Smart Sponge® Demonstration Project And Monitoring Report

Skagit County Marine Resources Committee
Final Report – October 2010

Project Subcommittee

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Skagit MRC

NORTHWEST STRAITS
marine conservation initiative

County: Skagit
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PROJECT TITLE: **Smart Sponge® Demonstration Project and Monitoring Report**

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The views expressed herein are those of the author(s) and do not necessarily reflect the views of NOAA or any of its sub-agencies.

Acknowledgments

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Project Management: Tracy Alker, Skagit County Public Works.

Contract Coordinators: Sasha Horst and Connie Price, Northwest Straits Commission.

Project Contractor: AbTech Industries, Scottsdale, Arizona.

Storm Drain Measurements: Kelly Jaske, Hydrophix Inc., Portland, Oregon.

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Partner Organizations: City of Anacortes, Skagit County Public Works and the Swinomish Tribal Community.

Smart Sponge® Demonstration Project and Monitoring Report

INTRODUCTION

Skagit County Marine Resources Committee (Skagit MRC) initiated a demonstration project to assess the operation of storm drain filters designed to remove oil, grease, bacteria, sediment and debris from several selected storm drains using a newly developed commercial Smart Sponge® filtering system. Skagit MRC collaborated with the City of Anacortes, Skagit County Public Works and the Swinomish Tribe to install and monitor the filters.

This report updates and replaces the initial final report submitted in June 2009 (Dinnel et al. 2009). The initial report covered the details of project initiation and filter installation, but little of the monitoring had yet been accomplished. This report incorporates the results of monitoring in 2009 and 2010 and additionally includes a student report on monitoring the effectiveness of Smart Sponge® filters in reducing the toxicity of storm water as measured by bioassays.

Seven Smart Sponge® filter units were supplied by the selected contractor, AbTech Industries of Scottsdale, Arizona. AbTech's Smart Sponge® technology's unique molecular structure is based on innovative polymer technologies that are chemically selective to hydrocarbons and can destroy bacteria (using Smart Sponge® Plus). Smart Sponge® fully encapsulates recovered oil, resulting in an effective response that prevents absorbed oil from leaching. It is also capable of removing low levels of oil from water, thereby successfully removing sheen. Once oil is absorbed, the Smart Sponge® transforms the pollutants into a stable solid for easy recycling, providing a closed-loop solution to water pollution (AbTech 2004, 2007; Galicki 2006; Mailloux 2008; Nolan et al. 2004).

According to AbTech Industries (http://www.abtechindustries.com/), Smart Sponge® technology provides a cost-effective best management practice (BMP) with low installation and maintenance labor costs. In comparison to other products, the Smart Sponge® technology also allows for less expensive and less problematic handling and disposal of the waste product since its technology transforms liquid oil and other pollutants into a stable solid. The Smart Sponge® was designed not to deteriorate in water, allowing for a longer product life.

AbTech Industries has also developed an antimicrobial technology synergistic with the Smart Sponge® technology. This effort produced Smart Sponge® Plus, which features an antimicrobial agent chemically and permanently bound in a proprietary process to the Smart Sponge® polymer surface. Due to this permanent bond, the antimicrobial agent is active but does not leach or leak, avoiding any downstream toxicity issues. AbTech's antimicrobial Smart Sponge® targets bacteria such as enterococcus, *Escherichia coli* and fecal coliforms.

Several studies conducted on the East Coast of the U.S. have shown that Smart Sponge® filter units have successfully removed about 70% of the oil and grease and from 50 to 99% of various classes of bacteria (AbTech 2007, Nolan et al. 2004). In Norwalk, CT, 275 storm drains with Smart Sponge® filters removed 38,000 pounds of trash and 1,200 gallons of oil and grease, equivalent to about 4.4 gallons of oil per filter unit over a two-year period (AbTech 2007).

METHODS

Purchase and Installation of the Filter Units

Possible locations for the Smart Sponge® units were explored by Anacortes and Skagit County Public Works departments in consultation with Skagit MRC. In selecting potential sites, we looked for a combination of runoff characteristics (e.g., parking lot size, traffic intensity, public property) and locations that afforded opportunities for the best public education. Four sites were finally selected in Anacortes (Fig. 1), two sites in Mount Vernon (Fig. 2) and one site on the Swinomish Tribe's Reservation near their administrative offices (across the channel from the city of La Conner).

The storm drain vaults in each of these locations were measured (Fig. 3) and the measurements supplied to companies that had an interest in submitting bids for supplying the units. Following a formal bidding process by Skagit County Public Works, AbTech Industries of Scottsdale, Arizona was selected as the winning bidder based on lowest price. AbTech Industries then supplied the seven requested Smart Sponge® units together with educational and demonstration materials (see back cover for a CD containing promotional videos and technical reports).

The four Anacortes Smart Sponge® units were installed on 29 April 2009 at the following locations (Fig. 1): 1) the Anacortes Depot, site of the Saturday Farmers Market, 2) the Anacortes Cinema parking lot, 3) Commercial Avenue at 9th Street, and 4) the Anacortes Senior Center parking lot. The Depot site receives drainage from about 25 parking slots (heavily used on weekends, less so during the week) plus street drainage. The Anacortes Cinema location receives drainage from 54 parking slots and is heavily used every day. The 9th & Commercial location receives drainage from Commercial Avenue (the main commercial traffic artery) plus about a half dozen well used parking slots. The Senior Center drain receives drainage from 54 parking slots and is moderately used most days. The two Smart Sponge® units in Mount Vernon were installed on 13 May 2009 in a new Skagit County Public Works parking lot (Fig. 2) containing approximately 160 parking spaces. The unit on the Swinomish Tribal Reservation was installed 18 August 2009 at the intersection of two roadways about a block from Tribal headquarters offices and two blocks from the Swinomish Channel.

During installation, each unit was assembled, collars trimmed to fit each drain vault and lowered into place. The individual pieces consisted of the main filter box containing the Smart Sponge® media, a pre-filter removable screen ("maintenance saver") to capture debris and sediment, four mounting straps and a mounting collar that supports the unit in the storm drain (Figs. 4 and 5). Once installed, a press release (Appendix 1) was prepared and issued to the local media. Three weeks following installation, an educational session was held at the Anacortes Depot site for local media and other interested parties, which included staff from the Northwest Straits Commission, the City of Anacortes and the Skagit Conservation Education Alliance. An educational stencil (Fig. 7) was applied next to each storm drain during or following the educational session. A newspaper article explaining the Smart Sponge® project appeared in the Anacortes American (Appendix 2) the following week.

