HARPETH RIVER
WATERSHED ASSOCIATION

HARPETH RIVER MAIN STEM DISSOLVED OXYGEN STUDY

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Introduction

Dissolved oxygen (dissolved O_2, a.k.a. DO) is essential for fish and benthic macroinvertebrates. Although the concentration of oxygen in the air is quite high, O_2 is not very soluble in water, as indicated in Table 1 (following page); at saturation under one atm of air the oxygen concentration in water at room temperature is about 8.2 mg/L (8.2 parts per million, ppm). This is sufficient to maintain aquatic life. The regulatory minimum permissible DO is 5.0 mg/L.

There are a number of factors that affect the DO concentration:

1. Efficiency of reaeration from the atmosphere. Efficiency of oxygen transport is high in shallow, turbulent streams; it is poor in deep, slow-moving or stagnant streams.

2. Temperature. The solubility of oxygen in water decreases with increasing temperature. For example, at 14°C the solubility of oxygen in pure water (no dissolved salts) is 10.30 mg/L, while at 30°C it is only 7.56 mg/L.

3. Presence of Biochemical (Biological) Oxygen Demand, BOD. BOD consists of organic material (food processing wastes, human and animal feces and urine, paper mill wastes, dead and decomposing algae and leaves, etc.) that can be used as food by stream bacteria naturally present in surface waters. As the bacteria feed upon the BOD, they consume oxygen. They also multiply. If there is sufficient BOD present, its metabolism by the stream bacteria will use up all of the dissolved oxygen in the water. At this point fish and most benthic macroinvertebrates die of suffocation—we have a fish kill.

4. Presence of plant nutrients and sunlight. If the water contains sufficient plant nutrients (principally nitrate and phosphate) and is exposed to a substantial

amount of sunlight, the algae in the water will grow very rapidly, perhaps to the point where a "bloom" results, making the water very turbid and greenish in color. During the day the algae use the sunlight, carbon dioxide, and water to photosynthesize, in the course of which they increase their biomass and also generate oxygen. This results in increasing DO concentrations during the daylight hours. At night, however, photosynthesis is not possible, the algae are metabolizing (a process that uses up oxygen), and DO concentrations go down. Streams that receive nitrates and phosphates from fertilizer runoff or other sources, and that are relatively unshaded from the sun are particularly prone to large day-to-night swings in DO concentration, with the minimum DO occurring just about at dawn and the maximum at about sunset. The effect is particularly large when the water is warm, so that biological processes are rapid, and days are long, so there is lots of light.

Table 1. Oxygen solubility in water at 1 atm (760 mm Hg) pressure of air

Temperature,	Chlorinity, g/L		
^{o}C	0.0	0.5	1.0
	Oxygen solubility, mg/L		
10	11.28	11.22	11.15
12	10.77	10.71	10.65
14	10.30	10.24	10.19
16	9.87	9.81	9.76
18	9.47	9.42	9.36
20	9.09	9.05	9.00
22	8.75	8.70	8.65
24	8.42	8.38	8.33
26	8.12	8.08	8.03
28	7.83	7.79	7.75
30	7.56	7.52	7.49
32	7.30	7.27	7.23
34	7.06	7.03	6.99
36	6.83	6.80	6.77
38	6.62	6.59	6.56
40	6.41	6.38	6.35

At barometric pressure P (mm Hg), the solubility S' is given from the corresponding value in the table, S, by

$$S' = S \cdot (P - p)/(760 - p)$$

where p is the pressure (mm Hg) of saturated water vapor pressure at the given temperature.

The Harpeth River exhibits characteristics that lead one to expect that it suffers from low DO concentrations during the latter part of the summer and early fall. It receives plant nutrients from wastewater treatment plant effluents, runoff from lawns and golf courses, and runoff from agriculture and animal husbandry. Much of the river is relatively unshaded due to destruction of riparian vegetation. And there are frequent relatively deep, quiescent sections in which reaeration is inefficient, particularly during periods of low flow during the summer and early fall. Data obtained by EPA during the period August 22-25 had indicated that there was a problem, with minimum DO concentrations ranging from 3 to 4.5 and maximum DO concentrations of 7-12 in the reaches of the river in which we were interested. Interestingly, the EPA study found a minimum DO concentration of 0.21 mg/L at their most upstream site at river mile 114.6, far upstream from Franklin.

The Harpeth River Watershed Association therefore decided to carry out a dissolved oxygen study on the Harpeth between Riverwalk Park in Franklin and the Highway 100 bridge in Bellevue. Members of the HRWA's Science and Policy Committee designed the study. The project design was based upon the lessons learned from a similar study in August 2001 using trained volunteers with Hydrolabs or a Winkler method digital titrator kit at four sites.

Methods and sampling stations

A number of techniques for measuring DO were tried (various meters, Winkler drop count titration, Winkler syringe, and Winkler digital titrator); the Winkler digital titrator kit from the Hach Chemical Co. was selected on the basis of consistent precision of the results. Three of these kits were used in the study.

