

Copper Concentrations at Lake Erie Marinas

Final Report

Lake Erie Protection Fund Project SG 439-12

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Abstract

One of the recent and challenging topics to address in the marina industry is managing the runoff from boat bottom washing vessels with antifouling paint. After the ban of tributyltin in the 1980s, copper became the primary biocide used in antifouling paints. During boat bottom washing, copper oxide can enter the water as a free copper ion and adsorb suspended particulate matter as it settles and accumulates in the sediment. Ohio Sea Grant collaborated with Bowling Green State University and marinas on Lake Erie to establish preliminary data on copper accumulation in sediment over the course of one boating season, and to quantify the amount of copper contributed by boat bottom washing during that season. Sediment samples were taken at 9 marinas along Lake Erie, at three targeted locations at each marina site: the boat haul-out area, permanent dockage, and at the mouth of the marina. There was a significant difference in the concentration of copper between the control marinas and those that have boat bottom washing. Also, there was a significant difference in the copper concentration in the sediment between the boat haul-out area and other sampling locations within the marina. Results demonstrate that there may be a significant source of copper loading occurring at marinas, but that the majority of the copper contamination may only be in the sediment close to the wash area, with minimal loading elsewhere in the marina. Future research should be conducted to identify impacts of copper oxide in the freshwater environment of Lake Erie marinas, and to explore the effectiveness of alternatives to copper-based antifouling paint.

Activities, timeline, and hurdles experienced

July – September 2012: Conducted trial sampling and monitoring.

October – December 2012: Conducted sampling at all marinas following fall boat bottom washing. Due to a late summer, many boaters did not take their boats out of the water until late November. Post sampling was conducted in December of 2012.

January – March 2013: Literature review conducted and fall samples analyzed.

April – June 2013: Conducted spring sampling 6 months after boat bottom washing.

July – September 2013: Processing of spring samples. Due to unanticipated delays in processing the samples, the data for the spring sampling period were not ready by fall of 2013. Samples had to undergo thorough analysis to ensure the best representative samples were used for data analysis. A grant extension request was made to allow for enough time to analyze the data and for review of project outcomes by agency and university project partners.

October – January 2013: Final data analysis performed and final report drafted. Deliverables drafted for display, presentation, and outreach materials. Engaged in outreach opportunities at trade shows, scientific meetings and conferences. Reviewed final report with project partners.

Deliverables

Final project deliverables include a final report, press release (forthcoming) with project overview, a project summary fact sheet, a Clean Boater tip sheet outlining best management practices on sanding and painting for boaters, and outreach materials for display presentation. A recommended best management practice to be included in the Ohio Clean Marinas Program checklist is being delayed until further research is conducted on alternatives to copper-based antifouling paint.

TECHNICAL REPORT

Introduction

Dealing with fouling organisms is a necessity for boaters to ensure vessels stay clean for improved fuel efficiency, to prevent the spread of fouling organisms including invasive species such as the zebra mussel, and to protect the vessel itself. Antifouling paint is effective in preventing the fouling of a boat hull either by sloughing off over time, or by steadily releasing a biocide from the paint surface. Currently, copper-based antifouling paint is the most common hull paint used by recreational boaters (EPA 2011). This type of paint contains copper in the form of either cuprous oxide (Cu_2O_2) or copper thioyanate (CuSCN) and often contains other biocides to aid in the delivery of the copper biocide (Voulvoulis 2002). As vessels are power washed, or boat bottom washes, to remove residual fouling, copper leaches into the wash water and can enter Lake Erie as wastewater runoff. It has been found that copper loading in marina basins generally comes from the passive leaching of coatings on vessels in the basin, and from boat bottom washing (EPA 2011). While one boat may contribute only a small concentration of copper to the water, over time the accumulation of this heavy metal can generate a large concentration of copper in the sediment.

Elsewhere in the United States, agencies have started to regulate boat bottom wash water at marinas. In 1996, the State of California San Diego Regional Water Quality Board added the Shelter Island Yacht Basin to its list of impaired water bodies due to high concentrations of copper. The TMDL found that 98% of the copper in the marina was due to boat hull paint, and by 2006 seven other Sand Diego Bay marina basins became listed as impaired for copper (EPA 2011). In 2009, the New Jersey Department of Environmental Protection implemented a revised permit requiring marina facilities to eliminate the exposure of industrial source materials to the surface water of the state, including boat bottom wash water (Ocean and Coastal Consultants 2009). Marinas must either cease boat bottom washing activity, or incorporate a boat bottom wash wastewater treatment system at their facility (Ocean and Coastal Consultants 2009). In 2011, the state of Washington passed a bill to eliminate the use of copper bottom paint on boats by 2020, after which no antifouling paint with greater than 0.5% copper is to be sold in the state (Washington 2011).

Copper for many organisms is essential for cellular processes, such as the functioning of proteins, and organisms have developed methods for uptake and excretion of copper from the environment. Within cell tolerance limits, copper has no impact and is beneficial to the organism, but when tolerance limits are exceeded copper toxicity can be observed in certain species (Arai et. al. 2009). Provided copper is bound to organic matter, research has shown that it is widely non-bioavailable, or unable to be absorbed into a living organism (Thomas and Brooks 2010). Water quality characteristics such as pH, salinity and dissolved oxygen play a role in whether copper is bioavailable to organisms in an aquatic environment, and therefore impacts of copper are highly dependent on these factors. Free copper ions are the most bioavailable and inorganic copper is bioavailable to some extent. Fish have been shown to be the most tolerant to bioavailable copper, and cyanobacteria the most sensitive to copper exposure. Research has demonstrated that copper also has been shown to accumulate in mussels and other filter feeders, and to impact larval stages of aquatic organisms (Damiens et. al. 2006, Rivera-Duarte et. al. 2005). While this study did not examine the bioavailability of copper at marinas in Lake Erie, it

should be noted that additional research should be conducted to examine this factor on overall impact of copper concentrations in Lake Erie.

