Effect of Turbidity on Dissolved Oxygen in the Lake Macatawa Watershed

Hope College GES 401 Research Project

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Introduction

Lake Macatawa has been classified as a hypereutrophic lake by the Michigan DEQ. Although eutrophication is part of the natural progression of a lake's cycle, this process is taking place at an unnaturally rapid rate in Lake Macatawa. As eutrophication progresses the levels of dissolved oxygen (DO) decreases. Low levels of DO mean that certain fish and other organisms can no longer survive in the lake[1].

The MDEQ Water Bureau June 2005 Staff Report for Lake Macatawa states that, "Lake Macatawa displays the classic symptoms of a hypereutrophic lake including: high nutrient and chlorophyll A levels, excessive turbidity, periodic nuisance algal blooms, low dissolved oxygen levels, and a high rate of sediment deposition."[2] Despite the high levels of nutrients and algae in the lake there is a very small rooted plant population. Though high, the algae population is lower than expected due to the extremely high nutrient content. Additionally, there is a very small rooted plant population. In their report on the environmental geology of Lake Macatawa, Anderson et al., states that "rooted plants were nonexistent as a result of high turbidity."[3]

According to the MDEQ, "Phosphorus and suspended solids are strongly correlated and nearly all efforts to reduce the levels of either parameter will impact both parameters."[4] The presence of phosphorus results in periodic algal blooms during the summer which greatly reduce the DO of the lake during their decomposition. Because of the well documented abundance of phosphorus in the watershed, it was decided that nitrates would be measured during the course of the experimentation.

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[1] Macatawawatershed.org
[2] MDEQ Water Bureau June 2005 Staff Report *Monthly Quality Assessment of Lake Macatawa and its Tributaries*.
[3] Geologic Assessment of Environmental Impact in Lake Macatawa Michigan
[4] MDEQ Surface Water Quality Division, 1999

There are several factors that contribute to the low level of dissolved oxygen in the lake. Some of these factors include temperature, turbulence, precipitation events, plant productivity, and level of aquatic life.

The goal of this study was to determine the relationship between the high levels of turbidity and the low levels of dissolved oxygen. It is our hypothesis that there is a negative relationship between water turbidity and DO levels within the Lake Macatawa watershed resulting from inhibited plant growth. It was also hypothesized that dissolved oxygen levels would be independent of nitrate levels. This means that as turbidity levels increase dissolved oxygen content would be expected to decrease.

Methods

Prior to sampling the equipment needed to be calibrated. Sampling sites were chosen throughout the Macatawa watershed. Locations were in the eastern basin of the lake (Kollen and Dutton Parks), the Macatawa River (Paw Paw Park), and the Upper Branch of the Macatawa River (Upper Macatawa Natural Area and Byron Road bridge). Four sample locations were chosen at the U.M. Natural Area. There was an approximate distance of 100 meters between each site. The Byron Road site was located just upstream of the U.M. Natural Area providing a baseline for water quality entering the area. At each location dissolved oxygen measurements were taken at a depth of 0.75 meters using an YSI 6820 sonde fitted with a dissolved oxygen sensor.

Dissolved oxygen was measured as a percent which took into account the varying temperatures of the water. Turbidity measurements were taken at each location using a handheld turbidity meter. A liter of water was collected in a liter Nalgene bottle at sample depth. These bottles were placed in Styrofoam coolers and transported back to the lab where nitrate and BOD (Biological Oxygen Demand) were measured. Nitrates were measured using an electrode. A standard curve was made in order to convert the electrode's output of millivolts to ppm. Nitrate measurements were made in order to confirm that nutrient levels are high in the watershed and would therefore not be a confounding variable in our research. Sampling took place between early October and mid November in a variety of temperatures and precipitation conditions.

The turbidity and dissolved oxygen percentage data were plotted on a scatter plot as an aggregate. The bottle of water was taken back to the lab where it was allowed to warm up to room temperature. Once at room temperature a DO% measurement was taken. After a period of three days the DO% was again taken. This data was used to determine the BOD_3 (Biological Oxygen Demand in 3 days) for the samples. BOD_5 measurements were taken after 5 days in order to get a more recognizable result. A null BOD test was created by placing E. coli bacteria in a sample bottle and measuring its BOD after 3 days. The BOD information was then correlated to the DO% measurements that were taken in the field. This was done so that the more expedient DO% could be taken in the field and interpreted as being representative of BOD in the watershed.

Results

The resulting data were taken from the sampling locations during the October-November sampling period. Figure 1 illustrates the relationship between dissolved oxygen (DO) percent and turbidity (FTU) at the various sampling sites plotted as an aggregate (R-squared = 0.1205). A negative trend was observed.