Monitoring

The monitoring tasks for the Smart Sponge® Demonstration Project were:

1. Conduct monthly checks of all seven storm drains fitted with the Smart Sponge® filters to assure that the units were not blocked. At these times, the drains were cleaned of accumulated debris and sediments as needed. The weights of debris and sediments were measured for each storm drain during each check.

2. Photographically recorded the sediment/debris load in selected filters at the monthly sampling periods.

3. Worked with the City of Anacortes, Skagit County Public Works and the Swinomish Tribe to identify maintenance and cost issues, which will help to assess the future value of installing additional Smart Sponge® units in strategic locations around the County.

In addition, the five filters installed in Anacortes and on the Tribal Reservation were collected and thoroughly washed midway through the monitoring period to measure how effective this cleaning procedure would be in restoring storm water flows through the filters. The collected filters were weighed before and after cleaning. Water flow rates through the five filters were also measured prior to washing with a jet of water from a garden hose, after washing, and then again for two months following reinstallation in the storm drains. Water flow through the filters was measured by rapidly pouring 15 liters of water into the filters and timing how long it took for the water to drain.

Toxicity Reduction Research

Previous projects have measured the ability of Smart Sponge® filters to remove sediment and debris, chemical contaminants and bacteria from storm water (e.g., AbTech Industries 2004, 2007; Galicki 2006; Mailloux 2008; Nolan et al. 2004). However, no previous studies have investigated the reduction in toxicity of storm water to sensitive stages of aquatic organisms. As part of this study, an undergraduate student at Western Washington University's Shannon Point Marine Center, located in Anacortes, collected samples of storm water from downtown parking lot storm drain sumps and tested the toxicity before and after filtration through Smart Sponge Smart Paks® in the laboratory. One experiment tested storm water as collected from a storm drain sump while a second tested storm water with extra added toxicants (copper, cadmium, lead and used motor oil).

Toxicity was measured by bioassays using the most sensitive life stages of two local marine animals. A bioassay is the use of a sensitive animal to measure the toxicity of our surroundings (e.g., canary in the coal mine). The two bioassay tests used for storm water testing were 1) a larval Pacific herring (*Clupea pallasi*) 7-day survival and growth test and 2) a green sea urchin (*Stronglylocentrotus droebachiensis*) 4-day embryo development test. A research paper (Padilla Rivera 2010) describing the methods used and results of the toxicity testing is included as Appendix 3 to this report.

RESULTS

Storm Drain Filter Monitoring

Filter Screen Monitoring

The weights of sediment and debris collected in the "maintenance saver" pre-filter screens (Fig. 4) were monitored at monthly intervals at all seven locations. The filter screen contents included sediments, trash of various sorts and leaves. Weights of the filter screen contents monitored over a 9 to 13 month period ranged from a low of 0 Kg to a high of 4.65 Kg with an average screen loading of 1.12 Kg (Fig. 9). The average screen loading (in Kg) by location was:

Senior Center	1.22
Cinema	0.87
Depot	1.94
9^{th} & Commercial	0.72
Swinomish Reservation	1.75
Mount Vernon Public Works #1	0.19
Mount Vernon Public Works #2	1.65

Filter Loading and Cleaning

Although the pre-filter screens trapped some sediments and most debris, finer sediments and sediments/debris that overflowed a full screen were still able to find their way into the Smart Sponge® filter matrix. Because of this, the water flow rates through the units gradually decreased from an estimated 1,000 liters/min for our filter model (DI1420) (http://www.abtechindustries.com/products/ultra-urban-filter.aspx) to a range of 0.3 to 6.6 liters/min after six months of service. The flow rates (liters/min) after six months for each of the Anacortes and Swinomish Reservation units were:

Senior Center	0.3
Cinema	0.5
Depot	0.5
9th & Commercial	6.6
Swinomish Reservation	4.6

Indeed, flow rates through the filters were so slow after six months that a number of the units showed clear signs of overflowing. In November 2009, the five Anacortes/Reservation filter units were removed and cleaned for several minutes each with a jet of water from a garden hose. Filter weights and water flow rates through each filter were measured before and following cleaning. For two of the filters, there was no apparent weight decrease, while the weights of the other three filters decreased by 0.7 to 2.5 Kg (Fig. 10). After washing, the flow rates through the filters increased from an average of 2.5 liters/min (as measured the previous month) to an average of 55 liters/min (range = 35 to 75 liters/min – Fig. 11).

After washing, the five filter units were immediately reinstalled and the flow rates monitored over the next two months. In three of the cases, flow rates decreased to <5 liters/min by the end of the first month with the remaining two filters decreasing to approximately 15 liters/min after two months (Fig. 11).

Education/Outreach

Education and outreach was accomplished by publishing a press release to the local media (Appendix 1), which resulted in a front page article in the 27 May 2009 edition of the Anacortes American newspaper (Appendix 2). In addition, Denny Padilla Rivera, an undergraduate student at Shannon Point Marine Center, presented the results of his Smart Sponge® toxicity reduction research via a platform presentation at the Pacific Estuarine Research Society's Annual Meeting held in Nanaimo, British Columbia in April 2010. In addition, Denny also presented his research via a poster at Western Washington University's Sigma Xi conference in Bellingham in May 2010.

Toxicity Bioassays

The first of three storm water bioassays used sea urchin embryos to test raw storm water collected from the Anacortes Cinema parking lot storm drain sump. Embryos were exposed at various concentrations (diluted with laboratory seawater) of both unfiltered storm water and storm water filtered through a Smart Sponge Smart Pak®. The unfiltered storm water proved toxic to the embryos at concentrations of 22.9% storm water and higher while little toxicity was observed in the Smart Sponge® filtered storm water at the highest concentration tested (66.7%). The 50% Effective Concentrations (EC_{50} – the estimated concentration that adversely affects 50% of the embryos) for the sea urchin normal development endpoint were 26.5% for the unfiltered and >66.7% for the filtered storm water.

For the first larval herring experiment with raw storm water, there was very little toxicity to herring in either the treated or untreated storm water following a 7-day exposure test. Both survival and growth (measured as dry biomass) were high, indicating that larval herring were able to feed and grow in both solutions. In each case, the calculated LC_{50}s were greater than 100% storm water.

Results of the second larval herring test (using storm water collected form The Market parking lot in Anacortes and supplemented with added toxicants) showed that toxicity was only slightly reduced by the Smart Sponge® filtered storm water as compared to the unfiltered water. The LC_{50}s for herring survival were 90% for the unfiltered storm water and 95% for filtered storm water, respectively. This means that a 90% concentration of unfiltered water killed half of the herring. After Smart Sponge® filtration, a slightly higher storm water concentration (95%) was needed to kill 50% of the herring.

