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Undergraduate Research Paper
Preliminary DOC Information
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ABSTRACT

During the last century, humans have impacted the ecology of aquatic ecosystems with waste disposal and increased commercial shipping. One elemental cycle that has been greatly altered in aquatic ecosystems is the carbon cycle. The three most important pools in this complex cycle are the dissolved inorganic carbon and particulate and dissolved organic carbon pools (Lampert 1997). Concentrations of dissolved organic carbon in different lake types are dependent on varying degrees of allochthonous vs. autochthonous inputs. When attempting to understand DOC concentrations in lakes it is important to consider other defining characteristics such as pH, temperature and specific conductivity. While many studies have been done relating DOC levels to watersheds few have investigated the influence of other lake characteristics. As we expected temperature readings for the four lakes were not significantly different. As expected NGB and FSB bog, which are surrounded by Sphagnum moss peatlands, have pH values significantly lower that the other two lakes. DOC concentrations among the four lakes differed significantly. The high DOC levels of NGB are due to the hydrology of the peatlands surrounding it. But additional research should be done to try and identify possible DOC sinks in FSB. The strong correlation between these two tests reveals that UV-Vis readings can be taken as preliminary indication of DOC levels in lakes. The strong correlation between conductivity and pH reflect the chemistry of the FSB, KL and TFL. With the continual increase of the human population and subsequent food and production demands, if left unchanged, the environmental impact of human activity will only increase. Serious analysis and evaluation is needed in order to regulate this phenomenon on a global level.

INTRODUCTION

During the last century, humans have impacted the ecology of aquatic ecosystems with waste disposal and increased commercial shipping. For decades, industry has dumped harmful chemicals into lakes, streams and rivers making these waterways unfit for water supply and recreation (EPA 2001). The city of Detroit, for example, discharges about 150 pounds of polychlorinated biphenyls, or PCBs, each year into surrounding rivers (EPA 2001). Scientists believe that PCBs and other toxins are responsible for reproductive failures in fish and wildlife that have led to decreases in population sizes (EPA 2001). Ballast water discharges from large cargo ships introduce exotic species into rivers and lakes. Although most of these species cannot survive in foreign environments others, such as the zebra mussel, have had devastating impacts on food webs and nutrient cycling. Further alterations of this delicate ecosystem could result in collapse of commercial fisheries, general species extinction and a decrease in usable water supplies.

One elemental cycle that has been greatly altered in aquatic ecosystems is the carbon cycle. The three most important pools in this complex cycle are the dissolved inorganic carbon, particulate, and dissolved organic carbon pools (Lampert 1997). First, the dissolved inorganic carbon pool, or DIC, is the largest carbon reserve (Lampert 1997). Input of DIC into lakes comes primarily from atmospheric carbon dioxide produced, in part, by cellular respiration (Lampert 1997). Outputs include the abiotic process of calcite precipitation and the biotic processes of photosynthesis and chemosynthesis (Lampert 1997). Second, the particulate organic carbon pool, or POC, is usually the smallest of the three and consists of carbon found in organisms and detritus (Lampert 1997). Primary production is the source of POC, and changes in concentrations are due to death, feeding, and parasitism (Lampert 1997). Finally, DOC, or dissolved organic carbon, is a mixture of less abundant biologically reactive, low-molecular-weight compounds and refractory, high-molecular-weight humic substances (Lampert 1997). Input of DOC comes from both autochthonous and allochthonous sources while heterotrophic microorganisms provide the major sink (Lampert 1997).

Concentrations of dissolved organic carbon in different lake types are dependent on varying degrees of allochthonous vs. autochthonous inputs. The main source of allochthonous DOC is terrestrial plants (Wetzel 1983). This form of DOC is divided into two pools: the old (>>40 years) soil-water pool and the more recent microbially labile pool (Kalff 2002). The older pool is composed mostly of catchment-recycled organic matter that is carried to streams and then to lakes by groundwater (Kalff 2002). The younger pool is derived from leaf litter or the surficial soil layer and is transported during periods of high water runoff (Kalff 2002). While oligotrophic and mesotrophic lakes with low humic contents receive most of their DOC inputs from these two pools, dystrophic lakes have high humic contents and get almost all of their DOC from allochthonous sources. Lakes with intermediate humic acid levels, or eutrophic lakes, are supplied with DOC from autochthonous sources. Autochthonous sources of DOC are secretion and excretion by organisms and autolysis of detritus (Lampert 1997).