In order to better understand the contribution of vessel wash wastewater to copper concentrations in the nearshore sediments of Lake Erie waters, Ohio Sea Grant's Clean Marinas Program conducted a copper concentration study at Ohio Lake Erie marinas. We expected that 1) the presence of boat bottom washing at a marina would increase copper concentrations in the sediment at that location and 2) that the presence of boat bottom washing at the marina would increase the concentration of copper found in the water at that location. We also expected that copper concentration would differ at locations within the marina. Copper concentrations at marinas have been documented elsewhere, but mostly in saltwater environments (Brooks 2009; Schiff 2006; Warnken 2004). The goal of the project was to obtain a clearer picture of the contribution of boat bottom wash wastewater to copper concentrations in the nearshore sediments of Lake Erie waters, a freshwater lake. The study is important to provide stakeholders with localized data that will enable them to make informed decisions when choosing sustainable solutions for boat bottom washing at Lake Erie marinas.

Methods

Assumptions and Limitations

Certain assumptions were made in the development of the study design:

- Antifouling-painted boats are sources of copper to marina waters and sediments.
- Copper can be introduced into the water from antifouling paints via boat bottom washing of antifouling-painted boats and passive leaching of boats over time.

Certain limitations were recognized in the development of the study design:

- There are non-antifouling paint-based sources of copper entering a marina beyond control.
- Copper concentrations at any marina could vary over time due to a number of factors including site-specific hydrology, dredging activity, and fluctuations in total suspended solid levels. The study attempts to address these limitations; however, these factors may still have effects on study results.

Sample Collection

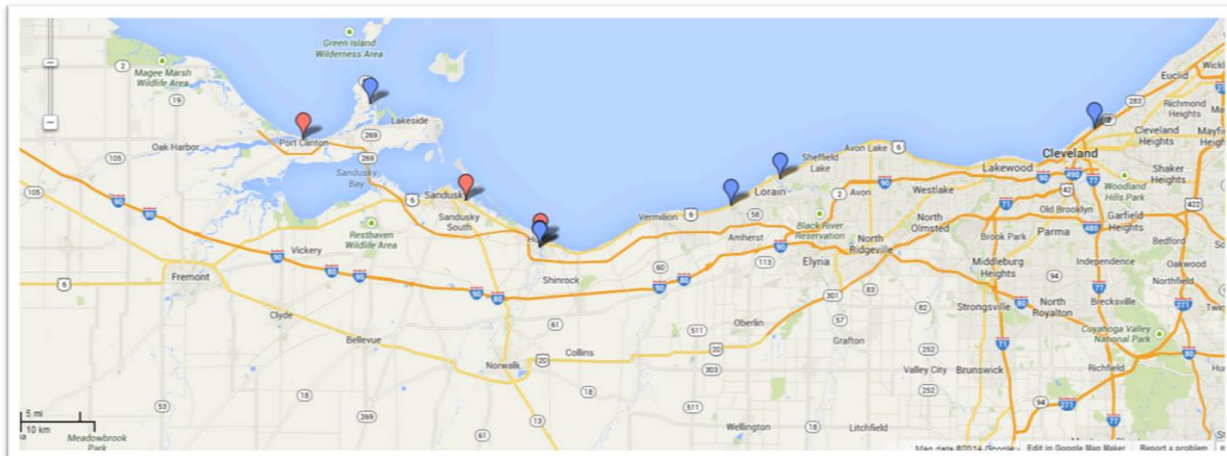
Copper sediment sampling was conducted at nine Lake Erie marinas in December of 2012 and April of 2013. Of the nine marinas, two received sampling in September 2012. The sample sites were selected to represent both small (< 100 slips) and large (> 200 slips) marinas with and without pull-out wash down areas for boat bottom washing vessels. Marinas included three control marinas (Marinas F, G, and H) that did not conduct boat bottom washing on site, and six marinas that did conduct boat bottom washing annually (Marinas A, B, C, D, E, and I). Seven of the nine marinas were located at the mouth of a stream or river (Table 1). Marinas were chosen based on similar characteristics, willingness to participate in the study, and ability to control for sources of copper other than copper-based antifouling paint at their facility. All of the marinas conducted boat bottom washing by hoisting the vessel in a sling over a concrete area, and used a

power washer to wash down the hull of the vessel. No solvents, soaps, or chemicals were used in the process. Of the marinas that conducted boat bottom washing, three marinas had a catch basin for paint chips, and three marinas used a brush in addition to the power washer as an abrasive. None of the marinas participating in the study had received herbicide or pesticide treatments on their property, a potential source of copper loading to the marina basin. Sample locations were mid-size facilities for Ohio marinas with an average of 207 boat slips. The marinas were located from Port Clinton to Cleveland, Ohio (Figure 1).

Table 1. Marina characteristics.