Further information on the bioassay testing can be found in Appendix 3.

Volunteer Hours

The project lead was Paul Dinnel, a Skagit MRC member and volunteer. Paul is also a Marine Scientist at Western Washington University's Shannon Point Marine Center. His estimated volunteer time spent on this project was 102 hours, which included 1) filter design and ordering, 2) site selection, 3) storm drain measurements, 4) installation of filters, 5) monthly filter monitoring, 6) filter washing and flow rate monitoring, 7) data entry and analyses and 8) preparation of two project reports. In addition, City of Anacortes personnel donated about four hours assisting with site selection and filter installation, Swinomish Tribal members donated about four hours related to selection of a site on the Reservation and a Shannon Point Marine Center student donated four hours to assist with monitoring. Thus, an estimated total of 114 hours were donated to this project. This does not include the time spent by Tracy Alker (Skagit MRC administrative lead) and Skagit County Public Works staff to install and monitor the two Mount Vernon filter units or the time of Denny Padilla Rivera to conduct the bioassay studies funded by the National Science Foundation.

DISCUSSION

Storm water discharges are rated as the biggest current threat to Puget Sound water quality and continuing healthy shellfish harvests. If we are to restore and conserve water quality, a variety of methods will need to be used. Some methods now being employed throughout the Puget Sound region include 1) programs to reduce use of pesticides, herbicides and chemical fertilizers, 2) programs to control farm animal and pet wastes, 3) more frequent inspections and repairs to septic systems, 4) installation of rain gardens and pervious paving to reduce storm water runoff, 5) use of integrated infiltration and bioswale systems (e.g., Seattle's Street Edge Alternative (SEA) Program -- http://www2.cityofseattle.net/util/tours/seastreet/slide1.htm, http://www.greeninfrastructurewiki.com/page/Seattle+SEA+(Street+Edge+Alternative)+Streets) and 6) filtration devices such as the Smart Sponge® storm drain inserts investigated during this study.

Previous studies of Smart Sponge® filtration devices have documented its apparent effectiveness at removing a variety of contaminants from storm water, including petroleum hydrocarbons, metals, sediments (with adsorbed contaminants) and debris (AbTech 2004, 2007; Galicki 2006; Mailloux 2008; Nolan et al. 2004). This study primarily focused on logistical issues including cost, ease of installation, sediment loading, filter longevity and attendant maintenance issues. Additionally, we investigated the ability of Smart Sponge® to reduce storm water toxicity to two sensitive marine organism life stages (see Appendix 3).

One distinct conclusion of this study was that excessive sediments will quickly clog the filters and render them useless until cleaned. We found that the monthly weights of sediments and debris (most of the weight was due to sediments) in the pre-filter "maintenance saver" screens ranged from a low of <0.2 Kg to a high of 4.6 Kg, with an overall study average of 1.1 Kg/month. For all seven filters over the course of the study (67 samples), a total of 75 Kg of sediment and debris was collected by the screens and prevented from being discharged to marine waters. This, however, is a two-edged sword. On the one hand, removal of sediments (especially) and debris effectively removes contaminants that are known to adsorb to the sediments (Baudo et al. 1990). On the other hand, sediments that are too fine to be captured by the "maintenance saver" screens gradually clog the Smart Sponge® filter matrices and reduce their effectiveness.

Given the above, it is clear that effective sediment management will be a key consideration in placement and maintenance. First, Smart Sponge® filters should not be used in high sediment load areas. Second, most storm drain installations will greatly benefit from a routine street sweeping schedule and third, a routine filter cleaning schedule will need to be established. Depending on sediment loading, filters may need to be cleaned of accumulated sediments as often as weekly during the rainy season to as little, perhaps, as every three to six months. It should also be noted that during periods of snowfall and the subsequent use of copious amounts of road sanding, filter units will be clogged very quickly and could contribute to restricted water flows into storm drains.

Assuming a good maintenance program, the Smart Sponge® filter matrix has been reported to remain effective at removing contaminants for approximately one to two years, depending on location (Smart Sponge can remove up to three times its weight in petroleum compounds) (AbTech Industries, pers. comm. and http://www.abtechindustries.com/products/overview.aspx). During our study, five of the seven filter units were cleaned. This cleaning with a jet spray from a garden hose did remove some of the sediments clogging the filter matrices (average of ~1 Kg/filter), but only restored the flow rates through the filters to about 35 to 75 liters/minute versus the estimated rate of >1,000 liters/minute when new. More frequent cleaning of the filters (i.e., weekly to monthly) may have improved the flow rates.

For any urban area draining to Puget Sound (or streams in the watershed), a variety of storm water reduction/treatment systems will likely need to be employed. Although use of Smart Sponge® filters in individual urban storm drain vaults could be expensive (about $700-$800 per filter unit) in terms of the individual number of units required and their maintenance costs, they may still be valuable in specialized circumstances (e.g., parking lots that have low sediment loading rates). Use of larger vaults (not investigated in this study), *with integrated pre-filter sediment traps*, located below the confluence of a number of storm drain lines could be more effective than individual storm drain units. AbTech Industries does supply both standard and customized vaults for this -- http://www.abtechindustries.com/products/overview.aspx.

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Figure 1. Locations in Anacortes where Smart Sponge® storm drain filters were installed in April 2009.

Figure 2. Locations in Mount Vernon where two Smart Sponge® storm drain filters were installed in May 2009.

Figure 3. Measuring a storm drain for a Smart Sponge® storm drain filter.

Figure 4. Components of a Smart Sponge® storm drain filter unit. Upper left: filter box containing the Smart Sponge® media; lower left: the sediment and debris pre-filter liner ("maintenance saver"); upper right: mounting collar that supports the filter basket and; lower right: mounting straps that connect the basket to the mounting collar.

Figure 5. Assembled Smart Sponge® storm drain filter ready to be lowered into a storm drain.

Figure 6. Smart Sponge® filter unit installed at the Depot in Anacortes, 29 April 2009.

Figure 7. Public information stencil applied to each Smart Sponge® location.

Figure 8. Photographs of the debris collection baskets from each of the Anacortes Smart Sponge® units sampled on 29 May 2009, one month following installation. Upper left: Anacortes Depot, Upper right: Anacortes Cinema parking lot, Lower left: (9th & Commercial Ave., Lower right: Anacortes Senior Center parking lot.