When attempting to understand DOC concentrations in lakes it is important to consider other defining characteristics such as pH, temperature and specific conductivity. First, pH is the negative base-10 log of H+ activity. The range of pH in most open lakes is between six and nine (Wetzel 1983). Levels are controlled mostly by the interaction of H+ ions arising from the dissociation of H2CO3 and by OH- ions produced during the hydrolysis of bicarbonate (Wetzel 1983). Low pH values are found in waters that are rich in DOC for example bog lakes (Wetzel 1983). In bog lakes H+ ions are released during the active cation exchange that takes place in the cell walls of Sphagnum moss (Wetzel 1983). Second, temperature influences lake structure by catalyzing biological reactions. Decomposition of organic matter, solubility of oxygen in water, and photorespiration of algae are all essential to lake health and directly impacted by changes in water temperature (Wetzel 1983). Temperature also effects the third variable, specific conductivity, or SC. This is the measure of the resistance of a solution to electrical flow (Wetzel 1983). In most lakes, the SC is closely proportional to the concentrations of major ions (Wetzel 1983). Variance in ion concentrations due to groundwater inputs therefore immediately changes conductance (Wetzel 1983).

This study used four lakes with varying levels of pH, temperature and specific conductivity to show preliminary data on possible influences on DOC levels. While many studies have been done relating DOC levels to watersheds few have investigated the influence of other lake characteristics. Measurements of pH, temperature and specific conductivity were done in situ and samples were taken from each lake to find DOC levels. We expected DOC, pH and specific conductivity levels to vary significantly between the four sites. We also expected pH to have an effect on DOC levels. Our final assumption was that there would be a positive correlation between DOC and UV-Vis readings.

MATERIALS AND METHODS

Sites:

Four lakes located in the Upper Peninsula of Michigan in Gogebic County at the University of Notre Dame Environmental Research Center (UNDERC) were chosen for analysis. The lakes represented a varying range of pH, conductivity, temperature and DOC levels. Tenderfoot Lake, a large clear lake, is surrounded mostly by forested areas. Kickapoo Lake is an intermediate sized lake encompassed by a grassy marsh wetland area. Forest Service and North Gate Bogs are both relatively small lakes surrounded by Sphagnum moss dominated wetlands.

Sampling:

The lakes were sampled each morning for five consecutive days using a pole approximately 1.5 meters in length with a one-liter bottle attached to the end. Samples were taken 6 inches below the surface of the water and within a meter of the shoreline. Measurements of pH, temperature and conductivity readings were taken on site. The water was then filtered through acid-washed GF/F filters into two 125-ml bottles that had been acid-washed and baked. The bottles were placed in a cooler on ice to prevent microbial action and exposure to sunlight.

Lab analysis:

In order to measure DOC, carbon standards of five, ten, fifteen, twenty-five, and fifty ppm were prepared. Each sample was then run on a Hewlett Packard DOC machine, located in the Fitztpatrick Hall of Engineering.

Statistical analysis:

The computer program SYSTAT version 10 was used to run the ANOVAs comparing the effects of pH, temperature and specific conductivity on dissolved organic carbon levels. First, the difference between the levels of DOC in the four lakes was compared. Then the effects of temperature, pH and specific conductivity on DOC were calculated. A Pearson Correlation Matrix test was also performed to show relationships between pH, specific conductivity, temperature, UV-Vis 280 and 330 readings, and DOC.

