Analysis of Total Phosphorus in Harvested Aquatic Plants

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Abstract

At Pewaukee Lake, near Milwaukee, Wisconsin, aquatic plant (weed) harvesting has been a consistent component of lake management. The plant material is then applied as a soil amendment. The impact of the harvesting, in terms of phosphorus (P) removal, is investigated in order to facilitate on-going P and plant monitoring. The plant material was collected at various locations and times and analyzed for total P. Phospho-molybdate colorimetric analysis followed P extraction. A comparison of two different extraction methods was made: a) by sulfuric acid/persulfate digestion (wet digestion: Nelson, 1987) and b) by muffle furnace (dry digestion: Plank, 1992). The wet digestion resulted in total P values that were an average of 13% greater than the dry digestion results. With this data and the volume of harvested plant material, the P removal can be calculated as a component for the P budget.

Introduction

Phosphorus is an environmental concern because P often promotes weed and algae growth in bodies of fresh water. The decomposition of the weed and algae material reduces dissolved O_2 levels. This phenomenon can lead to odors, death of fish, and a general degradation of the aesthetic and recreational value of the water. Point and non-point sources of P are of concern for the water quality monitoring, but the P outputs from a body of water are also important for a complete picture of a P budget. The knowledge of P concentrations in plant material is coupled with total volume of plant material that is harvested in order to determine the P output from the lake due to harvesting.

Figure 1. Typical weed harvester as used on Pewaukee Lake. http://aquaticweedharvester.com/photos.htm

Figure 2. Frederick Arthur Bridgman, *The Seaweed Gatherers*, 1912. Not entirely dissimilar to shoreline weed harvesting in Pewaukee Lake (Shong 2010).

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Methods

Sample Collection

Samples were obtained from eight different harvest events on Pewaukee Lake. Six of the samples were from in-lake mechanical harvesters, and two of the samples were from shoreline cleanup [Fig. 1 and 2]. Each sample collected was one cubic foot of plant material from the harvest. The plant material was dried, weighed, and ground to pass a 1-mm sieve for the phosphorus analysis. Each harvest was analyzed in quadruplicate.

Harvest Type and Dates	
1:	Harvester 08/11/09
2:	Harvester 08/18/09
3:	Harvester 08/25/09
4:	Shoreline 09/02/09
5:	Shoreline 10/02/09
6:	Harvester 10/08/09
7:	Harvester 10/20/09
8:	Harvester 10/28/09

Table 1. 2009 harvests.

Plant Material Analysis

Digestion for total P analysis was performed using two methods: wet digestion in an autoclave and dry digestion in a muffle furnace.

Wet Digestion

Approximately 0.15 g of each plant sample were weighed and put in a glass autoclave tube (exact masses were recorded). A half milliliter of 5.5 M of sulfuric acid (H_2SO_4) and 0.2 g of potassium persulfate ($K_2S_2O_8$) were dissolved in 4 ml of deionized water (DI) and added to the sample. Samples were put in an autoclave (Getinge vacuum steam sterilizer model 53325) for an hour at 130° C on the liquid cycle. Sample aliquots in the tube were quantitatively transferred by rinsing with 15 ml of DI to a 50-ml centrifuge tube.

Dry Digestion

Approximately 0.15 g of each plant sample was weighed in a crucible and heated in a muffle furnace chamber (Thermolyne 1400 Furnace Sybron) for an hour at 500-600° C. The sample was transferred to a 100-ml volumetric flask with 25 ml of 1N HCl. The solution was boiled for 15 minutes. The boiled solutions were diluted with DI to 100 ml. Approximately 50 ml of sample were transferred to a 50-ml centrifuge tube. and were filtered with Fischer P5 filter paper.

P Analysis

Phosphorus concentration was measured using the Murphy Riley method (Murphy and Riley, 1965). To do so, 1-ml aliquots of filtered (Fischer P5) extract were transferred to a 50-ml centrifuge tube, mixed with 4 ml of reagent B (Dick and Tabatabai, 1977). DI water was added to bring the volume to 25 ml. Samples were mixed and the color was allowed to develop for 30 minutes. The P concentration was measured at 710 nm on a spectrometer (SmartspectTM 3000). Total P concentration was calculated and is reported as mgP/kg dry plant matter.