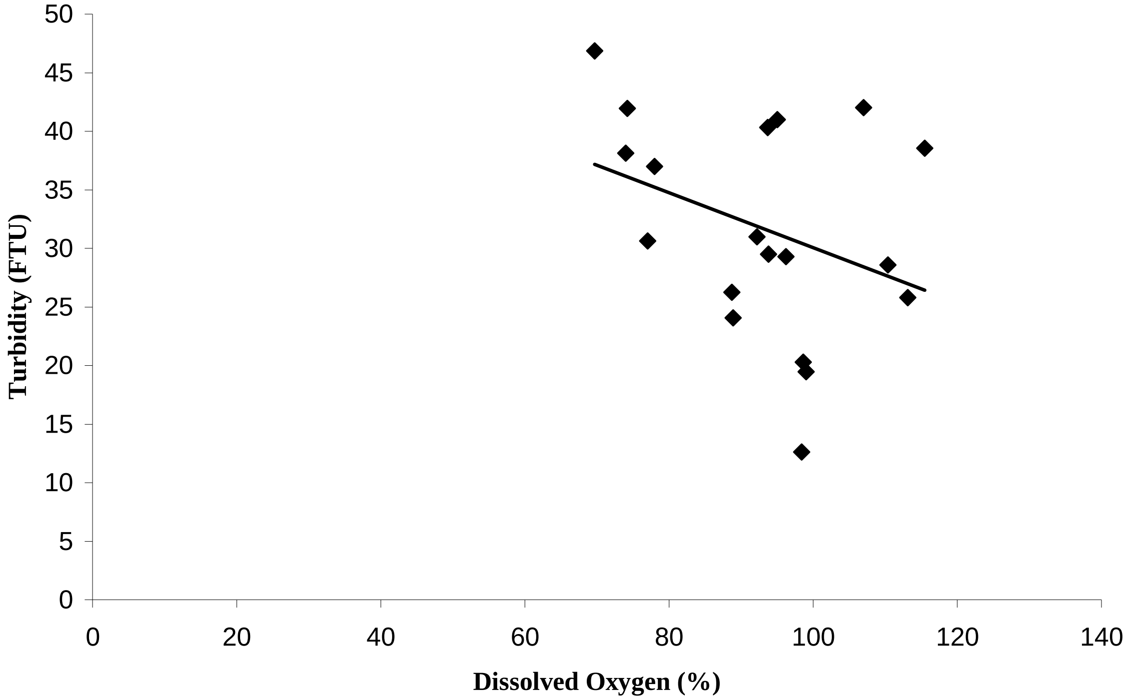

Figure 1. Turbidity (FTU) versus Dissolved Oxygen (%)

Figure 2 shows nitrate concentrations (ppm) from twelve samples. Each sampling location is represented at least once. The data points collected at various times during the sampling stage. These concentrations are based on a standard curve equation that relates the millivolt readings from the nitrate electrode to concentrations in ppm.

