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Measurement of Sediment Oxygen Demand (SOD) in the Royal River Estuary, Yarmouth, Maine

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1.0 INTRODUCTION

The Maine Department of Environmental Protection (MDEP), Water Quality Bureau, Total Maximum Daily Load Program (TMDL), requested assistance from EPA's Office of Environmental Measurement and Evaluation in conducting a Sediment Oxygen Demand Study (SOD) on the estuary area of the Royal River, in Yarmouth, Maine.

MDEP will reassess attainment/non-attainment status of dissolved oxygen criteria and the trophic status of the Royal River estuary. A water quality model will be developed based on the results of the SOD study and the water quality survey conducted by MDEP in 2004.

SOD is the total of biological and chemical processes in sediment that utilize oxygen. SOD studies are useful in the development of predictive mathematical models that will determine waste load allocations. They are also useful in measuring the depletion of oxygen in stratified waters when there are concerns about nutrient regeneration and the loss of aquatic life.

This project included monitoring eight sites on the Royal River, beginning just below the RT 95 Bridge and extending to Parker Point. The eight sites chosen were in areas of recent dredging as well as historical depositional areas that had not been dredged. Site descriptions and locations are shown in Table 1. Stations were also based on Royal TMDL sampling locations. Sediments were analyzed for SOD, total organic carbon (TOC) and grain size.

Land use in the area is mostly rural residential with some urban development. The Town of Yarmouth discharges secondary treated wastewater to the Royal River and several single-family homes have overboard discharges on the Royal Rivers. Water related activities to these estuaries have increased. The Royal River supports three marinas/boatyards and an anchorage area. Boating activity has increased significantly over the past decade and the harbor was dredged in 1995 and 1996 to accommodate larger boats.

2.0 MATERIALS

EPA field crews performed SOD analyses at the Yarmouth Wastewater Treatment Plant in Yarmouth, Maine in the EPA Biology Mobile Trailer. This site provided a controlled environment and close proximity to the field study location. An EPA 17' McKee Craft was used for collecting the samples with a Wildco KB Core Sampler and a hand corer sampler. Overlying water was retrieved using a Horizontal Alpha Water Sampler at each station just above the sediment water interface. SOD measurements were performed with five YSI Model 5100 dissolved oxygen meters. TOC and grain size samples were analyzed at the OEME laboratory in North Chelmsford, MA.

3.0 METHODS

3.1 Sampling Locations

The six sampling locations selected were based on the presence of fine sediment and proximity to stations used in the MDEP Water Quality Surveys. Station location descriptions can be found in Table 1 and on the map in Appendix C and GPS locations of each collected core in Appendix D.

Table I. Station Descriptions

Station #	Station Description
1A	*Channel By Yacht Club*
1A-L	*North of Channel by Yacht Club*
2	*Channel*
2A-L	Tidal flat North of treatment plant
4	*Channel*
4-L	*Tidal flat*
5	*Off Callon Point in Channel*
6R	*Tidal Flat by Parker Point*

3.2 Sediment Sampling

SOD samples were obtained by using a Wildco KB Gravity Core Sampler and a hand core Sampler. Five cores were retrieved from each site and capped on the top and bottom with #11 rubber stoppers. After SOD measurements were completed, the contents of each core were composited, homogenized and then aliquots were taken for total organic carbon and grain size analyses. These samples were stored at 4°C prior to analysis.

3.3 Dissolved Oxygen Ambient Water Collection

Ambient water was collected in a core tube and capeed on either end with #11 rubber stoppers as described in the procedure in Appendix B. Initial and final dissolved oxygen measurements in each of these bottles are used to simulate production or respiration in the overlying water in the sediment core tubes. The tubes were placed in the water bath and maintained at 20°C±1° until the end of the test, when the final readings were recorded. The results are used in the final SOD rate calculation if there is a significant oxygen demand in the water sample.

3.4 Sediment Oxygen Demand Determination

This method involves confining a measurable volume of water overlying a known area of sediment in a core tube and measuring the depletion of dissolved oxygen over a period of time.

After the five sediment cores are collected, the water column height (h) in each of the five cores is measured in meters and recorded in a logbook. Sediment sample cores are transferred to a temperature controlled water bath and incubated at 20EC∀1E for a 3 to 4 hour monitoring period. Often a 30-60 minute stabilization period is required for the core tube temperature to reach equilibrium with the water bath. The dissolved oxygen concentration within these cores is measured every 30 minutes for the test duration. Following the monitoring period, SOD rates are calculated for each core sample and then averaged to produce a mean rate at each site. The standard deviation is also calculated to determine the variability of the sediment. See the Sediment Oxygen Demand calculation sheet in Appendix A for site-specific SOD rates and standard deviations.

The formula for calculating SOD rates is as follows:

$$\text{SOD g } O_2/m^2\text{day} = \frac{\{(O_i - O_f) - (B_i - B_f)\}(h)}{(t)}$$

O_i = initial dissolved oxygen (DO) mg/P
O_f = final DO mg/P
B_i = initial DO in bottles mg/P
B_f = final DO in bottles mg/P
h = height of water column in meters
t = time in days

Dissolved oxygen and temperature measurements are recorded in a bound logbook for each station sampled. The meters are calibrated before analysis and a post calibration check is performed at the end of the analysis. In the final calculation of the SOD rate, data is used only where oxygen depletion versus time is a constant.

