Region 4 U.S. Environmental Protection Agency Laboratory Services and Applied Science Division Athens, Georgia	
Operating Procedure	
Title: Reaeration Measurement by Diffusion Dome	**ID: LSASDPROC-505-R5**
Issuing Authority: FSB Branch Chief	
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Purpose

The purpose of this operating procedure is to document both general and specific methods and considerations to be used when measuring reaeration using a diffusion dome. Reaeration is the rate at which atmospheric oxygen diffuses across the air-water interface of the surface of a water body.

Scope/Application

This document describes both general and specific methods to be used by field investigators when obtaining data for the purposes of determining reaeration using a diffusion dome. If Laboratory Services and Applied Science Division (LSASD) field investigators determine that any of the procedures described in this section are either inappropriate, inadequate or impractical for a given site or station or that another procedure must be used to obtain a representative measurement, the variant procedure will be documented in the field logbook, along with a description of the circumstances requiring its use. Mention of trade names or commercial products in this operating procedure does not constitute endorsement or recommendation for use.

Note: LSASD is currently migrating to a paperless organization. As a result, this SOP will allow for the use of electronic logbooks, checklists, and report forms as they are developed, which will also be housed in the LIMS and traceable to each project. LSASD is committed to maintaining its quality system by continued traceability of original observations in the final report as migration to an electronic system occurs.

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1. General Information

1.1. Documentation/Verification

1.1.1. This procedure was prepared by persons deemed technically competent by LSASD management, based on their knowledge, skills and abilities and has been tested in practice and reviewed in print by a subject matter expert. The official copy of this procedure resides on the LSASD local area network (LAN). The Document Control Coordinator (DCC) is responsible for ensuring the most recent version of the procedure is placed on the LAN and for maintaining records of review conducted prior to its issuance.

1.2. General Precautions

1.2.1. Safety

1.2.1.1. Proper safety precautions must be observed when conducting reaeration studies. Refer to the Region 4 Safety & Occupational Health SharePoint Site and any pertinent site-specific Health and Safety Plans (HASP) for guidelines on safety precautions. These guidelines, however, should only be used to complement the judgment of an experienced professional. For example, these methods may be employed during periods of high stream flow or in conjunction with boating operations.

1.2.2. Procedural Precautions

1.2.2.1. The following precautions should be considered when conducting reaeration measurements studies:

- All instrumentation should be in good condition and operating within the manufacturer's recommended tolerances.
- All instrumentation should be calibrated and deployed in accordance with the manufacturer's requirements.

2. Special Sampling Considerations

2.1. Quality Control

2.1.1. The reaeration rate coefficient is expressed as a rate in 1/day corrected to 20° Celsius (C). Dissolved oxygen (DO) meters should be calibrated according to LSASD Operating Procedure for Field Measurement of Dissolved Oxygen (LSASDPROC-106).

2.2. Records

2.2.1. Information generated or obtained by LSASD field investigators will be organized and accounted for in accordance with LSASD records management procedures. Field notes, recorded in a bound field logbook, in accordance with LSASD Operating Procedure for Logbooks (LSASDPROC-1002), will be generated, as well as chain-of-custody documentation. All measurements shall be thoroughly documented in field records. All measurements shall be traceable to the personnel making the measurements and the equipment utilized.

3. General Considerations

3.1. General

3.1.1. The techniques and equipment described in Section 4 of this procedure document are designed to provide representative measurements of reaeration rates. Care should be applied in the selection of measurement sites and/or reaches to ensure personnel and equipment safety.

3.1.2. Highly productive waters may cause ambient DO to rise significantly during the day. If it is known ahead of time that this may be the case, diffusion dome measurements may be conducted at night or in the late evening/early morning, as safety considerations allow, to minimize ambient DO changes associated with algal production.

3.2. Equipment Selection Considerations

3.2.1. LSASD utilizes domes constructed of stainless steel, fitted with a floatation ring, a water pump and tubing for cooling water, an inlet port and a purge port, and an internal bracket for securing a luminescent DO probe.

3.2.2. If measurements are made in a saline environment, a salinometer or other instrumentation should be deployed to allow for correction of dissolved oxygen measurements.