Sampling stations are located at the following sites (upstream to downstream):

1. Harpeth River at Riverwalk Park, 4th Ave N and Hillsboro Rd, upstream from the Franklin, TN sewage treatment plant (STP). Approx. river mi. 87
   35^{o}55'45"N, 86^{o}52'30"W

2. Harpeth River at Williamson County Park canoe dock, downstream from the Franklin STP. Approx. river mi. 85.5
   35^{o}56'40"N, 86^{o}52'15"W

3. Harpeth River at Highway 46 bridge, Old Hillsboro Rd. Approx. river mi. 76.5
   35^{o}59'35"N, 86^{o}53'58"W

4. Harpeth River at Moran Road bridge. Approx. river mi. 68
   36^{o}01'01"N, 86^{o}53'58"W

5. Harpeth River at Highway 100 bridge, Bellevue. Approx. river mi. 62.4
   36^{o}03'15"N, 86^{o}55'43"W

These are marked on the attached map of the Harpeth River watershed. (The map is not included in the electronic version of this report).

Early morning minimum DO values at the various stations, August 24, 2002

The following DO concentrations were observed at the five stations the morning of August 24, 2002:

Site	Time	DO, mg/L	T, °C	% sat'n.
1. Harpeth River at Riverwalk Park	4-5 AM	3.76		
		4.14		
2. Harpeth R at Williamson Co. Park dock	4-5 AM	5.42		
		5.48		
		5.28		
3. Harpeth R at Highway 46 bridge	4:50 AM	4.30	26.1	53
	5:15	4.28	"	53
	5:35	4.28	"	53
4. Harpeth R at Moran Rd bridge	5:40 AM	3.86		
	6:05	3.95		
	6:20	4.00		
5. Harpeth R at Highway 100 bridge	6:30 AM	4.12	26.1	51
	6:50	4.37	"	54
	7:13	4.24	"	52

Effect of algal diurnal cycle

Sets of runs were made at Site 6 (Harpeth River at Highway 100) at dawn and late in the afternoon on August 26, 2001, and again on August 24, 2002. The results are as follows:

Date	Time	DO, mg/L	T, °C	% sat'n.
August 26, 2001	4:15 AM	5.26		
morning	4:45	5.22		
	5:15	5.04		
	5:45	5.00		
	6:15	5.20	(bubble in DO bottle)	
	6:30	5.16		
	6:45	5.10		

	7:15	5.10		
	7:45	5.08		
	8:15	5.12		
	8:45	5.24		
	9:15 AM	5.10		
afternoon	5:15 PM	6.34		
	5:45	6.40		
	6:15	6.40		
August 24, 2002	6:30 AM	4.12	26.1	51
morning	6:50	4.37	"	54
	7:13 AM	4.24	"	52
afternoon	4:00 PM	6.95	28.9	90
	4:30 PM	6.78	"	88

In the 2001 sampling the diurnal variation in DO concentration was approximately 1.2 mg/L; in the 2002 sampling it was approximately 2.6 mg/L.

Sets of runs were made the afternoon of August 23, 2002 and in the early morning of August 24 at Sites 1 (Riverwalk Park) and 2 (Williamson County Park). The results are as follows:

Site	Time	DO (mg/L)
Site 1	1:20 – 2:00 PM, 8/23/02	6.8, 6.8
	4:00 – 5:00 AM, 8/24/02	3.76, 4.14
Site 2	2:15 – 3:00 PM, 8/23/02	6.7, 6.9
	4:00 – 5:00 AM, 8/24/02	5.42, 5.48, 5.28

Conclusions

Four of the five sites, including Site 1 (upstream from the Franklin STP) were in violation of the regulatory minimum DO standard of 5.0 mg/L the morning of August 24, 2002. The only site that is in compliance is Site 2, just downstream from the Franklin STP. Because of the rather limited data set at present, one can only tentatively draw the following conclusions:

1. The dissolved oxygen concentrations in the discharge from the Franklin STP appear to be sufficient that the DO levels of this discharge are not exacerbating the DO problem in this section of the Harpeth River.

2. Whatever is causing the low oxygen levels is negatively affecting the river upstream from the Franklin STP, as indicated by the results for Site 1. This is consistent with EPA's findings in August, 2000.

3. The moderately large diurnal swing (2.6 mg/L) in DO concentrations observed at Site 5 suggests that algae are a major contributor to the problem. This, in turn, suggests that the problems may be (1) nutrients—nitrates and phosphates, and (2) unshaded streams. The high temperature of the water and the low stream flow are certainly contributing factors.

Acknowledgements

This study was conducted under the auspices of the Harpeth River Watershed Association's Science and Policy Committee. The study was designed and carried out by David Wilson, professor of chemistry and environmental engineering emeritus at Vanderbilt University; John Callighan, chemical engineer, both as volunteer members of the committee; and John McFadden, HRWA Director for Science. This 2002 field study is based on the lessons learned from a similar study in 2001 with trained volunteers who were up at 5am to take measurements. We would like to thank these dedicated volunteers: Rick Lockwood, board member; Mike Walton, President of the Board; Dorene Bolze, Executive Director, and members Toni Peterson, Cooper Magli, and Dave Wilson.

The Harpeth River Watershed Association is very grateful to all the members of the Science and Policy Committee who represent a range of scientific and policy expertise that they donate on behalf of the mission to work together to protect and restore the ecological health of the Harpeth River and its watershed.