Statistical Analysis

Statistical analysis was performed using R (R Development Core Team, 2010). Treatment effects (digestion method and sample number (i.e. harvester type and date)) were evaluated using a two-way analysis of variance. Significant differences among treatment means were evaluated with Tukey's HSD (honestly significant difference at the 0.05 significance level. Both variables were significant, digestion method (P<0.001) and sample number (P<0.001). Figure 3 details the difference between the wet and dry methods of sample analysis, while Table 2 only shows average values.

	Wet Digest.	Dry Digest.
Sample	mgP/kg	mgP/kg
1	3883	3108
2	961	1086
3	1037	1014
4	1242	1401
5	820	672
6	2507	1817
7	2543	1841
8	3012	2463

Table 2. Total Phosphorus in dry matter from each harvest.

Results and Discussion

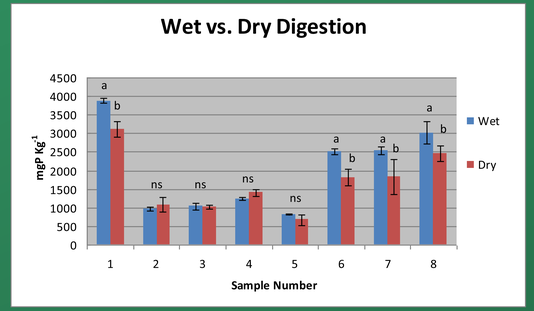

Figure 3. Total phosphorus in the aquatic plants as determined by wet (autoclave) and dry (muffle furnace) digestion. Error bars represent the standard deviations, n=4. For each sample number, values of total P followed by a different letter are significantly different (P<0.05) as determined by analysis of variance followed by Tukey's HSD; ns=not significant.

A 2003 lake management plan report shows an annual loading budget for Pewaukee Lake from 1976-77 measured data (SWRPC, 2003). The total P inputs to the lake are reported as 3,816 pounds. The macrophyte (aquatic plant) harvest is reported as removing 904 pounds of P (410 kg), for perspective, that is 24% of the input. Recent P loading estimates are double the 1976-77 values (Eco-Resource Consulting, 2007), and the 2009 harvest quantities are not as great. Therefore, plant harvesting is removing a smaller percentage than in the 1976-77 years.

An example of how the P data can be used in a rather crude way is shown using the following values for 2009:

Combined cubic yards of plant removed in 2009----------**2190 yd^3**

10 yd^3 truck carries ~ 9000 lbs plant matter wet wt.

~ 600 lbs dry wt. therefore 60 lbs/yd^3----------**27.2 kg/yd^3**

(Eco-Resource Consulting, 2007)

Overall average P in dry matter P found by wet digestion-------**2.00 x 10^3 mgP/kg**

2190 yd^3 x 27.2 kg/yd^3 x 2.00x10^3 mgP/kg x 1 kgP/10^6 mgP = **119 kgP/yr(262 lbsP)**

This value is only an approximation that does not take into consideration the location, date, and type of plant harvested.

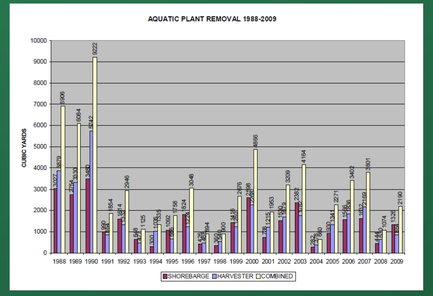

Figure 4. Estimate of Pewaukee Lake aquatic plant matter removal., for use with P concentration data for P outputs (Shong, 2010).

Conclusions

-Dry vs. Wet

Dry digestion did result in an average of 13% lower P concentrations and greater standard deviations in this study. The greatest differences seemed to be relegated to the higher P-content plant harvests. A study comparing dry digestion variables (furnace time, temperature, acid concentration, and boiling time) would likely help determine a better digestion protocol. In these researchers' limited experience and opinion, the wet digestion is easier and has, here, resulted in more reliable data. Therefore it will remain the method of choice for the lab.

-Use of [P] Values

Phosphorus ranges of aquatic plants have been reported to generally range between 1500 and 4000 mgP/kg dry matter (Cooke, 2005). The values calculated in this report are similar to this range (average 2000 mgP/kg), but both high and low extremes are mostly represented. This indicated significant variability in the harvests. The data in this analysis can be helpful for determining P output due to harvesting, however, further analysis of location, date, and type of plant would provide greater information for planning harvests and for calculating the impact on the lake P budget.