4. Diffusion Dome Reaeration Measurement

4.1. Reaeration is the process by which oxygen is dissolved into a water body, and the reaeration process for an open channel is characterized by its surface reaeration coefficient. The actual quantity of oxygen transferred to the water column is a function of the water column dissolved oxygen deficit and the reaeration rate coefficient.

4.2. The diffusion dome technique for measuring reaeration is based on the work of Copeland and Duffer (1963) and Juliano (1969). In general, the method involves purging the volume of a floating dome with nitrogen gas and monitoring the recovery of

oxygen within the dome. Thus, diffusion of oxygen from the water column into the atmosphere inside the dome is a surrogate for reaeration. It is assumed that oxygen crosses the air-water interface at the same rate in both directions, all other factors being equal. Where site conditions allow, the dome should be free-floating in the water body. Usually, the dome is tethered to an unanchored boat to allow the field crew access to the dome for purging and mixing during the float. If necessary, based on the site, a "static" float may be conducted, where the dome is tethered to a stationary object.

4.3. Field Measurement Method

4.3.1. The diffusion dome method requires two DO meters. One meter is installed inside the dome to measure DO and temperature in the dome air space. The second meter is used to measure ambient water column DO and temperature as close to the dome as practical. The ambient DO probe should be located just below the water surface, deep enough to represent the entire water column for a non-stratified system. If DO probes are equipped with attachable stirrers, the stirrer should be installed on the ambient probe, but not on the dome probe. The dome is equipped with a manual baffle for circulating air inside the dome.

4.3.2. Once the DO probe is installed in the dome, the dome is placed on the water surface and the nitrogen gas line is connected to the inlet valve. The cooling pump is then placed in the water and started, and DO/temperature monitoring is initiated inside the dome, as well as ambient DO, temperature, and salinity (if appropriate). The temperature inside the dome should stabilize relatively close to the ambient air temperature before purging is conducted. Based on the ambient data, the water column DO deficit is calculated. Then the dome is purged with nitrogen to create a DO deficit between the water column and the dome atmosphere that approximates the ambient water column DO deficit. If a method for calculating the deficit has not been predetermined, the following example method may be used.

4.4. Example Deficit Calculation:

$$Deficit = Ambient\ DO - DO\ Saturation\ Concentration$$

Where:

DO Saturation Concentration = $0.0035T^2 - 0.3369T + 14.407$

Then:

$$Dome\ Purged\ DO\ Value = Ambient\ DO - Deficit$$

4.4.1. Ambient and dome monitoring data should be recorded at 15 minute or more frequent intervals throughout the measurement period. If possible, monitoring should continue for a period sufficient to recover at least 5% of the initial DO deficit imposed in the dome. Depending on the magnitude of the deficit and environmental conditions affecting the measurement (e.g., debris blocking channel, rapids affecting dome seal), a 5% recovery may not be possible. In such cases, the measurement should continue for a minimum of 30 minutes or until conditions prevent continued monitoring. Locational data (latitude/longitude) and depth should also be recorded concurrent with monitoring data readings, in accordance with SESD Operating Procedure for Global Positioning System (LSASDPROC-110).

4.4.2. Wind data should always be collected during diffusion dome measurements on open water bodies (e.g., lakes, estuaries) and may be desirable on river or stream systems. This data is given to end-users of the reaeration rate coefficient for standard method calculation of reaeration. Wind speed from a hand-held wind meter should be recorded, concurrent with monitoring data readings, with an approximation of wind direction. Alternatively, a weather station or stationary logging wind meter deployed in the study area can provide wind data. If the handheld meter or weather station is so equipped, barometric pressure should also be recorded.

4.4.3. The circulation pump helps maintain a constant temperature in the diffusion dome. The pump should be checked frequently throughout the diffusion measurement period. If temperatures rise significantly even with proper operation of the circulation pump, the dome should be shaded with a loose-fitting heavy-duty aluminum foil dome placed on top of the diffusion dome.

