UNIVERSITY OF MINNESOTA
ST. ANTHONY FALLS LABORATORY
Engineering, Environmental and Geophysical Fluid Dynamics

Project Report No. 458

Dissolved Oxygen Demand at the Sediment-Water Interface in Monongalia Lake, Minnesota

By

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Prepared for

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1. Objective

The objective of this study is to determine the sediment oxygen demand in Monongalia Lake. The measurements will be utilized in designing a cost-effective aeration system at the New London Mill Ponds. The activities outlined below were conducted at the Saint Anthony Falls Laboratory, University of Minnesota:

1.) Determining the chemical composition of sediments at the sediment-water interface;
2.) Sampling 3-5 sediment cores in the field at representative locations within the New London Mill Pond/lower Monongalia Lake area;
3.) Determining the Sediment Oxygen Demand (SOD) of core samples using appropriate techniques under controlled laboratory conditions;
4.) Providing summary information to be used by another investigator for a cost-effective aeration design at the New London Mill Pond.

2. SOD measurements

Seven sediment cores were collected at different ponds in Monongalia Lake on September 9, 2002. Sampling locations are specified in Fig 1. Intact sediment core samples were collected using a messenger-activated gravity core-sampler (Aquatic Research Instruments). The sediment cores were installed in five specially designed SOD measurement systems and incubated in a refrigerator as shown in Fig. 3 and Fig. 4. In order to simulate winter conditions, the temperature in the incubator was set at 7.7 ^{o}C. Plexiglas cylinders above the sediment-water interface were filled with distilled water in order to eliminate the BOD in water samples. Therefore, the reduction in dissolved oxygen (DO) concentrations is attributed to the sediments only. The water above the sediments was cycled by a pump that simulated moving fluid above the sediment-water interface. The dissolved oxygen concentration was recorded every 5 minutes and stored in a data logger. The test was conducted until the DO was reduced below 2 mg/L in the experimental setup. The reduction of DO in the experimental setup for different sediment cores is provided in Fig. 5.

From the experimental measurements, SOD is estimated using the following equation:

$$SOD = \frac{(DO_2 - DO_1)h}{\Delta t}$$

SOD is the sediment oxygen consumption rate in mg/m^2/day, DO_1 and DO_2 are the intial and end DO concentrations in g/m^3, h is the water depth in the sediment cores in m, and Δt is the time interval between the initial and end measurements of DO in the experimental setup in days. The SOD results are listed in Table 1.

Table 1. Measured Sediment Oxygen Demand at seven sampling stations in Monongalia Lake, MN

Station	#1	#2	#3	#4	#5	#6	#7	Average
SOD (g/m^2/day)	0.27	0.60	0.48	0.50	0.49	0.57	0.30	0.46

