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American Society of Civil Engineers

Measurement of Oxygen Transfer in Clean Water

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STANDARD

American Society of Civil Engineers

Measurement of Oxygen Transfer in Clean Water

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ABSTRACT

This standard, Measurement of Oxygen Transfer in Clean Water, is a revision of the July 1984 version, and represents the current consensus of the ASCE Committee on Oxygen Transfer Standards after five years of monitoring the original standard. It was developed to measure the rate of oxygen transfer from diffused gas and mechanical oxygenation devices to water. The standard is applicable to laboratory- scale oxygenation devices with small volumes of water as well as to full-scale systems with water volumes typical of those found in the activated sludge wastewater treatment process. It is intended that this standard be used by engineers in the preparation of specifications for compliance testing. This test method is based upon removal of dissolved oxygen (DO) from the water volume by sodium sulfite followed by reoxygenation to near the saturation level. The DO inventory of the water volume is monitored during the rearation period by measuring DO concentrations at several points, selected so that each point senses an equal tank volume. The method specifies a minimum number, distribution, and range of DO measurements at each point. This procedure is valid for a wide variety of mixing conditions. The primary result of this testing is expressed as the standard oxygen transfer rate (SOTR). The standard also describes how clean water tests can be applied to estimate oxygen transfer rate in process water. In addition, various components of power consumption are defined; methods for measurement of gas rate and power consumption by oxygenation devices are given; computer programs for nonlinear regression analysis are presented; and the preparation of data analysis is discussed.

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Standards

In April 1980, the Board of Direction approved ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by the Society. All such standards are developed by a consensus standards process managed by the Management Group F on Codes and Standards. The consensus process includes balloting by the balanced standards committee made up of Society members and nonmembers, balloting by the membership of ASCE as a whole, and balloting by the public. All standards are updated or reaffirmed by the same process at intervals not exceeding five years.

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FOREWORD

This standard is a revision of the July 1984 standard and represents the current consensus of the ASCE Committee on Oxygen Transfer Standards after five years of monitoring the original standard.

Preparation of a standard general enough to be applied to all clean water unsteady-state tests and specific enough to incorporate all essential procedures was difficult. Users of this standard must give particular attention to use of the mandatory "shall" and advisory "should" terms. For particular applications of this standard, it may be advantageous for the user to elevate certain advisory steps to the mandatory level. The body of this standard is supplemented with Annexes and a Commentary, which follow the text. The Annexes provide *mandatory* information and include material that is an essential part of the standard but is too lengthy to place in the text. The Commentary, which follows the Annexes, provides *nonmandatory* information to supplement the standard. The Commentary is not a part of the standard.

It is intended that this standard be used by engineers in the preparation of specifications for compliance testing. When this is the case, the engineer should consider the costs of requiring extensive compliance testing in relation to the initial cost of the oxygen transfer system and present worth of future operating costs.

The substance of this standard is based on recommendations made in the report, "Development of Standard Procedures for Evaluating Oxygen Transfer Devices," by the ASCE Oxygen Transfer Standards Subcommittee, W. C. Boyle, Chairman. The user is referred to this document, which contains References 1 to 4, to Reference 5 for background information, and to Reference 6 for a report on accuracy and precision of the method.

Formulas given in parenthesis throughout the standard are for use with SI units.

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The American Society of Civil Engineers acknowledges the devoted efforts of the Committee on Oxygen Transfer Standards of the Special Standards Division. This group comprises individuals from many backgrounds including consulting engineering, research, education, waste water equipment manufacturing, government, industry, and private practice.

The contributions of U.S. EPA for workshops and for laboratory and field studies that supported the development and refinement of this standard is gratefully acknowledged.

The late James McKeown served on the Oxygen Transfer Standards Committee for 13 years and participated fully in the activities of the Committee throughout that time. His untimely death, just prior to the completion of the Committee's charge, came as a shock to his colleagues. It is with genuine sorrow at his passing that we hereby dedicate this revised standard to his memory. Jim will be missed by the profession.

This standard was formulated through the consensus standards process by balloting in compliance with procedures of ASCE's Management Group F. Those individuals who serve on the Committee on Oxygen Transfer Standards are:

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Measurement of Oxygen Transfer Rate in Clean Water

1.0 Scope

This method covers the measurement of the Oxygen Transfer Rate (OTR) as a mass of oxygen per unit time dissolved in a volume of water by an oxygen transfer system operating under given gas rate and power conditions. Methods for measurement of gas rate and power are also described in the Annexes A and B, respectively. The method is applicable to laboratory-scale oxygenation devices with small volumes of water as well as the full-scale system with water volumes typical of those found in the activated sludge wastewater treatment process. The procedure is valid for a wide variety of mixing conditions.

The primary result of this test is expressed as the Standard Oxygen Transfer Rate (SOTR), a hypothetical mass of oxygen transferred per unit of time at zero dissolved oxygen concentration, water temperature of 20°C, and barometric pressure of 1.00 atm (191kPa), under specified gas rate and power conditions. The method is intended primarily for clean water meeting the requirements of Section 5.2 and 6.3. The results can be applied to estimate oxygen transfer rate in process water as described in Commentary.

2.0 Summary of Method

The test method is based upon removal of dissolved oxygen (DO) from the water volume by sodium sulfite followed by reoxygenation to near the saturation level. The DO inventory of the water volume is monitored during the reaeration period by measuring DO concentrations at several determination points selected to best represent tank contents. These DO concentrations may be either sensed in situ using membrane probes or measured by the Winkler or probe method applied to pumped samples. The method specifies a minimum number, distribution, and range of DO measurements at each determination point.

The data obtained at each determination point are then analyzed by a simplified mass transfer model to estimate the apparent volumetric mass transfer coefficient, K_La, and the steady-state DO saturation concentration, C^*_∞. The basic model is described in Reference 1 and is given by

$$C = C^*_\infty - \left(C^*_\infty - C_0\right)\exp\left(-K_L a\, t\right) \qquad (1)$$

where

C = DO concentration, mL^{-3}†;

C^*_∞ = determination point value of the steady-state DO saturation concentration as time approaches infinity, mL^{-3};

C_0 = DO concentration at time zero, mL^{-3}; and

K_La = determination point value of the apparent volumetric mass transfer coefficient, t^{-1}, defined so that,

K_La = rate of mass transfer per unit volume/$(C^*_\infty - C)$.

† m = mass, L = length, t = time, f = force

Nonlinear regression is employed to fit Equation 1 to the DO profile measured at each determination point during reoxygenation. In this way, estimates of K_La and C^*_∞ are obtained at each determination point. These estimates are adjusted to standard conditions, and the standard oxygen transfer rate (mass of oxygen dissolved per unit time at a hypothetical concentration of zero DO) is obtained as the average of the products of the adjusted determination point K_La values, the corresponding adjusted determination point C^*_∞ values, and the tank volume.

3.0 Significance and Limitations

Oxygen transfer rate measurements are useful for comparing the performance and