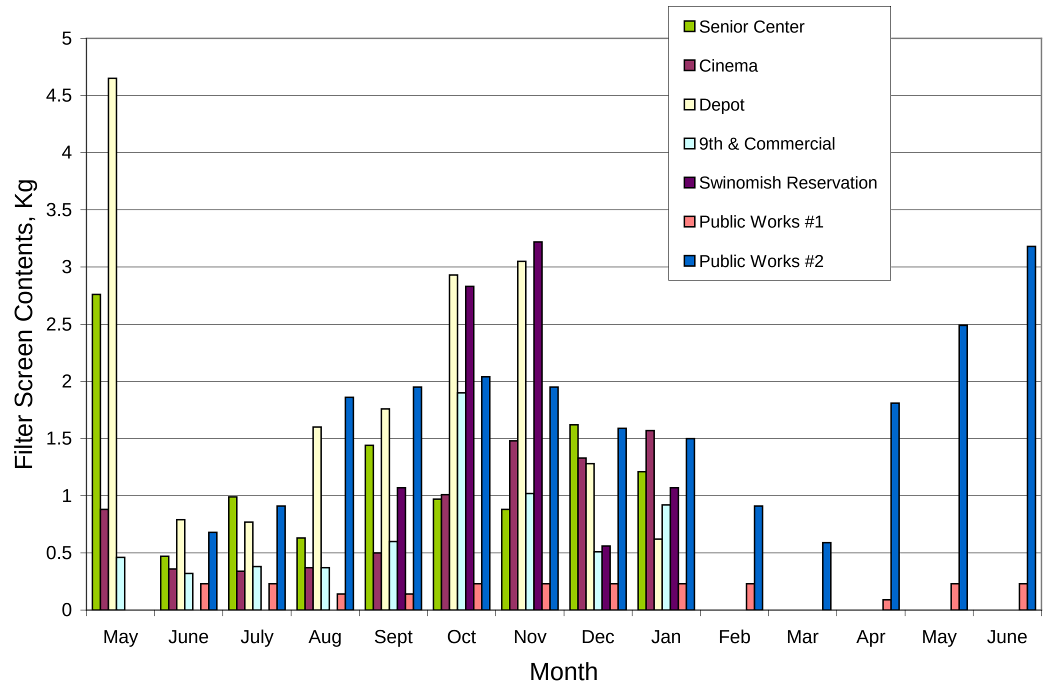

Figure 9. Weights of sediment and debris measured from the seven Smart Sponge® filters screens from May 2009 through June 2010. Only the Mount Vernon filters (Public Works #1 and 2) were measured after January 2010.

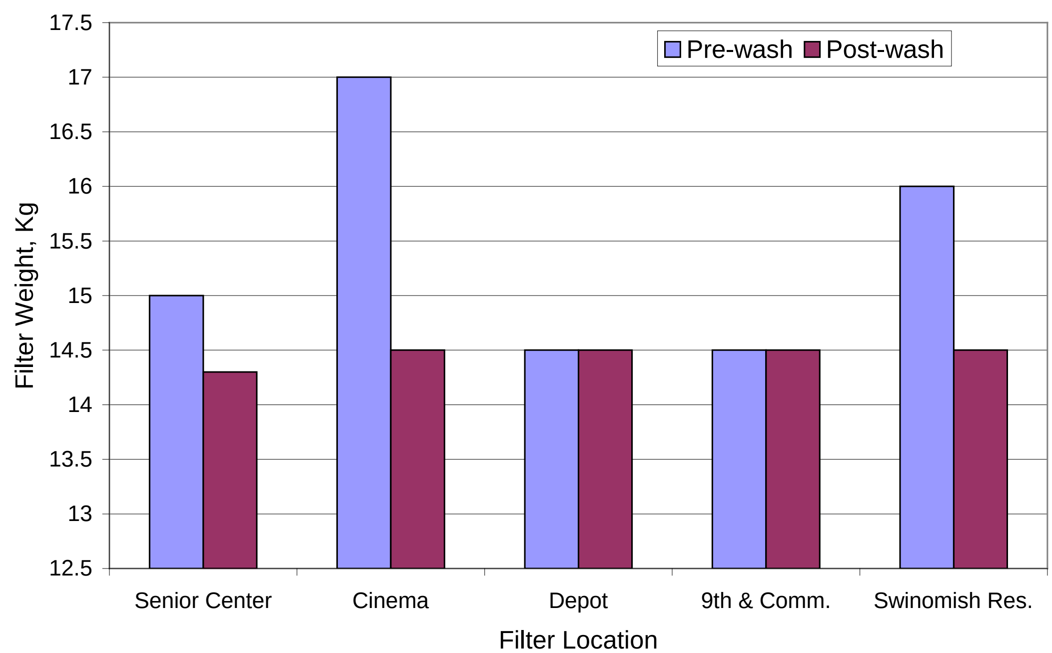

Figure 10. Total weight of the Smart Sponge® filter units (not including screening basket or mounting straps & collar) following collection on 25 November 2009 (pre-wash) and following washing (post-wash) with a jet of water from a garden hose.