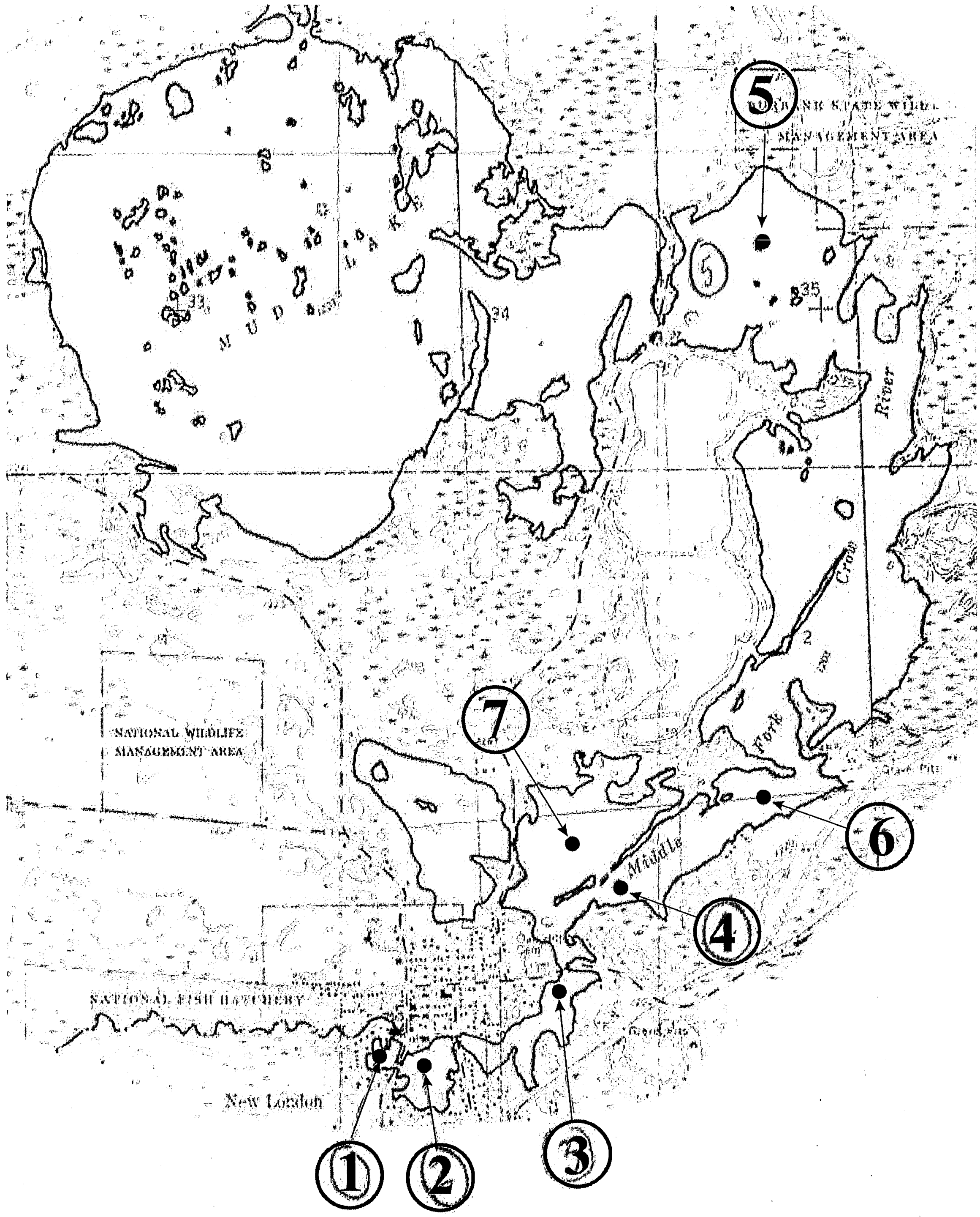

Fig. 1. Sediment core sampling locations in Monongalia Lake, MN

Fig 2. Collection device for intact sediment core samples

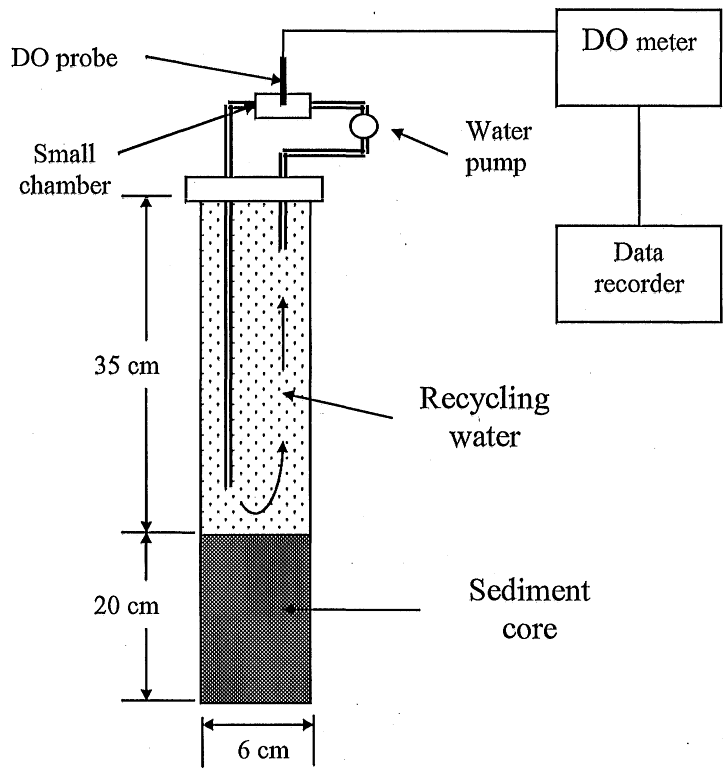

Fig. 3. Experimental setup for sediment oxygen demand at the Saint Anthony Falls Laboratory.