Marina	Number of Slips	Boat Bottom Washing?	Stream or River?	Type of Surface Washed Over	Catchment Area?	Abrasive Used?
A	194	BBW	yes	concrete	no	brush
B	338	BBW	yes	concrete	yes	brush
C	200	BBW	no	concrete	no	no
D	132	BBW	no	concrete	no	no
E	241	BBW	yes	concrete	yes	brush
I	350	BBW	yes	concrete	yes	no
F	70	no	yes	n/a	n/a	n/a
G	180	no	no	n/a	n/a	n/a
H	160	no	yes	n/a	n/a	n/a

Figure 1. Lake Erie marina locations for 2012-2013 copper concentration in sediment sampling. Green pins represent control marinas, red pins represent marinas that conducted boat bottom washing.



The samples were collected at three different times of the year; prior to the fall removal and boat bottom washing of the boats, winter just after the boats were pulled out and washed down, and in spring before the boats were put back into the water. At each marina, the sediment samples were collected at the pullout/washing location, at a boat slip where a boat was docked most of the summer but not associated with the pullout area, and out in the channel/river that connects each of the marinas to Lake Erie.

The sediment samples were collected using an acid washed Petite Ponar following Ohio EPA sediment sampling guidelines (OEPA 2001). The centermost, top 3 cm of sediment from within each grab was collected using a plastic spoon, avoiding detritus (e.g., leaves, sticks, shells), and placed into a labeled plastic ziplock baggie (Figure 2). Duplicate samples were collected from each pull. The samples were put on ice for transport to the laboratory where they were transferred to a refrigerator (4°C) for storage until analysis.



Figure 2. Sediment sampling using a Petite Ponar at Lake Erie marinas.

Surface water samples (50 mL) were collected with a separate Luer-Lok Tip sterile syringe and filtered through a 0.45 μm nylon syringe filter into an acid washed, polypropylene Nalgene bottle (Figure 3). The filtered water samples were acidified (2% vol/vol) with metals grade nitric acid following US EPA method 3015. Water samples were transported on ice and stored at 4°C prior to element analysis.

Figure 3. Surface water sampling at Lake Erie marinas.

Analytical Methods

Sediment samples were dried at 60°C in acid washed crucibles until a constant dry weight was obtained (typically 24 to 48 hours). The samples were then homogenized using an acid washed mortar and pestle. Sediment samples were digested following USEPA Method 3051A (Microwave Assisted Acid Digestion of Sediments, Sludges, Soils and Oils) for spectrochemical determination of acid-leachable elements. This method was selected over total digestion (i.e., USEPA method 3052) because it yields the amount of metal that may become available under



worst case environmental conditions (the bioavailable fraction) rather than the total amount of metal present in the sample (Link et al. 1998).

Dried sediment samples of approximately 0.5 g were weighed using a factory calibrated Denver Instruments (model SI-134) analytical balance (accurate to ± 0.0001 g) and then transferred into Teflon MARS Xpress vessels, to which 9 ml and 3 ml of trace-metals grade concentrated HNO_3 and HCl were then added, respectively. Link et al. (1998) determined that the use of the 9:3 mixed-acid leach enhances the recovery of metals during analysis. The vessels were loosely covered with plastic wrap and allowed to react for 30 minutes or until fizzing ceased before being capped. Following the USEPA method 3051A protocol, samples were microwave digested using a CEM-MARS Xpress system. The protocol for this method defines that the temperature of each sample should reach $175 \pm 5^\circ\text{C}$ in approximately 5.5 ± 0.25 minutes followed by a hold at 175°C for 4.5 minutes, or for the remainder of the 10-minute digestion period. After digestion, samples were allowed to air cool overnight, sample vessels were weighed to insure no loss of material during digestion before they were gravity filtered through qualitative filter paper and diluted to 100 ml with ultrapure (Milli-Q) water in preparation for analysis. The digested samples were then analyzed using a Cetac ASX-520 autosampler and a ThermoElectron iCAP 6500 Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) following EPA method 6010C. Each sample was analyzed in triplicate with a 60 second sample flush time.

The percentage of organic material in the sediment samples was determined using a loss-on-ignition method after Beaudoin (2003). A 1 gram aliquot of the dried (60°C) homogenized sediment was transferred to a clean crucible, weighed and then heated in a muffle furnace at 375°C for 12 hours. The samples were allowed to cool in a desiccator then weighed again to give weight loss during heating. This method is recommended for sediments that are composed mostly of clays and have low organic contents (Beaudoin 2003, Boyle 2004).

Quality Assurance

Precision of the ICP-OES analysis was calculated (minimum detection limits) based on blanks and standards prepared using SPEX CertiPrep AA/ICP-AES Plasma Grade standard solutions. Reliability of the sediment digestion method was evaluated using method (acid) blanks and standard reference material (SRM 2710a Montana I Soil). Reaction vessels were randomized for each microwave digestion run and one out of every sixteen contained a method (acid) blank or reference material to ensure no contamination between sediment samples. Potential instrument drift during analysis was monitored by running a quality control sample after every ten unknown samples. The accuracy of the ICP-OES analysis was checked using SPEX CetriPrep Multi-element solution 2 certified standard which was randomly included in each set of thirty unknowns. The mean minimum detection limits for copper in solution was 1.34 ± 1.20 ppb corresponding to $0.03 \mu\text{g/g}$ dry wt. in the sediment samples, and acid blanks were below the copper detection limits. The SRM 2710a Montana I Soil samples yielded a mean value of $3493 \pm 514 \mu\text{g/g}$ (accepted range is 3100-3500 $\mu\text{g/g}$). Analysis of the multi-element solution 2 certified standard yielded a mean copper concentration of 10.32 ± 0.35 ppm (calibration value 10 ppm).

