BIOCHEMICAL OXYGEN DEMAND (BOD)

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Biochemical Oxygen Demand (BOD)

BOD is the amount of oxygen consumed by microorganisms as they degrade organic compounds in an aqueous waste stream. It was initially intended as a practical method for anticipating the effects of primarily sewage wastes that are added to natural water sources like rivers and lakes. For example, large volumes of high BOD wastes can cause depletion of oxygen levels in bodies of water leading to depletion of local fauna and potentially serious ecological and economic damage. The method has been refined to make it more broadly applicable, consistent and specific and it has been used to determine acceptability and cost of disposal of certain waste sources.

Several factors are confusing and inconvenient about BOD measurement. First, it is actually a collection of separate measurements that use the same name. Originally, the method measured the action of endogenous microorganisms (i.e., those that naturally populated the sample to begin with) on degradable, carbon-rich compounds also contained in the sample. This makes sense for outputs from sewage treatment plants or water sources where waste streams have had a chance to mix with local microflora, but it is inadequate for samples with very low levels of microorganisms as one might have in industrial waste streams such as Pepsi to use a recent example. In these cases, exogenous microorganisms ("the seed") are added as a source of known waste degraders.

Second, the BOD test takes 5 days (!) and consequently results are often reported as BOD_5. BOD is not exactly a real-time monitoring tool. The rationale is that when the method was developed in England in the 1920's someone estimated that it took about five days for water from any stream to reach and estuary (although the exact meaning of this point is not evident to me). Five days is far too long for most practical decision-making and there are numerous recent initiatives to find alternative BOD-like measurement that can be made in as little as two minutes.

Third, the method measures the consumption of O_2 dissolved in the sample as an indirect means of measuring the amount of oxidizable material. Consequently, anything that leads to O_2 consumption will be swept into the BOD measurement. There are numerous related and derivative methods that attempt to provide a comparable measurement of different subsets of probable waste components. Many compounds that do not contain carbon can also be oxidized by microorganisms making the carbon load appear artificially high. For example, CBOD (Carbon Biochemical Oxygen Demand) attempts to measure just that O_2 consumption that can be directly derived from carbon by adding compounds that block the oxidation of nitrogen-containing compounds. COD (Chemical Oxygen Demand) attempts to eliminate the need for microorganisms and measures oxidizable compounds by using fairly severe chemical methods

(sulfuric acid and sodium dichromate). It is noteworthy that the COD measurement is often very similar to the BOD measurement and the test takes only three hours!