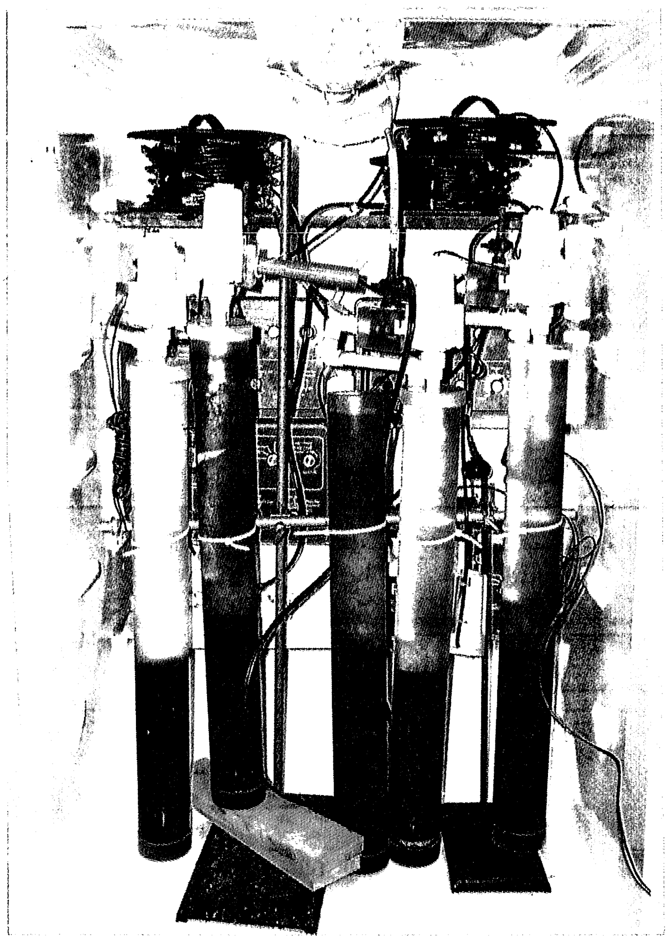

Fig 4. Sediment oxygen demand experimental setup in a controlled temperature environment (T = 7.7 °C) at the St. Anthony Falls Laboratory