4.0 RESULTS

4.1 Sediment Oxygen Demand

SOD results ranged from a low of 1.09 g/(m²day) at station 4 to a high of 4.06 g/(m²day) at station 1A-L. Six stations wree in the medium range of 1.0 to 2.0

g/(m²day) which include stations: 2; 2A-L; 4; 4-L; 5; 6R. Stations 1A and 1A-L are in the high SOD range of greater than 2.0 g/(m²day). Further investigations should be conducted to determine the source of the high oxygen demand from the sediment at these two stations. Standard deviations were less than 1.0 at six of the eight sites. Stations SBT-04 and SBT-05 had standard deviations greater than 1.0 due to the possible location of different type of sediment collected in the cores and the high oxygen demand of some of the cores. See Appendix C for the map and location of the samples and Appendix A for worksheets with data.

Table II. SOD Results Fall 2004

Station #	Station Description	Mean SOD g/m²day	Standard Deviation
1A	*Channel By Yacht Club*	**2.47**	1.48
1A-L	*North of Channel by Yacht Club*	**4.06**	2.85
2	*Channel*	**1.39**	0.97
2A-L	Tidal flat North of treatment plant	**1.82**	0.66
4	*Channel*	**1.09**	0.22
4-L	*Tidal flat*	**1.56**	0.61
5	*Off Callon Point in Channel*	**1.28**	0.31
6R	*Tidal Flat by Parker Point*	**1.66**	0.28

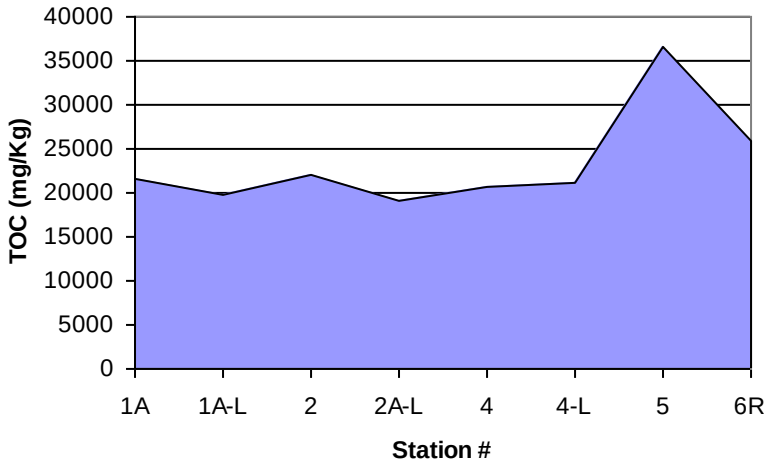
4.2 Total Organic Carbon

TOC results ranged from a low of 1.9% at 1A-L by the Yacht Club to a high of 3.7% at Station 5, Off Callon Point. There appears to be a slight trend in TOC from upstream to downstream before the mouth of the river. TOC provides an indication of the binding capacity of sediment and the potential bioavailability of certain organic compounds. TOC lab report can be found in Appendix E.

Table III. TOC Results

Station #	TOC (mg/Kg)
1A	21700
1A-L	19800
2	22000
2A-L	19000
4	20700
4-L	21200
5	36600
6R	26000

Figure 1. TOC Results



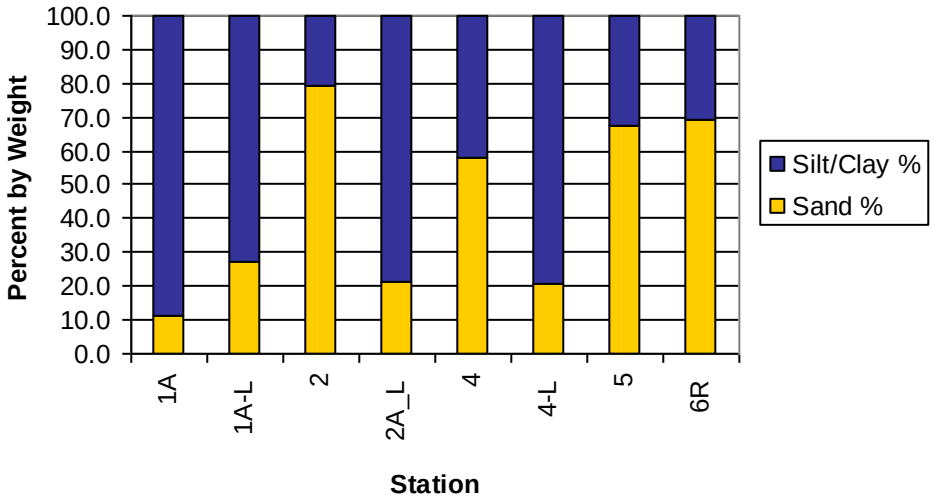
4.3 Grain Size

Grain size analysis was performed to categorize sediment particle size at each of the sample locations. In general the grain size fell into the silt/clay range. Station 2 had a much higher sand percentage (%) compared to the other sites (fig.2). Finer sediments were sought for the sediment cores because the small particle size and proportionately greater surface area have a higher affinity for binding contaminants. Laboratory results can be found in Appendix F.

Table 4. Grainsize Results

Station #	Sand (%) >0.075mm	Silt and Clay (%) <0.075mm
1A	11.3	88.7
1A-L	27.0	73
2	79.5	20.5
2A-L	21.4	78.6
4	57.7	42.3
4-L	21.0	79.0
5	67.2	32.8
6R	69.3	30.7

Figure 2. Sand and Silt/Clay Distribution by Weight Percent



4.4 Duplicates

Field duplicates for SOD were performed at each site with the use 5 cores. The standard deviation varied from a low of 0.22 at station 4 to a high of 2.85 at station 1A-L. A Field duplicate for TOC was performed at station 2 with results of 220000 mg/kg and 207000 mg/kg. Laboratory results can be found in Appendix B.

Table V. Field Duplicates

Analyte	*Station*	*Duplicate*	*% Difference*
TOC (mg/Kg)	220000	207000	94 - 106

5.0 REFERENCES

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