Statistical Analysis

All data were analyzed using SPSS 22.0 at an alpha level of 0.05 (IBM Corp 2013). The data were tested for normality, and a log transformation was used for the copper concentration in sediment variable and percent of organics variable to account for a positive skew in these variables. A one-way analysis of variance (ANOVA) was employed to test for differences in mean effects of treatments (control vs. power wash, sample location) on copper concentration in the sediment. A Tukey post-hoc test was employed where necessary to clarify which groups differed from one another. In addition to copper concentration in the sediment, copper concentration in the water and percent of organics in sample were analyzed.

Results

Copper Concentrations in Sediment

Amongst the marinas studied, the activity of boat bottom washing had a statistically significant impact on the concentration of copper in sediment at that facility (ANOVA; $F_{1, 207} = 74.589$, $p = 0.000$, Figure 4).

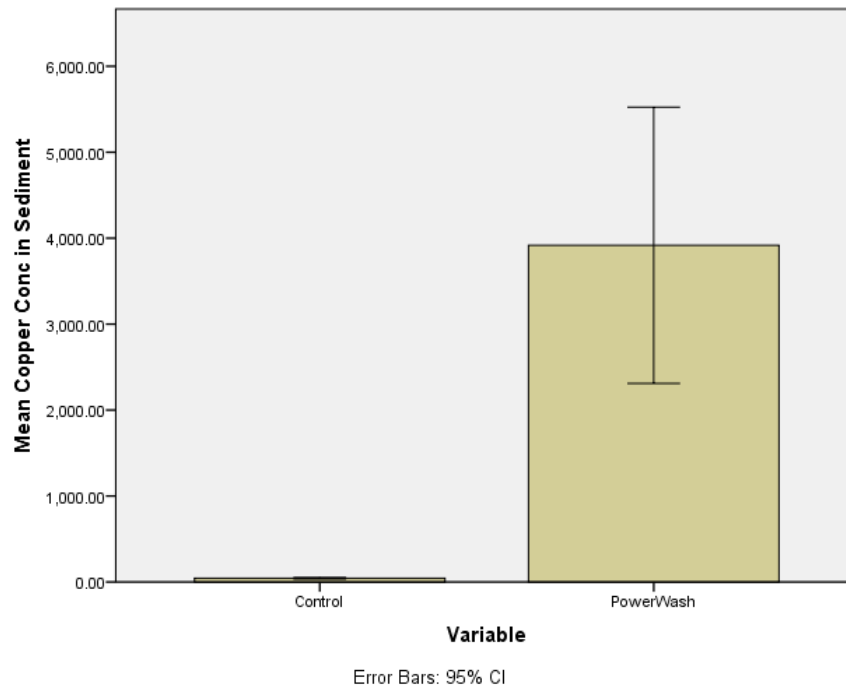


Figure 4. Mean copper concentrations in sediment sampled at control marinas and marinas that perform boat bottom washing (PowerWash).

There was also a statistically significant difference in the copper concentration in the sediment (log transformed) between the boat haul-out area and other sampling locations within the marina (ANOVA; $F_{2, 206} = 96.976$, $p = 0.000$, Figure 5). A Tukey post-hoc test revealed that the copper concentration in the sediment (log transformed) was statistically significantly lower in the dock

($4.411 \pm .980$, $p = 0.000$) and channel ($3.533 \pm .671$, $p = 0.000$) locations than at the boat bottom wash location (7.031 ± 2.072).

The mean copper concentration in sediment at the control marinas was 43.345 parts per million, or ppm. Mean concentration at the boat bottom washing marinas was 3917.23 ppm. The copper concentrations in channel samples are similar for each sampling date and are consistent with the accepted background value for the region (Ohio EPA 2008).