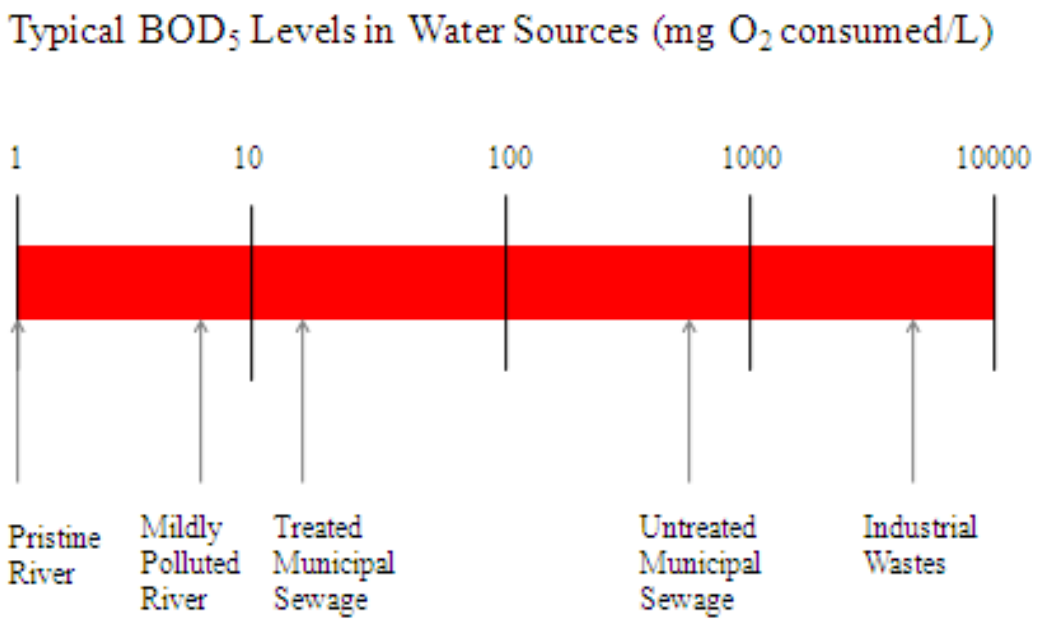
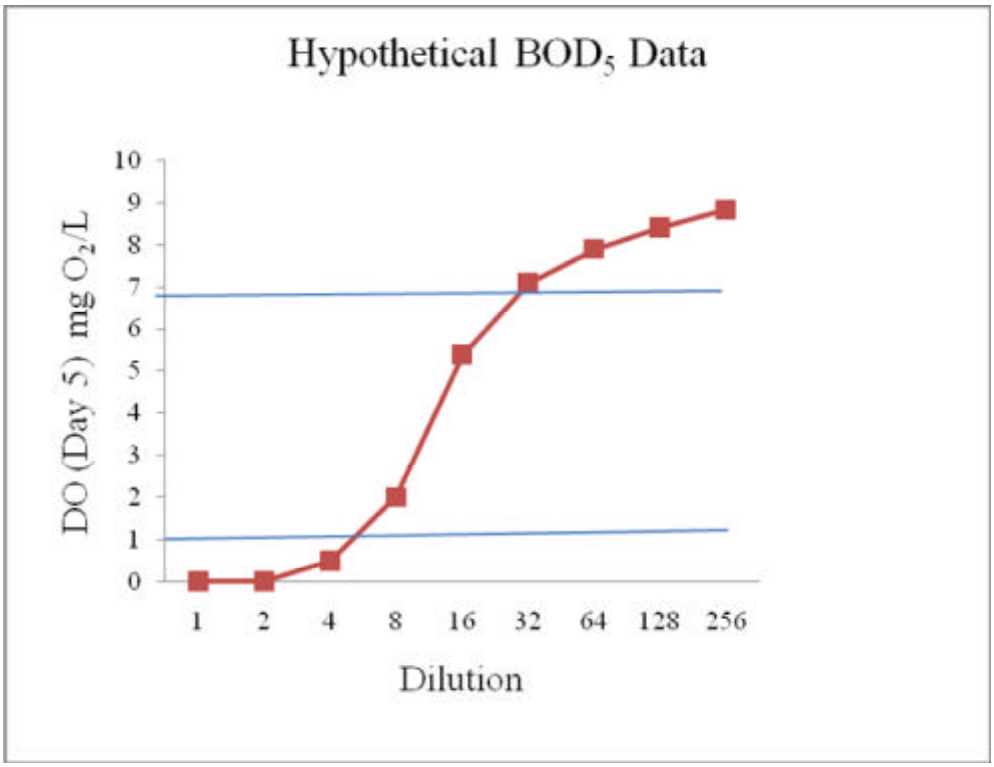


Fig. 1. Typical BOD_5 Levels in Water Sources. Sewerable BOD_5 levels for vary with the type of waste and the type of waterway into which the wastewater is discharged.

Depicted in Fig. 1 are representative values of BOD_5 observed in various water sources on a log scale. Sewerable levels may be in the low hundreds for processed industrial wastes so only 1-2 orders of magnitude reduction are necessary, e.g., 8000 down to 300.

The actual performance of the BOD_5 test requires the measurement of dissolved O_2 consumption is a series of samples. This is because the analytic range of the test is quite narrow. The saturation level of O_2 dissolved in water not very high, about 8.84 mg/L at 20 °C. Conventions to minimize error are that at least 2 mg/L must be consumed (i.e., the observed value must be less than 6.84 mg/L) while at least 1 mg/L must remain at the end of Day 5. Hypothetical data is presented in Fig. 2. Serial dilutions of the sample are prepared in water saturated with O_2 and

seed is added at Day 0; the remaining dissolved O_2 is measured at Day 5. Dilutions with high concentrations (low dilutions) will consume all or most of the O_2 rendering them too low to be used; conversely, dilutions with too little oxidizable material will not consume the required 2 mg/L. Only a few dilutions in the middle of the range will provide usable data (the two points between the blue horizontal lines).



Rules of Thumb

1. The typical standard for BOD measurement is a solution containing 150 mg/L glucose and 150 mg/L glutamic acid. The observed BOD_5 is typically about 198 $\pm$ 30.5 mg/L O_2 consumed.
2. Minimum detectable level is 2 mg/L (by definition).
3. BOD_5 is typically 0.64 times COD. N.B., COD takes only three hours instead of five days!
4. Ultimate Oxygen Demand = 1.5 BOD_5 plus 4.6 NH_4-N.
5. BOD_5 typically measures about 60-70% of oxidizable material; to drive it to completion would require a 20-25 day test!