RESULTS

Temperature did not vary significantly between the four sites (P=.812). Specific conductivity, pH, UV-Vis 280 and UV-Vis 330 were all significantly different between the lakes (P=0, for each). Also, the levels of dissolved organic carbon among the four lakes differed significantly (P=0). Neither temperature nor specific conductivity had an effect on DOC levels (P=.20 and P=.144). pH, however, significantly effected DOC concentrations (P=.0002).

The Pearson matrix revealed a strong correlation between DOC levels and UV-Vis readings at 280 and 330 (R2=.901, R2=.909). Another strong correlation was seen between pH and specific conductivity (R2=.88). Moderate negative correlations were also observed between DOC, UV-Vis 280, UV-Vis 330 and pH (R2=-.68, R2=-.644, R2=-.592).

DISCUSSION

As we expected, temperature readings for the four lakes were not significantly different. The greatest source of heat to lakes is solar radiation (Wetzel 1983). Although TFL and KL are substantially larger that NGB and FSB and should therefore experience greater mixing due to wind the fact that all of the samples were taken only six inches below the surface of the water negates this effect. Six inches is not a great enough depth to pierce the sun warmed epilimnion layer that can extend anywhere from five to twenty meters below the surface of the water (Ricklefs 2000).

Research has shown that Sphagnum moss dominated peatlands have low pH values. This results from the release of H+ ions during the active cation exchange that takes place in the cell walls of the moss (Wetzel 1983). This exchange, or absorption of positively charged ions to the surface of negatively charged humus particles, increases the acidity and thus lowers the pH of lake waters that receive inputs from these peatlands. Our results support this (Wetzel 1983). NGB and FSB bog are surrounded by Sphagnum moss peatlands and have pH values significantly lower that the other two lakes (Wetzel 1983). Another source of H+ ions is the dissociation of weak organic acids resulting from anaerobic decomposition (Crum 1988). Galacturonic acid, for example, increases the acidity of bog waters by dissociation from the cell walls of Sphagnum moss(Crum 1988). Further investigation should be carried out to explore what other factors could be effecting pH levels.

As expected DOC concentrations among the four lakes differed significantly. Forest Service Bog and North Gate Bog are both surrounded by sphagnum moss dominated peatlands thus we assumed that DOC levels in these two lakes would be higher than those of Kickapoo and Tenderfoot lakes. However, this was not the case. NGB's DOC levels were higher, but FSB had DOC readings comparable to those of KL and TFL.

The high DOC levels of NGB are due to the hydrology of the peatlands surrounding it. Peatlands form because of two basic processes: water balance and peat accumulation (Mitsch 1993). A positive water balance in an area occurs when precipitation plus water inflow is greater than evapotranspiration plus runoff (Mitsch 1993). Second, low decomposition with relatively high primary production rates promotes the accumulation of peat (Mitsch 1993). It is the uppermost portion (.5m) of this peat that experiences the greatest hydrologic flow and DOC production (Schiff 1998). In NGB it is the water that flows into the lake from this DOC laden area that results in DOC readings higher than those of KL and TFL. We would have expected the same to be true for FSB. Low readings here could be the result of heterotrophic bacteria in the lake. Additional research should be done to try and identify possible DOC sinks in FSB.

The correlations between DOC levels and UV-Vis readings at 280 and 330 were expected (Figures 1 and 2). These measurements were taken as another way to quantify DOC levels. The strong correlation between these two tests reveals that UV-Vis readings can be taken as preliminary indication of DOC levels in lakes. The strong correlation between conductivity and pH reflect the chemistry of the FSB, KL and TFL. SC usually decreases with the addition of ion laden groundwater inputs. For the three lakes mentioned groundwater inputs are primarily responsible for the mid-range pH values and should therefore reflect of positive correlation with SC.

Recent studies have revealed the enormous negative impact of current human activity on the environment. The production of green house gases, decrease in species diversity, and reductions in the size of commercial fisheries are only a few of these changes. With the continual increase of the human population and subsequent food and production demands, if left unchanged, the impact will only become greater. Serious analysis and evaluation is needed in order to regulate this phenomenon on a global level. Support of research into alternative fuel sources and more ecologically sound waste disposal is needed to avoid catastrophic and permanent changes to the environment.

