventions as those in chapter NR 106 would simplify procedures and avoid confusion. However, there are really no accepted procedures for determining LODs and LOQs for BOD and total suspended solids. Instead, the reporting limitations given in the BOD and Total Suspended Solids Test Methods* apply. Therefore, this document describes a practical procedure for reporting results that are limited by test method sensitivity.

The Department is somewhat concerned about permittees abusing the ability to report less-than values. In cases where abuse is obvious, we have some authority, since the BOD and Total Suspended Solids Test Methods* instruct analysts to select sample sizes to meet the stated minimum criteria. Not following these method instructions could be considered a quality control exceedance. However, we believe that, in most cases, permittees are unaware of our concerns in this area and will voluntarily adjust their procedures if we train them on the accepted practices.

Permit Standard Requirements instruct permittees that they may report a non-detected result as < the detection limit and assign it a value of zero for initial compliance determinations. A similar mechanism for BOD and total suspended solids would be to report a result below the reporting limit as < the reporting limit and assign it a value of zero for initial compliance determinations. As is the case for the chapter NR 106 procedure, the Department has discretion in making final decisions on compliance and enforcement. Depending on individual circumstances, it may be appropriate to assign a value other than zero to a less-than result when and if we need to consider follow-up on problem discharges.

Some program staff have suggested that we may want to start rule-making on how we regulate BOD and suspended solids. There are also signs that the references cited in the future versions of BOD and Total Suspended Solids Test Methods* may more precisely define expectations. Until one or both of those happen, we hope this guidance will be useful to staff who need to make case-by-case decisions.

Are the Reporting Limits LODs or LOQs?

In this document, we are careful to use the term "reporting limit" to signify when permittees should report a monitoring result for BOD and suspended solids as "less than". We make this distinction because this value is not determined through some sort of statistical treatment by an individual laboratory. Rather, the value is dictated by the hard and fast rules specified by the BOD or Total Suspended Solids Test Method*. Therefore, it is neither an LOD nor an LOQ, as we commonly define them.

BOD and suspended solids tests were used as measures of pollution long before we began dealing with test sensitivity issues with the toxic substances. The BOD and Total Suspended Solids Test Methods* writers specified certain conditions that must be met before results may be considered to be valid. These conditions include the 2-mg/L minimum depletion requirement for the BOD test and the 1-milligram minimum residue requirement of the suspended solids test. The technical group believes these guidelines suggest minimum values above which results are quantifiable. Therefore, we should consider these values more like the chapter NR 106-defined LOQ. As evidence, the BOD Test Method* states that dilution water must not be used if its own depletion exceeds 0.2 mg/L. This implies that this slight difference can be precisely measured. In practice this requirement is sometimes difficult to achieve. If we assume the LOQ to be 2.0 and that the LOD and LOQ differ by the commonly-cited factor of 3.33, then LOD = 2.0/3.3 or 0.6. This seems about right.

A similar situation exists for suspended solids. The minimum allowable filter residue is 1 milligram. However, the Total Suspended Solids Test Method* specifies use of an analytical balance capable of measuring to 0.1 milligram (and recommends even more sensitive instruments for low-residue measurements). It further specifies that the filters be dried to a constant weight, by making successive weighings until the weight loss is no more than 0.5

milligram. This implies an LOD for weight-gain somewhere in this range, perhaps 1.0/3.33 or 0.33 milligram. This converts to an LOQ of about 2 mg/L when filtering 500 milliliters of sample.

The reason why we make this distinction is to suggest how numbers close to these reporting limits should be treated. If these reporting levels are considered to be LOQs, then values just above them should not be given the same questionable treatment that chapter NR 106 species for values between LOD and LOQ.

## RECOMMENDATIONS OF THE EXPERT GROUP

### BOD

We recommend that we convey to permittees that, for the consistently cleanest effluents, the desired reporting limit for BOD is 2 mg/L. Given the commercial availability of single BOD sample, pre-measured nutrient packets, it is not unreasonable for laboratories to test undiluted wastewater effluent for samples commonly showing the lowest possible reportable results. Our communication should inform them of steps they should follow to achieve this reporting limit. Permittees using a reporting limit other than 2 mg/L should be prepared to explain to the Department their basis for using that different reporting limit.