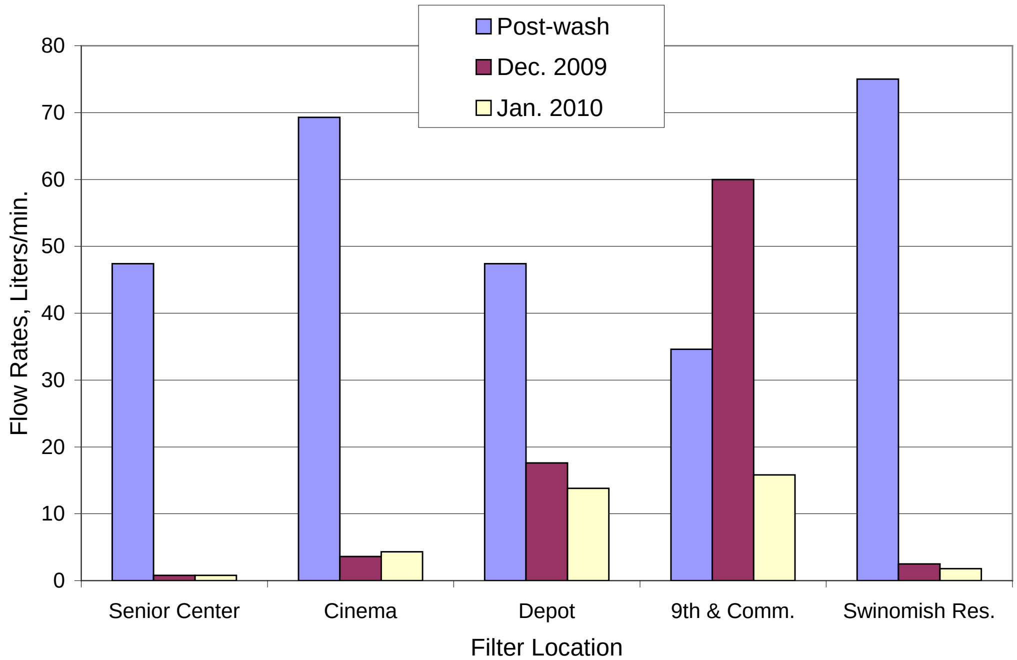

Figure 11. Flow rates of water through Smart Sponge® filters collected from the storm drains on 25 November 2009 after washing (post-wash) and for two months following reinstallation. Prior to washing, the flow rates through the filters had been reduced to only 0.3 to 6.7 liters/min.

Appendix 1 – Press Release

SKAGIT COUNTY MARINE RESOURCES COMMITTEE

Contact: Paul Dinnel
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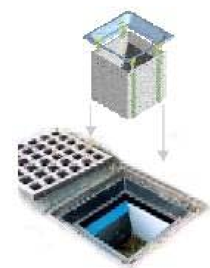
Email: padinnel@aol.com

FOR IMMEDIATE RELEASE

STORM DRAIN SPONGES SOAK UP OIL AND BACTERIA
New Technology Helps Protect Water Quality

Have you ever noticed all of that oil and gas from streets and parking lots heading for the storm drains every time it rains, which is often here in the Northwest? Storm water is one of the biggest sources of contaminants entering our marine waters and shellfish today, but a partial solution may be on the way. The City of Anacortes and Skagit County Public Works are collaborating with the Skagit County Marine Resources Committee (Skagit MRC) to test the feasibility of using sponge inserts installed in storm drains to remove oil and bacteria to keep them out of marine waters and shellfish.



Smart Sponge®, invented and manufactured by AbTech Industries (http://www.abtechindustries.com/), has a unique molecular structure that is based on innovative polymer technologies chemically selective to hydrocarbons. Smart Sponge® fully encapsulates recovered oil and prevents absorbed oil from leaching. Once oil is absorbed, the Smart Sponge® transforms the pollutants into a stable solid for easy recycling, providing a closed-loop solution to water pollution.

AbTech has also developed an antimicrobial technology synergistic with the Smart Sponge® technology. This effort produced Smart Sponge® Plus, which features an antimicrobial agent chemically and permanently bound in a proprietary process to the Smart Sponge® polymer surface which destroys bacteria. Due to this permanent bond, the antimicrobial agent is active but does not leach or leak, avoiding any downstream toxicity issues. AbTech's antimicrobial Smart Sponge® Plus targets bacteria such as enterococcus, *Escherichia coli* and fecal coliforms.

Several studies conducted on the East Coast of the U.S. have shown that Smart Sponge® filter units have successfully removed about 70% of the oil and grease and from 50 to 99% of various classes of bacteria. In Norwalk, CT, 275 storm drains with Smart Sponge® filters removed 38,000 pounds of trash and 1,200 gallons of oil and grease, equivalent to about 4.4 gallons of oil per filter unit, over a two-year period.

A Smart Sponge Plus® unit will be installed in Anacortes at the Depot at 2:00 PM on Wednesday, May 20th and in Mount Vernon at a later date. For further information, please call Paul Dinnel (Anacortes: 360-293-2188 [AM], 299-8468 [PM]).

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Appendix 2 – Anacortes American Newspaper Article 27 May 2009

Anacortes American
Anacortes, Washington 98221 · Volume 120, Number 2 · Wednesday, May 27, 2009 · © 2009 SVP Co. · 75 cents

Sponge keeps oil, bacteria out of bay

BY JOAN PRINGLE
American staff writer

With a shirt decorated with images of fish, Paul Dinnel was appropriately dressed for a demonstration of a Smart Sponge that removes oil and grease from storm water before it can enter marine water and harm marine animals.

The new technology is now part of the city of Anacortes' infrastructure due to funds provided by the Northwest Straits Commission to the Skagit County Marine Resources Committee. In all, seven units were purchased for a total of $5,000, Dinnel said.

Dinnel, an MRC member and Shannon Point Marine Center scientist, demonstrated how a Smart Sponge works May 20 at the Depot Arts Center where one of four units are installed in the city. The MRC partnered with the city of Anacortes to install the Smart Sponges to test the feasibility of using them in this area.

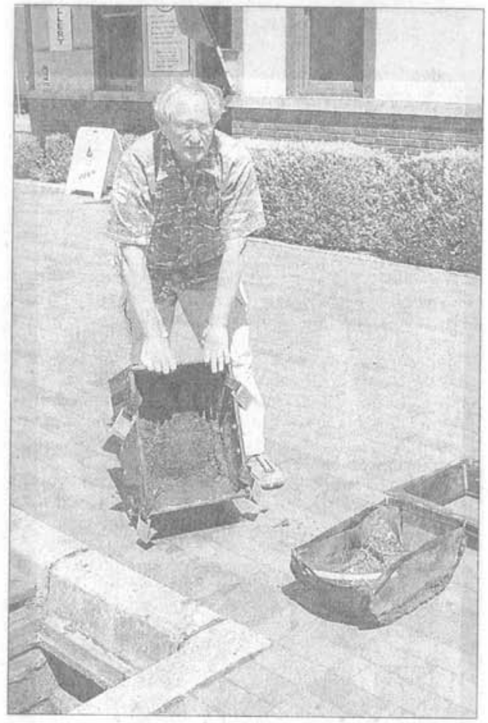
Others are located in drains near the Fidalgo Senior Center on 22nd Street, the Anacortes Community Theater on M Avenue, and at Ninth Street and Commercial Avenue. Each is indicated with a stenciled sign that shows a Smart Sponge is working to remove oil and bacteria.

The MRC is also working with the Skagit County public works department to install more filters in Mount Vernon, near the Swinomish Northern Lights Casino and possibly Bay View.

Each apparatus, purchased from AbTech Industries, has a box frame that fits into the storm drain. A basket insert catches material such as trash, leaves and branches while a filter beneath it absorbs oil and grease, preventing it from leaching.

If the unit becomes full of debris, it is designed to overflow into the drain without clogging it or overflowing onto the street, Dinnel said.