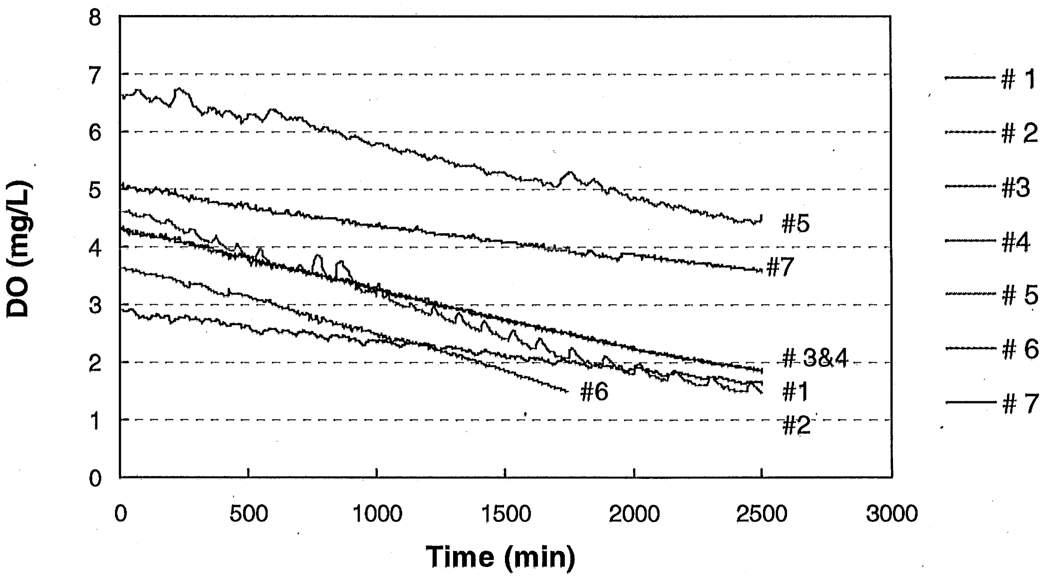

Fig 5. Dissolved oxygen concentrations versus time in the experimental setup

3. Chemical analysis

The top 5 cm sediment samplies collected at Stations 1, 2, 3, 4, and 5 were used for the chemical analysis. The analysis include pH, organic content, total sulfur, and metals. The results are shown in Table 2 and Table 3. The sediments have a pH close to 7, indicating a neutral condition. The organic content ranged from 7.2% to 33.8% in the lake sediments. The high organic content in the lake sediments contributed significantlly to the reduction of oxygen in the water above the sediments. In addition, the high organic content in sediments is a source of substrate for sulfate-reducing bacteria. Under anaerobic conditions, anaerobic microbial processes cause sulfate ions to be reduced to hydrogen sulfide.

Table 2 Chemical analysis of sediment samples collected in the Monongalia Lake, MN (ppm)

Sample location	pH	O.M. (%) by L.O.I.	Total S (%)
# 1	7.6	7.2	0.3
# 2	7.5	9.0	0.24
# 3	7.5	26.3	0.68
# 4	7.6	27.6	1.43
# 5	7.6	33.8	1.03

Table 3 Metal analysis of sediment samples collected in the Monongalia Lake, MN (ppm)

Sample location	P	Ca	Mg	K	Mn	Fe	Zn	Cu	Na
# 1	9.2	8023	984	138	231.1	638.3	7.5	0.4	23.3
# 2	11.3	10703	976	87	80.2	453.0	9.8	1.8	27.9
# 3	8.2	21077	1644	101	144.4	453.4	1.6	0.8	51.4
# 4	22.0	29436	1903	128	204.1	172.9	5.3	1.4	60.8
# 5	16.0	39667	2158	56	153.3	485.8	2.4	1.5	47.6

4. Aeration design

A dissolved oxygen conentration increase in the water above the sediments is a possible management alternative for the reduction of hydogen sulfide in a water column. Anearobic microbial processes cause sulfate ions to be reduced to hydrogen sulfide. Under aerobic conditions the generation of hydrogen sulfide will be reduced. In addition, hydrogen sulfide is a volatile species that oxidizes in aerobic water prior to escaping from the water phase. Therefore, a potential aeration design should provide aerobic conditions in the water above the sediment-water interface, especially under winter conditions with snow cover on the ice. The aerobic conditions should be maintained and uniformly distrubuted throughout the lake above the sediments. Aerating a pond at one location will not result in an efficient aeration design.

Table 4 provides an example estimating the air supply and required power per unit area for the design of an aeration system. Note the design parameters are based on an average SOD in the experimental setup and with a fine bubble aerator. The parameters will vary with different types of aerators and system designs for delivering DO in a water column. Therefore, the SOD rates should be used in conjunction with the specification of corresponding diffusors and an aeration system. The required power and air supply (Table 4) are estimated per unit area and should be multiplied by a corresonding area required to be aerated.

Table 4. An example of aeration design parameters based on an averaged SOD in the experimental setup.

measured DO demand	0.004mg/l/(5min)	SOTR	1lb/hr	
measured DO demand	1.152mg/l/d (or g/m^3/d)	Area	254852ft^2	
mean depth	0.4M	For fine bubble aerators:		
SOD	0.4608g/m^2/d		MIN	MAX
SOD	9.4172E-05lb/ft^2/d	SAE	1.5	6lb/kWh
SOD	3.9238E-06lb/ft^2/hr	SOTE	10%	40%
		Power	2.62E-06	6.54E-07kW/ft^2
		Air Supply	3.78E-05	9.44E-06SCFM/ft^2