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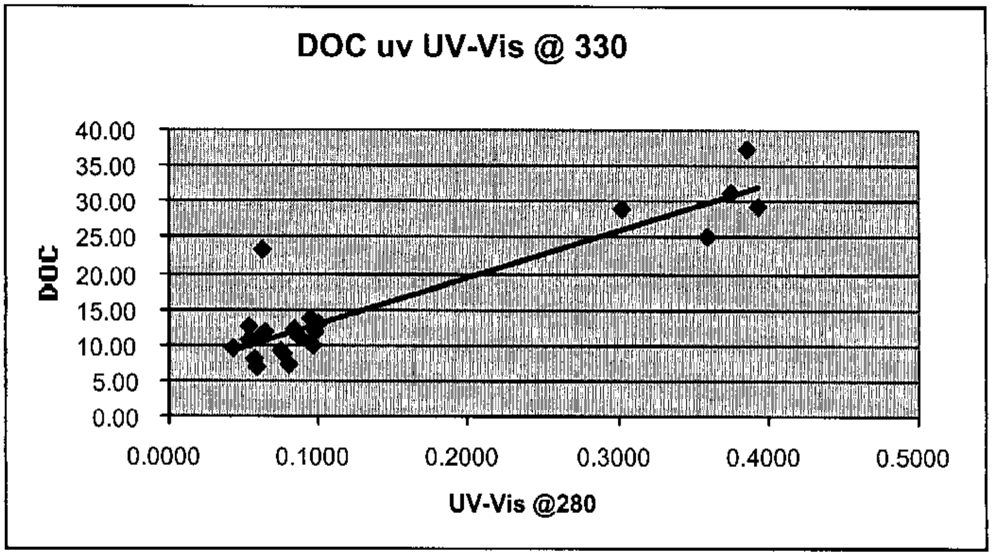

Figure 1 shows the relationship between DOC levels and UV-Vis readings at330nm. There is direct positive correlation between the two (R2=.909).

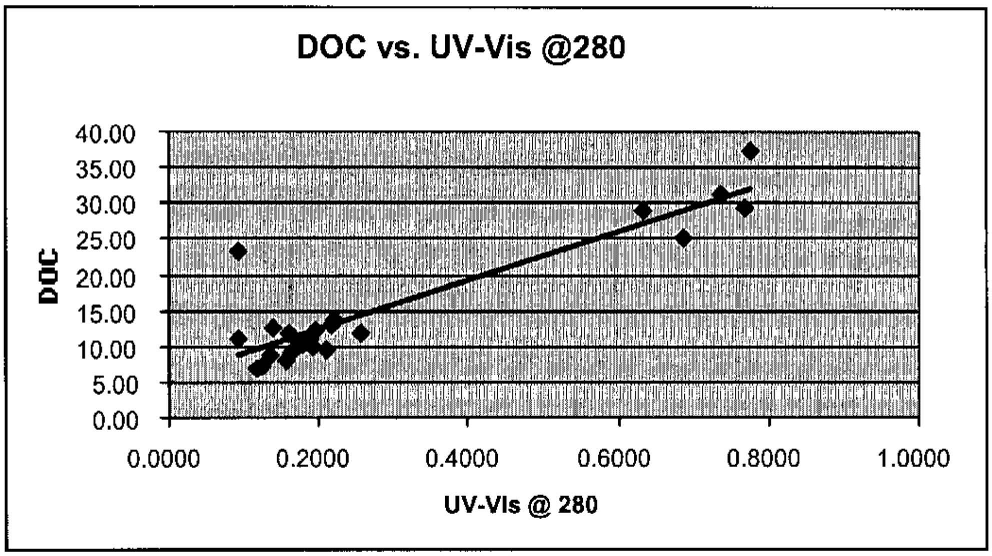

Figure 2 shows the relationship between DOC levels and UV-Vis readings at280nm. There is direct positive correlation between the two (R2=.901).