Studies have shown the filter can remove about 70 percent of oil and grease entering



JOAN PRINGLE

Paul Dinnel demonstrates a Smart Sponge developed by AbTech Industries at the Depot Arts Center on May 20. The device helps trap debris, oil and grease entering a storm water drain and prevents it from reaching marine waters.

Sponge

Continued from page A1

it, according to AbTech. The Smart Sponge turns the contaminants into a stable solid for recycling and provides a closed-loop solution to water pollution. The company also produces a Smart Sponge Plus, which includes an agent that destroys bacteria entering a storm drain, such as E. coli and fecal coliforms from pet waste.

Storm water is one of the main sources of contaminants to Puget Sound waters and shellfish, Dinnel said. In the past, the biggest problem was discharge from industry but the U.S. Environmental Protection Agency's Clean Water Act has changed that.

After the Smart Sponges in Anacortes have been in place for a month, Dinnel will clean the units out and weigh the contents to determine how they are working and what the maintenance issues are. Dinnel may also recruit a student to test storm water before and after entering the units in the near future.

The intent is to encourage the city and the county to purchase more of the devices or ones similar and eventually take over the maintenance of them.

The city may eventually be required to use such devices because of EPA's National Pollutant Discharge Elimination System regulations, which work to control water pollution.

Appendix 3

Do Smart Sponge® Filters Reduce Storm Water Toxicity?

A Student Research Paper by

Denny Joel Padilla Rivera

Shannon Point Marine Center

And

University of Puerto Rico, Humacao

Do Smart Sponge® Filters Reduce Storm Water Toxicity?

Denny Joel Padilla Rivera
University of Puerto Rico, Humacao

Advisor: Dr. Paul Dinnel

Summer 2010 REU Program
Shannon Point Marine Center, Western Washington University

Do Smart Sponge® Filters Reduce Storm Water Toxicity?

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Abstract

Toxic storm water is difficult to manage because it is diffused in nature. AbTech Industries has developed a sponge-like filter capable of removing hydrocarbons, metals, bacteria and debris from water. But, we do not know whether the filter reduces toxicity of the storm water. The goal of my research was to test the ability of Smart Sponge® filters to reduce storm water toxicity. I tested the sponge toxicity removal by using two sensitive marine bioassays, testing storm water before and after treatment with Smart Sponge®. The two bioassay organisms were green sea urchin (*Strongylocentrotus droebachiensis*) embryos, and feeding larvae of Pacific herring (*Clupea pallasi*). In each case, the Smart Sponge® filter reduced storm water toxicity, but the two organisms responded differently. Smart Sponge® reduced the storm water toxicity to sea urchin embryos more than to larval herring.

Key words: *Clupea pallasi, Strongylocentrotus droebachiensis,* bioassay, toxicity, storm water, Smart Sponge® filters

Introduction

Storm water is the portion of precipitation and snow melt that does not percolate into soils, but runs off into streams and estuaries. Storm water is a non-point source of contamination, meaning that a specific source cannot be identified. This makes control difficult because it is impossible to treat or regulate the source. Storm water contaminants can include hydrocarbons, bacteria, debris, nutrients and metals.

Different methods of storm water treatment already exist. Examples include organoclays, wetlands, oil-water separators and water treatment plants. There are different kinds of water treatment plants. First phase facilities function as a coarse filter and only remove debris. The second phase facility removes organic material and additional toxicants. A third phase facility, which uses micro-filtration and other advanced cleanup technology, removes bacteria and chemicals. Such advanced treatment methods are very expensive and require a large infrastructure. AbTech Industries has developed a cheap, small and reportedly effective way to treat storm water. They call it Smart Sponge® (Fig 1).

Smart Sponge® filters encapsulate and solidify many storm water contaminants. This technology could provide an easier, safer and cheaper way to manage certain contaminants, because the toxicants do not leach from the sponge. Galicki (2006) found that Smart Sponge® removes approximately 80% of the hydrocarbons in the water tested. The sponge also works as a filter, collecting trash and other debris. Smart Sponge® has been tested in different water flows and found to remove approximately 65-78% of sediments (Sil-Co-Sil 106 silica sand from 0.8-125 microns in diameter) (Mailloux, 2008), with associated contaminants absorbed in the sediments. Some of these contaminants include copper, cadmium, lead, oils and hydrocarbons, metals and bacteria. Nolan *et al.* (2004) found that the sponge removes 50% of bacterial coliforms and other fecal-related bacteria, such as *Escherichia coli*.

Used Smart Sponge® filters cannot be cleaned and must go to landfill or be incineratedh. The filters contain concentrated contaminants and these are harmful for the environment and human health. Some of these contaminants can concentrate in the sediments and animal tissues.

Therefore, sponges used in large quantities that are heavily contaminated might require treatment as chemical or hazardous material.

Landis *et al*. (2004) proposed that sediment toxicity is a stressor with extensive effects. They found that exposure to contaminated sediments for long time periods can suppress the immune system and increase disease in marine organisms. Despite research that shows an ability to remove contaminants from storm water, it is not clear that Smart Sponge® treated storm water is actually less toxic than untreated storm water.

One way of measuring toxicity is through bioassays. Bioassays use the responses of sensitive stages (stages where the organism is more sensitive to changes in the environment) of organisms to determine toxicity. Early life history stages are used because larval or embryonic stages are often more affected by toxic materials. The test results can be used to determine if Smart Sponge® is a viable way to reduce storm water toxicity. I hypothesized that storm water treated with Smart Sponge® will reduced storm water toxicity.

Materials and Methods

For bioassays using larval Pacific herring (*Clupea pallasi*) or embryos of the green sea urchin (*Strongylocentrotus droebachiensis*), storm water was collected from downtown Anacortes, WA. Half of the water was treated with a Smart Sponge® filter pack (8cm by 30cm^2) by pouring the storm water through the sponge. The Smart Sponge® filter was first soaked with reverse osmosis (RO) deionized water three times to remove any residual contaminants associated with its manufacture. The other half of the storm water sample was kept untreated to provide a toxicity baseline. For statistical analysis, I used CETIS software (Comprehensive Environmental Toxicity Information System).

For the sea urchin test, eight liters of storm water were filtered through the Smart Sponge® filter pack. For the sea urchin embryo test we prepared natural sea water brine by freezing filtered sea water. By letting it partially melt, I collected the hypersaline brine, which was 90 ‰ salinity, and this brine was used to adjust the storm water sample salinity to 30 ‰.