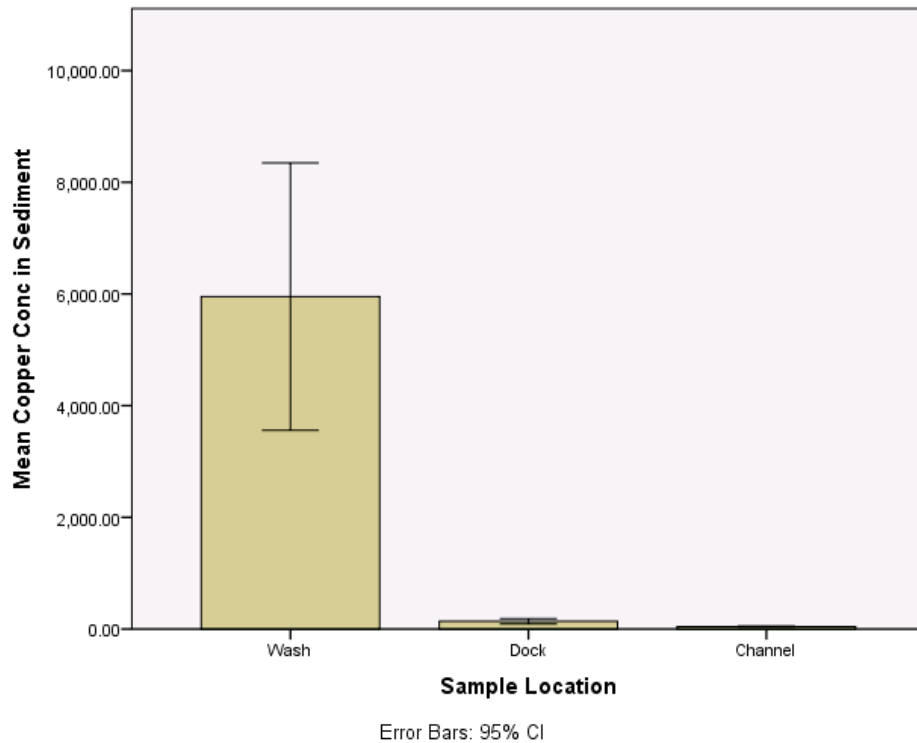


Figure 5. Mean copper concentrations at the boat bottom wash area, dock, and channel at marinas sampled.

Subsample

A subsample was taken at one of the marinas to perform a gradient sampling within the boat bottom washing pullout area. The concentration of copper in the sediment was very high at the inner pullout area, where the washwater and paint debris would first enter the water following boat bottom washing. Copper concentration declined rapidly within 10 meters from the inner pullout area (Table 2). Samples collected in September (before boat bottom washing), December (after boat bottom washing) and April (6 months after boat bottom washing) show copper concentrations increased from September to December but changed little from December to April (Figure 6).

Table 2. Subsample: Copper concentrations (ppm) in samples Collected Fall 2012, Winter 2012, and Spring 2013 at Marina B.

Sample Location	September	December	April
Inner Pullout	1481	8190	10182
Midway Pullout (~6m)	568	1360	971
Channel	48	32	25

Additional Factors

While all boat bottom washing marinas had higher copper concentrations than the control marinas, there was high variability in the extent of copper concentrations between the marinas (Figure 6). These differences may have been influenced by a variety of factors, both man-made and environmental, and warrant further research.

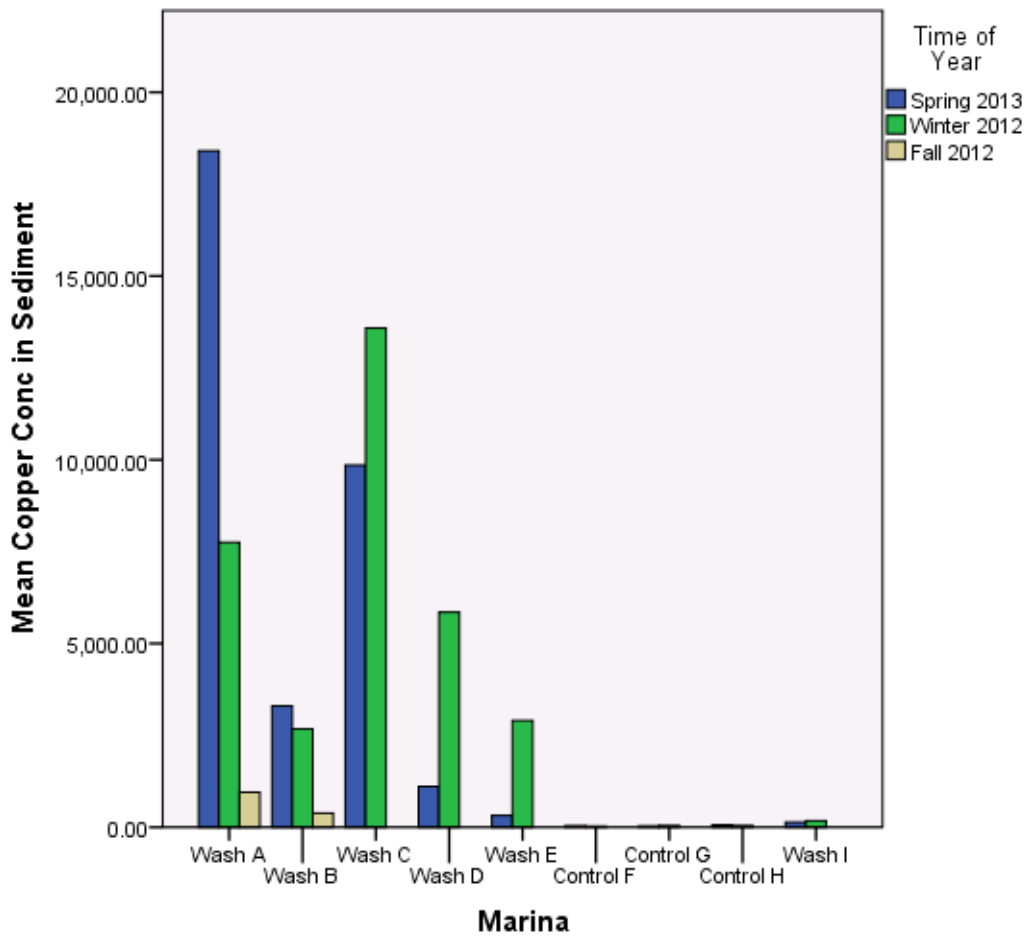


Figure 6. Copper Concentration in sediment by time of year sampled for boat bottom washing marinas (A, B, C, D, E, and I), and control marinas (F, G, and H).

Two variables, catchment and abrasives, were examined to determine influence on the overall concentration of copper in the sediment. Mean copper concentration in the sediment at marinas that captured paint chips and large particle runoff in a catchment basin was 1482.70 ppm, and the mean copper concentration was 7445.55 ppm for those marinas with no catchment basin. Mean copper concentration in the sediment at marinas that used an abrasive (brush) was 4532.38 ppm, and the mean copper concentration was 3088.50 ppm for those marinas with no abrasive used.