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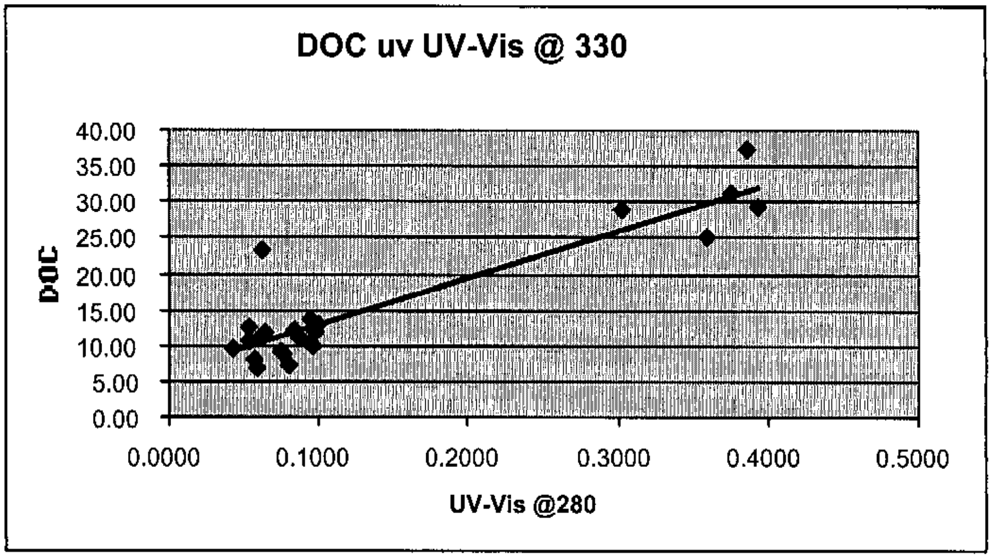

Figure 1 shows the relationship between DOC levels and UV-Vis readings at330nm. There is direct positive correlation between the two (R2=.909).

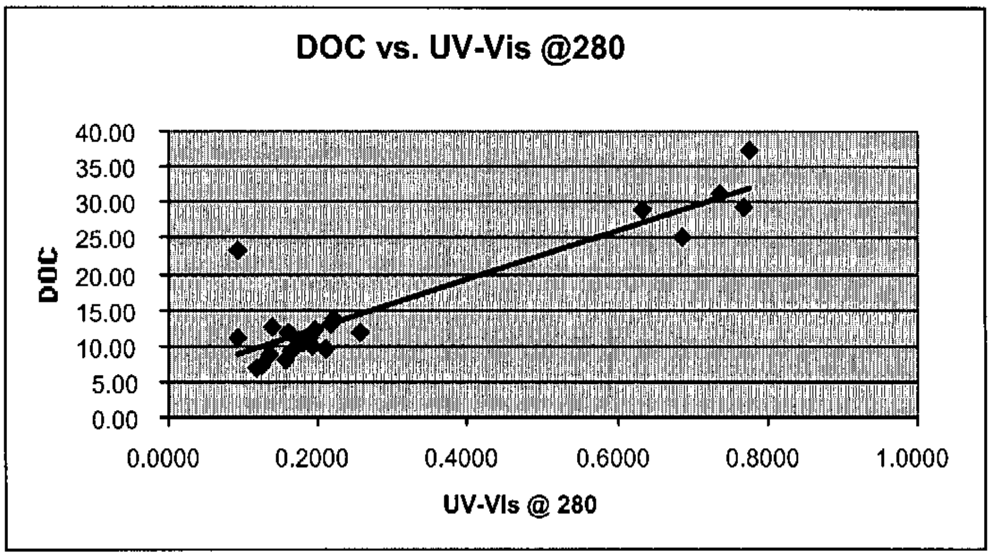

Figure 2 shows the relationship between DOC levels and UV-Vis readings at280nm. There is direct positive correlation between the two (R2=.901).