I next prepared a series of concentrations of treated and untreated storm water using a 0.7x dilution series (e.g., 66.7, 46.9, 32.7, 22.9, 16 and 11.2% storm water). Two control solutions were additionally made; one of natural filtered sea water and one of brine diluted with RO water to 30 ‰ salinity. Each test or control concentration was replicated three times.

To get embryos for testing, I spawned sea urchins by injecting 1 ml of 0.5 M KCl through its peristomial membrane. Sperm and eggs were mixed and after one hour embryos were counted and assessed for fertilization success. The fertilized embryos were added to the test beakers at a density of 15 eggs/ml. Sea urchin 4-day embryo development tests were conducted in 400 ml of the test solutions in 600 ml beakers using an American Society for Testing and Materials protocol (ASTM 1998). At day 4, 10 ml subsamples of the sea urchin cultures were collected and preserved in a 5 to 10% formalin solution. Later, the pluteus larvae were counted and assessed for normality. Larval normality was determined using ASTM (2000) figures and guidelines.

For larval Pacific herring testing, we used a 7-day survival and growth test protocol developed at Shannon Point Marine Center (SPMC) for the Washington Department of Ecology (Dinnel *et al.* 2008). Washington Department of Fish and Wildlife personnel collected herring eggs from Birch Bay, near Blaine, WA. Herring eggs were held in flowing seawater tanks until hatching. Newly hatched herring larvae were held and fed brine shrimp (*Artemia sp.* nauplii) for

5 to 7 days prior to testing. For herring testing, storm water was collected from the Anacortes Cinema and The Market's parking lot in downtown Anacortes, WA.

For the first herring experiment, herring were tested using unaltered storm water. To ensure a LC_{50} high enough for statistical analysis, a second experiment used storm water with added toxicants. Added toxicants included copper, cadmium, lead and used motor oil. These were added to enhance the toxicity to approximately 1/3 of the LC_{50} concentration for each metal (Dinnel *et al*. 2005). For each experiment, half of the storm water was filtered with Smart Sponge® and half was left unfiltered. Each sample was salinity adjusted to 30 ‰ with Red Sea® (artificial sea salt) and stored in an incubator at 12 ^{O}C. I used a 0.7x dilution factor to make a series of storm water concentrations (e.g., 100, 70, 49, 34.3, 24 and 16.8%) of both the treated and untreated samples. Additionally, I made one filtered seawater control and one Red Salt® control at 30 ‰ salinity. Each test concentration and control was replicated 3 times.

To start the tests, approximately 15-20 herring larvae were put in each 400 ml beaker containing 200 ml of solution and 1 ml of 2,000 *Artemia sp./*ml was added as food. A sample of the herring was taken and preserved to determined initial weight. One day later, all dead or non-feeding herring were removed from the beakers with a glass pipette until 10 healthy feeding herring remained. These herring were then considered the test organisms for the tests. From day 1 to day 7, the fish were fed 1,000 *Artemia sp*./day. Every two days, 150 ml of new test or control solutions was removed from each beaker along with sediments, dead fish and old *Artemia sp*. After removal, 150 ml of new solution and 1,000 *Artemia sp.* were added. At day 7, dead fish were removed and live fish were transferred to a solution of MS 222 (a fish anesthetic) at 200 mg/L concentration. Fish in MS 222 were counted and then transferred to a dark vial of MS 222 to which formalin was added. To obtain herring weights, aluminum weigh boats were put in an oven at 70 ^{O}C for one day then weighed to obtain their tare weights. After fish had been in formalin for three days, I put them in the tared aluminum boats. The boats were put in the oven at 70 ^{O}C for 3-4 days, then I determined dry weights for each batch of fish.

Results

All bioassays were validated as good tests based on acceptable control performances. Sea urchin embryos had greater than 70% normal embryos in the controls as specified by the ASTM (2000) protocol. The herring controls had a mean survival of more than 80% as specified by the Dinnel *et al.* (2008) protocol. In the sea urchin test, the Smart Sponge® filter reduced storm water toxicity. Sea urchin normal development was significantly higher in treated than untreated storm water samples (Fig. 2). The 50% Effective Concentrations (EC_{50}) for the normal development endpoint were 26.5% for the untreated and > 66.7% for the treated storm water.

For the first herring experiment with unaltered storm water, there was very little toxicity to herring in either the treated or untreated storm water. Survival (Fig. 3) and dry biomass (Fig. 4) were high. In each case, the calculated 50% Lethal Concentrations (LC_{50}) were greater than 100%. That means that more than 100% of storm water was needed to kill 50% of the herring. Results of the second herring test (using storm water with added toxicants) showed that toxicity was only slightly reduced by the Smart Sponge® treated storm water as compared to the untreated water (Figs. 5 and 6). The LC_{50}'s for herring survival were 90% for the untreated storm water and 95% for treated storm water, respectively. This means that a 90% concentration of untreated water killed half of the herring. After Smart Sponge® treatment, a higher storm water concentration (95%) was needed to kill 50% of the herring.

Discussion

Pacific herring eggs and larvae are found in near shore environments attached to eelgrass or kelp and are vulnerable to hydrocarbons and other toxicants (Smith and Cameron 1979). Likewise, sea urchin gametes are shed into seawater in near shore areas and the embryos develop in the water column for a week or more. The sensitive early life stages of both of these species are thus vulnerable to storm water discharged along shorelines.

Survival is not always the most sensitive endpoint as Weis and Weis (1989) reported. For some contaminants embryo stages are most sensitive, but for other contaminants larval stages are more sensitive (Weis and Weis 1987). For this reason, we used both the acute endpoint of survival as well as the sublethal endpoints of sea urchin embryo normal development and herring growth measured as dry weight or biomass.

My testing showed that the early life stages of sea urchins and Pacific herring can be adversely affected by storm water, but sea urchin embryos were more sensitive than herring larvae. My research further showed that Smart Sponge® filters can reduce storm water toxicity, especially to sea urchin embryos. Besides toxicity and contaminant removal, routine use of Smart Sponge® must also be evaluated from a cost (as compared to other treatment alternatives) and maintenance perspective. The useful lifespan of a single deployed sponge will depend on the load of toxicants, sediments, hydrocarbons and debris that passes through it. The lifespan may vary from one to several years.

Conclusion

Smart Sponge® appears to be an effective storm water treatment product. It has been reported to remove sediments, bacteria, hydrocarbons, metals and debris. Prior to this study, toxicity removal had never been tested. Smart Sponge® reduced toxicity to two sensitive life stages of marine organisms, although the degree of toxicity reduction was species dependent. Further studies might evaluate the toxicity of both treated and untreated storm water to other sensitive stages of marine (and freshwater) organisms.