Copper concentrations in sediment were compared between marinas with no boat bottom washing activity and those with boat bottom washing activity with/without a catchment basin. There was a statistically significant difference in the copper concentration in the sediment (log transformed) between the groups as determined by one-way ANOVA ($F_{2, 206} = 35.016$, $p = 0.000$, Figure 7). A Tukey post-hoc test revealed that the copper concentration in the sediment (log transformed) was statistically significantly higher in the marinas with boat bottom washing both with (5.544 ± 1.978 , $p = 0.000$) and without (6.805 ± 2.340 , $p = 0.000$) catchment compared to the marinas with no boat bottom washing ($3.576 \pm .678$, $p = 0.000$). There was also statistically significantly higher copper concentrations in the marinas with no catchment that performed boat bottom washing (6.805 ± 2.340 , $p = 0.000$) compared to those that had catchment basins (5.544 ± 1.978 , $p = 0.000$).

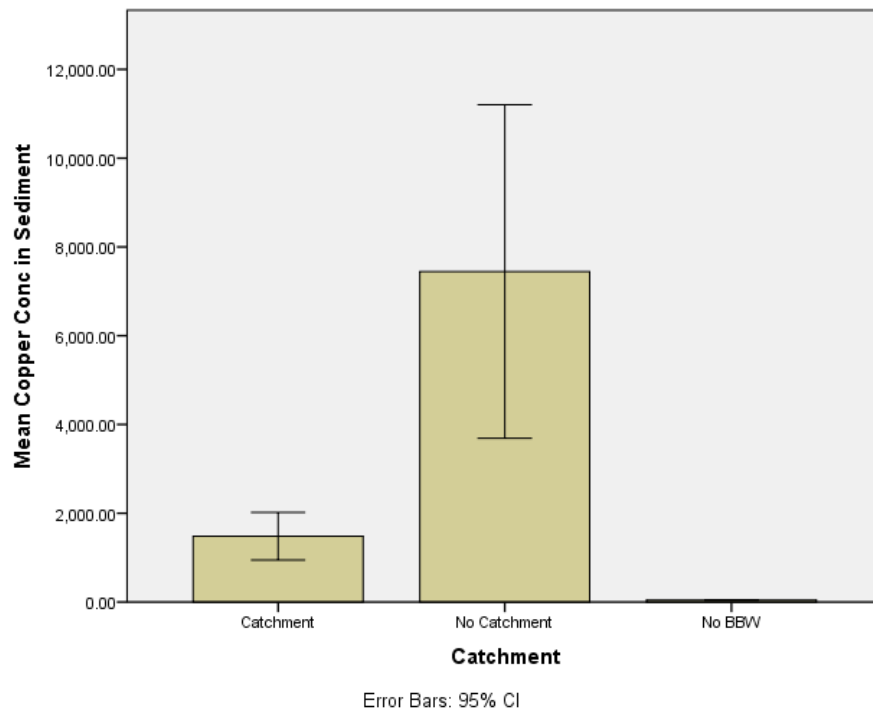


Figure 7. Mean copper concentration in the sediment between marinas that conduct boat bottom washing with a catchment basin, with no catchment basin, and marinas with no boat bottom washing activity.

Analysis was also conducted to compare the copper concentrations in sediment between marinas with no boat bottom washing activity and those conducting boat bottom washing activity

with/without an abrasive, such as a brush. There was a statistically significant difference in the copper concentration in the sediment (log transformed) between the groups as determined by one-way ANOVA ($F_{2, 206} = 26.174$, $p = 0.000$, Figure 8). A Tukey post-hoc test revealed that the copper concentration in the sediment (log transformed) was statistically significantly higher in the marinas with boat bottom washing both with (6.286 ± 2.390 , $p = 0.000$) and without (5.753 ± 1.930 , $p = 0.000$) an abrasive compared to the marinas with no boat bottom washing ($3.576 \pm .678$, $p = 0.000$). There were no statistically significant differences in copper concentration in the sediment between the abrasive and non-abrasive marina groups ($p = 0.205$).