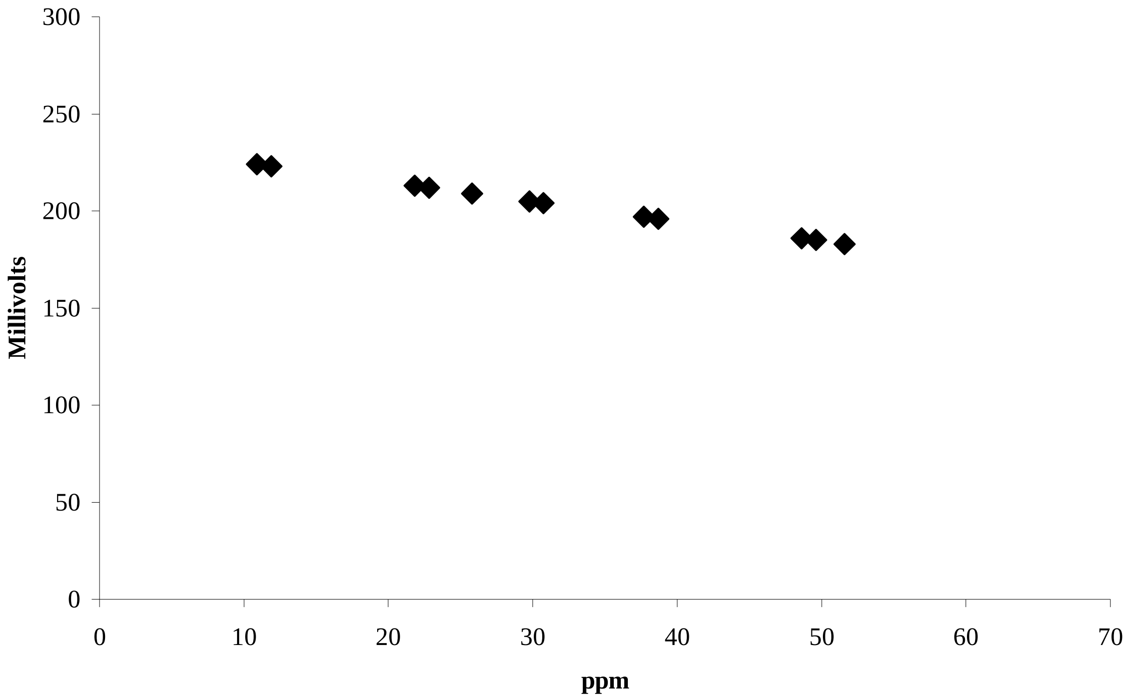

Figure 2. <u>Nitrate Concentrations at Various Sampling Sites</u>

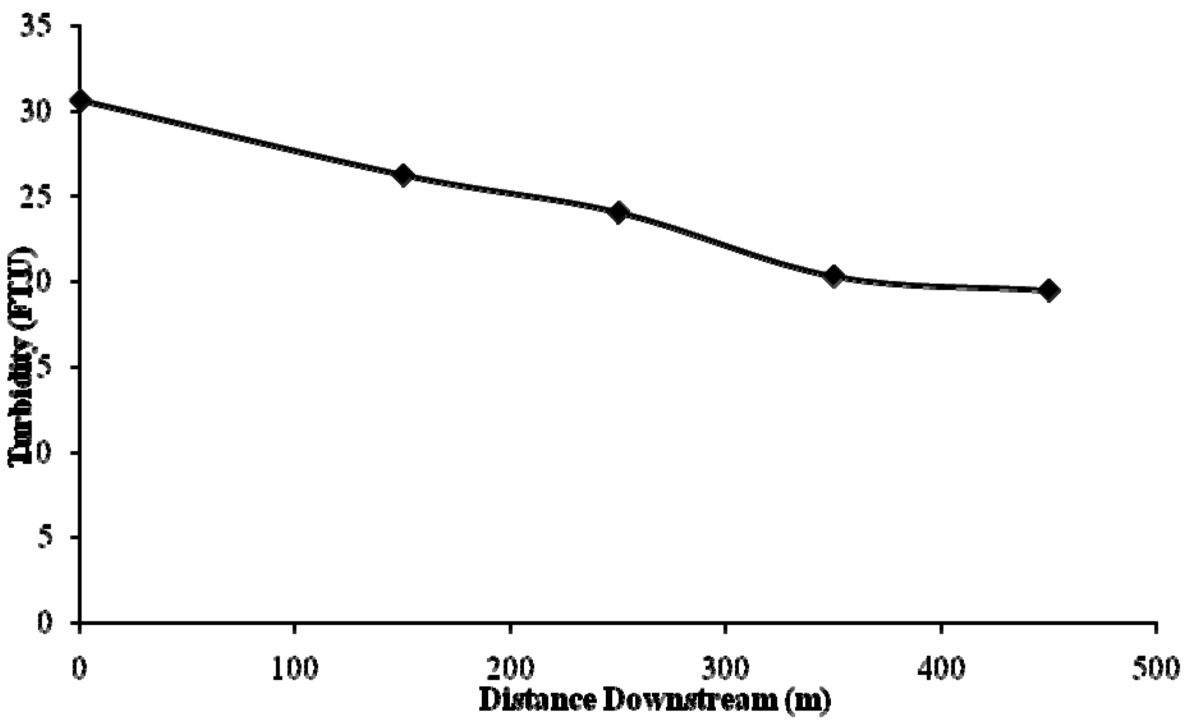

Figure 3. Turbidity (FTU) vs. Distance Downstream (meters) from the Upper Macalawa Watershed

Figure 3 shows the relationship between turbidity (FTU) and the distance downstream (meters) from the Upper Macatawa Watershed. The first data point was taken from the Byron Road site located just upstream from the U.M. project. Note that as distance downstream increases the turbidity of water decreases.

Table 1. BOD5 Tests of Sampling Sites

Sampling Location	*Initial DO (mg/L)*	*Final DO (mg/L)*	*BOD5 (mg/L)*
Kollen Park	8.20	8.10	0.10
Dutton Park	8.48	8.00	0.48
Upper Macatawa	8.96	7.20	1.76
Black Creek	9.13	7.60	1.53
Paw Paw (1)	9.18	8.20	0.98
Paw Paw (2)	8.96	8.70	0.26

Table 1 shows a small decrease in dissolved oxygen from initial to final measurements. The average BOD_5 was determined to be 0.85 mg/L. The amount of dissolved oxygen is relatively high (all are greater than 5 mg/L) – a typical standard for natural water conditions. To determine whether these readings were accurate a null test was conducted by placing aerobic E.coli bacteria in a water sample (Table 2). A much greater difference between initial and final DO measurements was observed confirming the validity of the BOD_5 procedure.