4.5. Reaeration Rate Coefficient Calculation

4.5.1. Following field data collection, a reaeration rate coefficient is calculated for each diffusion measurement period and corrected to a base temperature of 20°C as follows:

4.5.2. The amount of oxygen diffused into the dome, D, during the test is represented by:

$$(1)\ D(g/m^3/hr) = \frac{(V)(32g/mole)(0.0446moles/liter)}{(CA)(t)(Z)}$$

Where:

V = change in volume of O2 in chamber (liters),
CA = diffusion Dome area at water-surface interface (meters [m]2)
t = period of measurement (hours)
Z = average depth of unstratified water column (m)

4.5.3. The change in O2 chamber volume, V, is calculated as follows:

$$(2)\ V\ (liters) = \{(273.15V1/273.15 + T1) - (273.15V0/273.15 + T0)\}(CV)(f)$$

Where:

V1 = final dome DO as percent saturation (as fraction)
V0 = initial dome DO as percent saturation (as fraction)
T1 = final temperature in dome (°C)
T0 = initial temperature in dome (°C)
CV = dome (chamber) volume (liters)
f = % O_2 in ambient atmosphere (atm) (as fraction)

$$f = \frac{0.2095(P - P_{wv})}{P}$$

where:

P = barometric pressure (atm)
P_{wv} = water vapor partial pressure (atm)

4.5.4. When barometric pressure is not available, local pressure, P, can be estimated from altitude and air temperature as:

$$P = \{(273.15T - 0.0065Z)/273.15T\}5.2559$$

Where:

T = ambient temperature (°C)
Z = local elevation (m)

4.5.5. When water vapor partial pressure is not available, P_{wv} can be estimated by the Arden Buck Equation:

$$P_{wv}\ (hPa) = 6.1121exp\{(17.502T)/(240.97 + T)\}$$

Where:

T = ambient temperature (°C)
1 (hPa) = 9.8692 e -4 (atm)

4.5.6. The reaeration rate, K_a (Base e), is then calculated as:

$$(3)\quad K_a(1/day) = \frac{(D)(24\ hrs/day)}{(S_{def})(C_s)}$$

Where:

D = oxygen diffusion from equation 1 ($g/m^3/hr$)
S_{def} = average saturation deficit between dome and water column (as fraction)
= {1 – (average dome DO/average water column DO)}
Cs = average water column saturation DO (g/m^3)

4.5.7. The reaeration rate, K_a (Base e, @ 20 ºC), is then calculated as:

$$(4)\quad K\ (1/day) = (1.024)\ \hat{}\ (20 - T_a)$$

Where:

T_a = average ambient temperature (ºC)

References

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LSASD Operating Procedure for Logbooks, LSASDPROC-1002, Most Recent Version.

LSASD Operating Procedures for Measurement of Dissolved Oxygen, LSASDPROC-106, Most Recent Version.

LSASD Operating Procedure for Global Positioning System, LSASDPROC-110, Most Recent Version.

SESD Operating Procedure for In-situ Water Quality Monitoring, SESDPROC-111, Most Recent Version.

Region 4 Safety & Occupational Health SharePoint Site at:
https://usepa.sharepoint.com/sites/R4_Community/Safety/SitePages/Forms%20and%20Resources.aspx

Revision History

History	Effective Date
LSASDPROC-505-R5, *Reaeration Measurement by Diffusion Dome*, replaces SESDPROC-505-R4. SOP put in the new SOP format. Equipment Selection Consideration section modified. Edits made to the Diffusion Dome Reaeration Measurement Section. Changes were made to reflect the SESD reorganization, replaced SESD with LSASD. Updated SOP references.	August 11, 2021
SESDPROC-505-R4, *Reaeration Measurement by Diffusion Dome*, replaces SESDPROC-505-R3. **General:** Corrected any typographical, grammatical, and/or editorial errors. Throughout the document, references to retired SESD operating procedures were omitted. **Title Page:** Changes were made to reflect recent SESD reorganization.	September 8, 2017
SESDPROC-505-R3, *Reaeration Measurement by Diffusion Dome*, replaces SESDPROC-505-R2.	May 30, 2013
SESDPROC-505-R2, *Reaeration Measurement by Diffusion Dome*, replaces SESDPROC-505-R1.	November 6, 2009
SESDPROC-505-R1, *Reaeration Measurement by Diffusion Dome*, replaces SESDPROC-505-R0.	November 1, 2007
SESDPROC-505-R0, *Reaeration Measurement by Diffusion Dome*, Original Issue	February 05, 2007