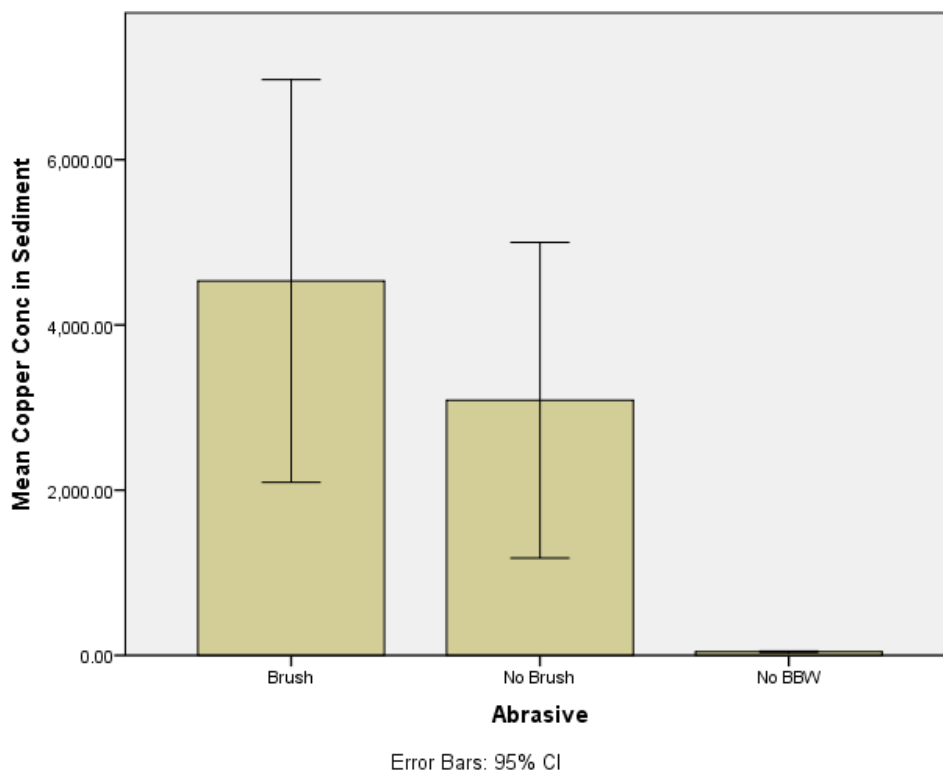


Figure 8. Mean copper concentrations in sediment at marinas that conduct boat bottom washing using an abrasive (brush), marinas that do not use an abrasive during washing, and marinas with no boat bottom washing activity.

Copper Concentrations in Water

At the time of sampling, the activity of boat bottom washing had a statistically significant impact on the concentration of copper in the water at that facility (ANOVA; $F_{1, 112} = 25.510$, $p = 0.000$, Figure 9). The mean concentration of copper in water at control marinas was 1.995 ppm, and 3.392 ppm at marinas that perform boat bottom washing.

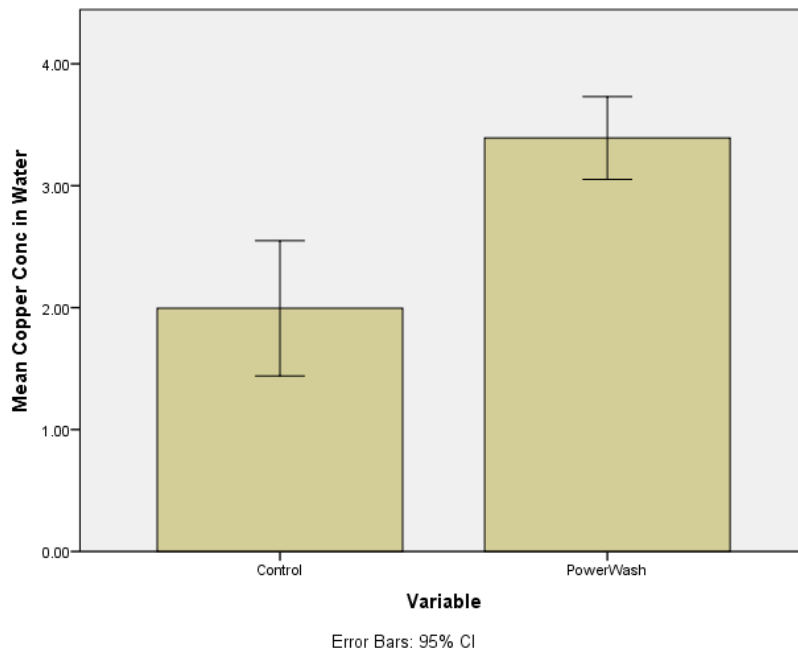


Figure 9. Mean copper concentrations in water sampled at control marinas and marinas that perform boat bottom washing (PowerWash).

Percent Organics

Amongst the marinas studied, the activity of boat bottom washing had no statistically significant impact on the percent of organics (log transformed) at that facility (ANOVA; $F_{1, 141} = 2.144$, $p = 0.145$, Figure 10). The mean percent of organics at control marinas was 6.416%, and 7.417% at marinas that performed boat bottom washing.

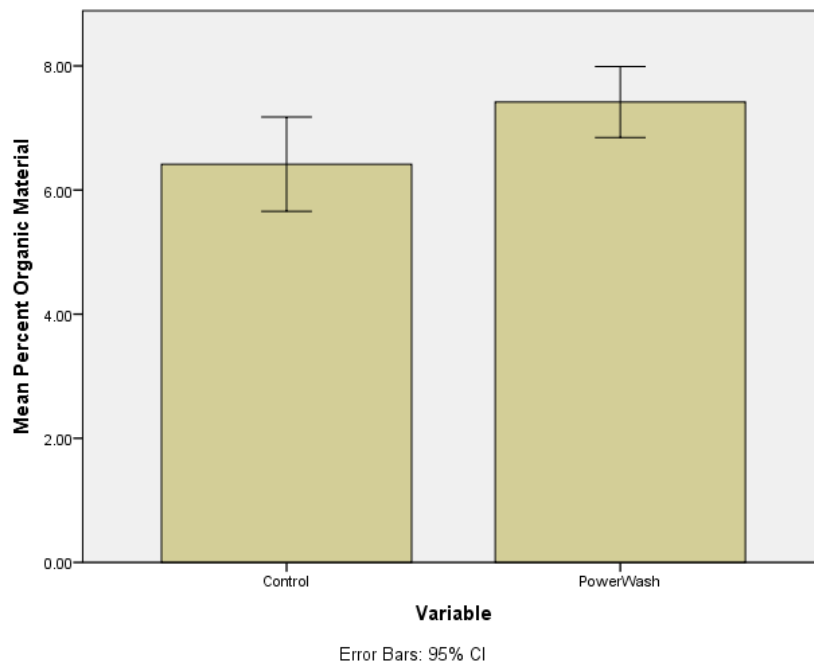


Figure 10. Mean percent of organics sampled at control marinas and marinas that perform boat bottom washing (PowerWash).