Table 2. BOD3 Results from the E.coli Null Test

Initial DO (mg/L)	*Final DO (mg/L)*	*BOD3*
5.00	2.78	2.22

Figure 4. Algal Growth in Samples Related to Turbidity

The samples in figure 4 are arranged in order of decreasing turbidity from left to right in the photo. Turbidity measurements were taken both at initial sampling and after settling out. The results were consistent, with the more turbid the water producing less algal growth visible. The algae blooms could photosynthesize once turbidity was decreased with settling and light could penetrate into the water.

Discussion

The graph in figure 1 shows a negative correlation between turbidity and dissolved oxygen levels. Statistical significance of this correlation was low because of the numerous environmental variables that effect dissolved oxygen in the field. The results were also affected by weather events and the continually high dissolved oxygen levels found in the watershed. DO levels stayed above 75% due to aeration and low temperatures, while turbidity levels changed quickly with precipitation ranging from 14 to 48 FTU. This factor lowered the R^2 correlation value, but the trend still supports the hypothesis that turbidity is effecting algae growth.

Nitrate levels were consistently high throughout the watershed, proving that nitrates were not a limiting factor to primary productivity. Spring Lake is in the same climate as Lake Macatawa and has similar hydrological features. Nitrate measurements in Spring Lake were found to be around 10 ppm according to The Village of Spring Lake Annual Water Quality Report. These levels are considered acceptable by state water quality standards. Nitrates in Lake Macatawa ranged from 10 to 50 ppm which is much higher than acceptable levels. Past research has shown that phosphorus is not the limiting nutrient in the watershed and this data shows that nitrates are also plentiful throughout the watershed. This leaves turbidity, rather than nutrients, as a possible limiting factor.

Turbidity measurements downstream in the Upper Macatawa Watershed Project showed that the project is removing turbidity slowly during times of low flow. Over the course of the 0.5 km section that was measured, turbidity was lowered by 11 FTU. After storm events, access to the same locations was inhibited by the high water levels. However, turbidity measurements taken from the flood plain were drastically lower than the turbidity in the center of the channel. This reinforces the previous finding that the project is effectively removing turbidity.

The high levels of dissolved oxygen measured when testing biological oxygen demand suggests that there were very few micro-organisms living in the water during the sampling period. Oxygen levels were well above 5 mg/L throughout the watershed indicating that micro-organisms were not limited by lack of oxygen. This low BOD could be attributed to the time of year (many of the organisms my have died by late fall) or could be caused by the relatively low primary productivity. Plants and algae creating primary productivity form the basis of the food chain the basis of the lake's food chain. A low level of primary productivity can be correlated to a decrease in native species. The null test proved that BOD could be measured using the selected procedure. The low levels of biologic activity measured during the course of the experiment suggest relatively low populations of aerobic organisms in the lake.

Sample bottles left in the well lit climate controlled envirofridge produced varying amounts of algal growth. This was an interesting observation because the bottles with the lowest turbidity produced the most algae. This supported the theory that turbidity was limiting growth by showing that all of the nutrients necessary for plant growth were present in the water, but no growth took place until the turbidity settled out. This theory was reinforced by re-measuring the turbidity and finding that as turbidity levels decreased in the individual bottles, algae growth steadily increased.

Conclusions

There are several factors that determine the level of dissolved oxygen in any watershed. The data and experiments conducted in the course of this research project demonstrate that high levels of turbidity contribute to reduction of dissolved oxygen in the Macatawa watershed. The growth of algae in the low turbidity bottles supported our hypothesis that turbidity was keeping light from penetrating the water and thus preventing plant growth that would produce oxygen. This hypothesis was further supported by the measurement of consistently high levels of nitrates suggesting that nitrates are not a limiting factor in this watershed. The nitrate levels were high enough to support plant growth at every sampling location, and reports published by the MDEQ state that phosphorus levels are not a limiting factor. For these reasons, we believe that high levels of turbidity are limiting primary productivity, thus limiting the production of oxygen and resulting in a lower dissolved oxygen concentration. Increased sunlight penetration resulting from a decrease in turbidity, combined with the high nutrient levels may result in increased algal blooms. If these conditions are generated, a drastic decrease in phosphorus and nitrate levels would be required before the lake's natural biodiversity is restored.

Works Cited

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