For effluents of somewhat lower quality, we should expect an occasional reported value of < 4 mg/L or < 6 mg/L. Field personnel should use discretion when following up on these problems. Obviously, this issue is less serious for permittees with effluent limitations higher than perhaps 10 or 15 mg/L.

### Suspended Solids

We recommend that we convey to permittees that, for the consistently cleanest effluents, the desired reporting limit for suspended solids is 2 mg/L or less. Considering the 1-milligram minimum residue restriction, this translates to filtering at least 500 milliliters of sample. In other words, if 500 milliliters is filtered and the weight gain is less than 1 milligram, then the proper reported value is < 2 mg/L. 500 milliliters should be a comfortable volume if the permittee has to transport sample to a remote-location lab. In addition, the time required to filter will almost always be reasonable. We know that many municipal permittees routinely filter 1000 milliliters without trouble. Permittees using a reporting limit greater than 2 mg/L should be prepared to explain to the Department their basis for using that higher reporting limit.

We should expect occasional deviations to the 2-mg/L reporting limit for cases where effluent is unexpectedly good. It is also conceivable that certain effluents could contain fine solids of just the right size that filtration time might be excessive for the passage of 500 milliliters. We should be prepared to consider this type of justification. However, we believe that the old gooch crucible method (if anyone still uses it), which uses a very small filter area, is not a good excuse for an excessively high reporting limit.

### Reporting of Results

We should ask permittees to report results not meeting the minimum depletion or minimum residue requirements found in the test methods, as < the number that would result if the depletion were exactly 2 mg/L (for BOD) or the residue were exactly 1 milligram (for

suspended solids). Values above these reporting limits should be considered to be quantifiable for purposes of determining compliance.

SWAMP is currently set up to treat any value preceded by a < symbol as zero for purposes of assessing compliance, including calculating averages. SWAMP does not, nor do we want it to, flag all results where the value following a < is greater than 2. However, staff reviewing DMR data should consider contacting any permittee who routinely reports less-thans with a reporting limit greater than 2.

A number following a < below 2 mg/L for BOD is also a problem, since it may be an indication of other analytical problems or analyst misperception. However, a reporting limit below 2 mg/L may be valid for suspended solids if an analyst filters a volume greater than 500 milliliters.

**INFLUENT LESS-THAN VALUES**

Less-than values are sometimes also reported for POTW influent samples. This most commonly happens during extreme wet weather when clear water greatly dilutes the raw wastewater. The problem this causes is that a couple of zero values averaged in with the other values in the 200 mg/L range will significantly skew the average downward. This skewed data may result in improper decisions if the data are later used for purposes of determining when facilities planning should commence (Compliance Maintenance) or for what design parameters to use for a facility upgrade.

The preferred solution to the problem of influent less-thans is, for BOD, to change or set up additional dilutions to cover the predicted lowering of the BOD result and, for suspended solids, to filter additional sample volume. Labs serving their own treatment plants will know when to make these changes. Operators sending samples to a contract lab for analysis should be careful to inform their labs that influent samples will be lower than normal.

In the event that a less-than value still occasionally occurs, it seems appropriate to use the value corresponding to the reporting limit for the averaging step. For example, if the largest sample volume for BOD is 10 ml and the resulting depletion is less than 2 mg/L, then the test result would be < 60 mg/L. For averaging purposes in this case, we should use a value of 60, rather than 0. In other words, for influent results, we should ignore the < symbol.

*Note: We are currently investigating the possibility of SWAMP just ignoring the < symbol for influent values. This may be something that could be accomplished in the future, but likely would not receive high priority for changes immediately. The alternative is to inform operators to not use less-thans when reporting influent data.*

* As used in this guidance, BOD Test Method and Total Suspended Solids Test Method refer to analytical methods for testing *Biochemical Oxygen Demand ($BOD_5$)* and *Residue – nonfiltrable (TSS)* cited as approved in s. NR 219.04(1), Wisconsin Administrative Code.