Discussion

Results demonstrate that there is a statistically significant difference in copper concentrations at boat bottom washing marinas versus marinas that do not conduct boat bottom washing, but that containment such as a catchment basin does impact the copper concentration in the sediment at marinas that perform boat bottom washing. Samples from within the pullout bay show copper concentrations that greatly exceed the USEPA Probable Effect Level (PEL) or the concentration above which adverse health effects to organisms are probable for freshwater sediments of 197 $\mu\text{g}/\text{g}$ dry wt., but the values drop significantly within <10 meters from the point source. Historical studies of copper concentrations in bed loads of Lake Erie detected concentrations of up to 3.2 times the PEL at the time (USGS 1997). The mean copper concentration in sediment at boat bottom washing marinas in this study was 25 times the current PEL. There was a statistically significant difference in the concentration of copper in the water between control and boat bottom washing marinas, but mean copper concentration in the water was much lower than the mean concentration of copper in the sediment. No statistically significant difference in percent organics was observed between the groups. It should be noted that copper concentrations in the water were sampled at the time of sediment sampling, and not immediately following boat bottom washing. Based on the results of the study, the majority of the copper contamination may only be in the sediment close to the wash area, with minimal loading elsewhere in the marina. This may allow for a variety of options that can minimize either the copper runoff or the amount of contaminated sediment at these targeted locations.

It is important to note that copper is a known contaminant in stormwater runoff (USGS 1997). In addition to copper-based antifouling paint, there are other potential sources of copper at a marina and outside of the marina's control. These include uses in the electrical industry, in alloys for cooking utensils, in water pipes, insecticides, fungicides and algal control (USGS 1997).

Toxicity is primarily related to the amount of metal bound to a biochemical receptor on an organism (e.g., gill membrane on a fish). Many water quality characteristics, including pH, alkalinity, dissolved organic carbon (DOC), and hardness, can affect the bioavailability, and thus the toxicity, of a metal like copper. Therefore it is imperative that not only research is conducted on the amount of copper in Lake Erie marinas, but on the bioavailability of this copper – to determine the true environmental impact, or lack thereof, of copper-based antifouling paint in Lake Erie.

While copper is in high concentrations in some marinas along Lake Erie, there are several alternatives emerging with the goal of mitigating the issue. Elsewhere in the United States, communities have taken different approaches for reducing vessel wash water pollution. East coast states have required treatment of vessel wash wastewater prior to discharging into a body of water. Treatment options range from temporary, portable wash pads to full treatment systems that separate sludge and recycle the boat bottom wash water (Ocean and Coastal Consultants 2009). States along the west coast have banned copper-based antifouling paint altogether, switching to less toxic antifouling paint. Options for this alternative include non-biocide, zinc-oxide only, organic-biocide, and zinc-biocide coatings (Johnson 2011). Prior to the adoption of any alternatives to copper-based antifouling paint, cost, effectiveness and potential environmental impacts of these alternatives in Lake Erie should be considered.

Future Research

Further research is required to better understand the impact of copper oxide on Great Lakes ecology, and to study comparative communities for additional data on concentrations of copper in sediment and in the water at marinas. It is recommended that an expanded study be conducted in similar marina sites throughout the Great Lakes in order to identify other potential sources of copper runoff besides marinas, and to obtain a more targeted analysis of the contribution marinas have to copper contamination in nearshore sediments. Additional research in this area should employ rigorous sampling and control for as many variables as possible, such as number of boats washed at the marina, type of paint used by boaters, and whether the marina is downstream of significant sources of copper loading. Future research should be conducted to identify impacts of copper oxide in the freshwater environment of Lake Erie marinas, as concentration of copper in the sediment is not a direct measure of the toxicity of that heavy metal to the environment. Studies employing the biotic ligand model would incorporate copper concentration and numerous water quality characteristics to allow for a site-specific reading on the bioavailability of copper at each sampling location (USEPA 1999). Also, research must be completed to assess the effectiveness of alternatives to copper-based antifouling paint, including non-copper based paints and wash water treatment technologies.

Outreach Efforts

Results of this research were presented at the 2013 Nonpoint Source Monitoring Conference and at the 2014 International Marina and Boatyard Conference. A summary of the results will be posted to the Ohio Clean Marinas website (ohiocleanmarina.osu.edu), and will be made available to participating marinas and to the general public through distribution at the annual Cleveland Boat and Fishing Show. The Ohio Clean Marinas Program Clean Boater Tip Sheet, "Sanding and Painting," provides Best Management Practices for boaters to reduce copper runoff in their sanding and painting activities. Tip sheets will also be made available at Ohio Clean Marinas outreach events, and at least one post will be made on the Ohio Clean Marinas and Ohio Clean Boaters Program Facebook page with a link to the project summary and promotion of the sanding and painting BMPs. Results have also been shared with all project partners. During all of the presentations given by the Ohio Clean Marinas Program, recognition will be given to the Lake Erie Protection Fund and the Lake Erie Commission for the grant money they provided to make this project possible.

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