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Figure Captions

Figure 1: New Smart Sponge® Block (7 cm by 30 cm^2).

Figure 2: Average percent normal development of sea urchin pluteus larvae (y axis) per concentration of storm water (x axis). Any mean value (red dot) under the red line is statistically different from the controls, meaning that the null hypothesis is rejected. The edge of the light blue squares is the mean before the statistical transformation. The dark blue squares are the range for the mean data. The 0N represents the control data. Sea urchin embryos raised in untreated storm water had an EC_{50}= 26.5% (Figure 2a) and sea urchin embryos raised in treated storm water had an EC_{50} > 66.7% (Figure 2b).

Figure 3: Percent of herring survival (y axis) per storm water concentration (x axis) for the first herring experiment. Each red dot is the average of each replicate, the blue line represents the best fit and the dotted red line is the range. Both the untreated (Figure 3a) and treated (Figure 3b) storm water had LC_{50}'s > 100%.

Figure 4: Average dry biomass (y axis) per concentration of storm water (x axis) for the first larval herring experiment. Figure 4a shows results of untreated storm water. Meanwhile, Figure 4b shows results of treated storm water. For symbol legend refer to Figure 2.

Figure 5: Percent of herring survival (y axis) per storm water concentration (x axis) for the second herring experiment. Each red dot is the average of each replicate, the blue line represents the best fit and the dotted red line is the range. The untreated storm water (Figure 5a) had a LC_{50} = 90% and treated storm water (Figure 5b) LC_{50} = 94.5%.

Figure 6: Average dry biomass (y axis) per concentration of storm water (x axis) for the second larval herring experiment. Figure 6a shows results of untreated storm water. Meanwhile, Figure 6b shows results of treated storm water. For symbol legend refer to Figure 2.

Figure 1

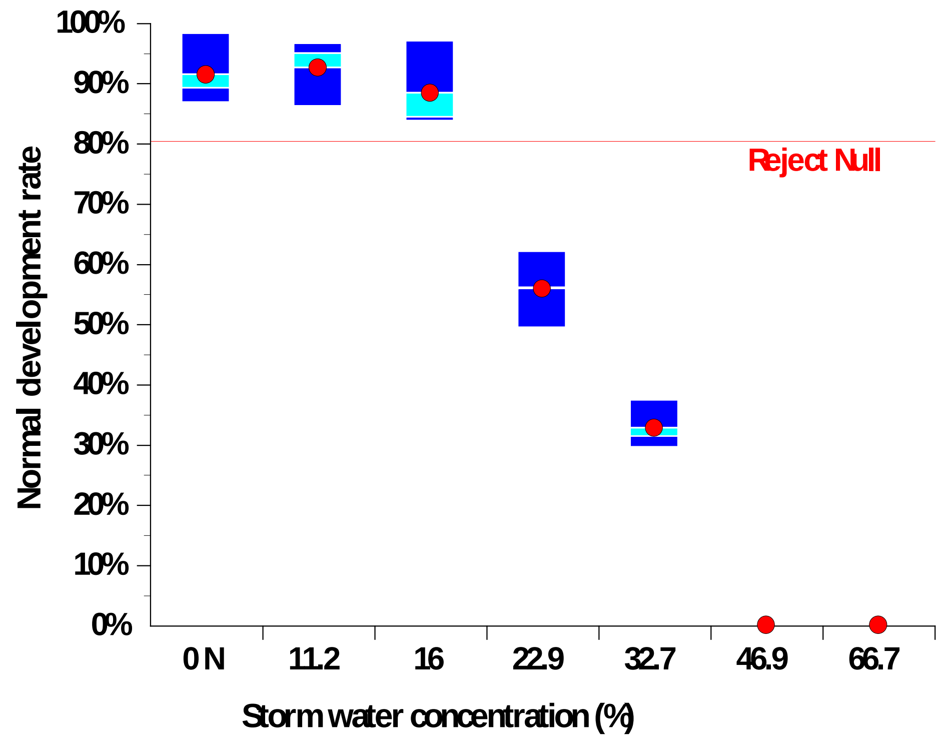


Figure 2a

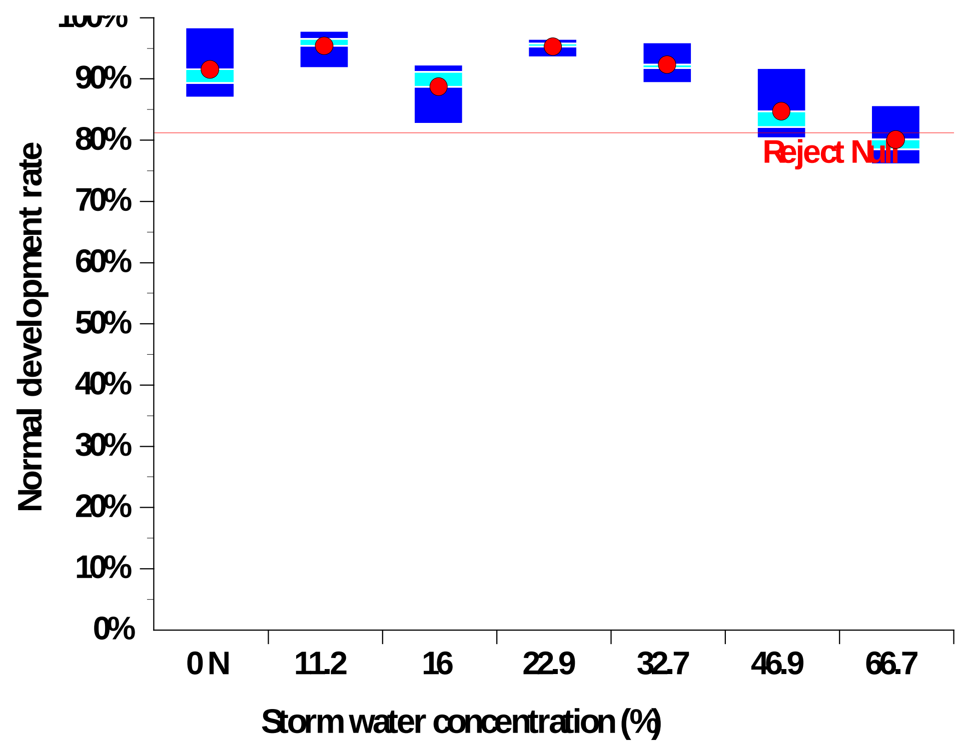


Figure 2b

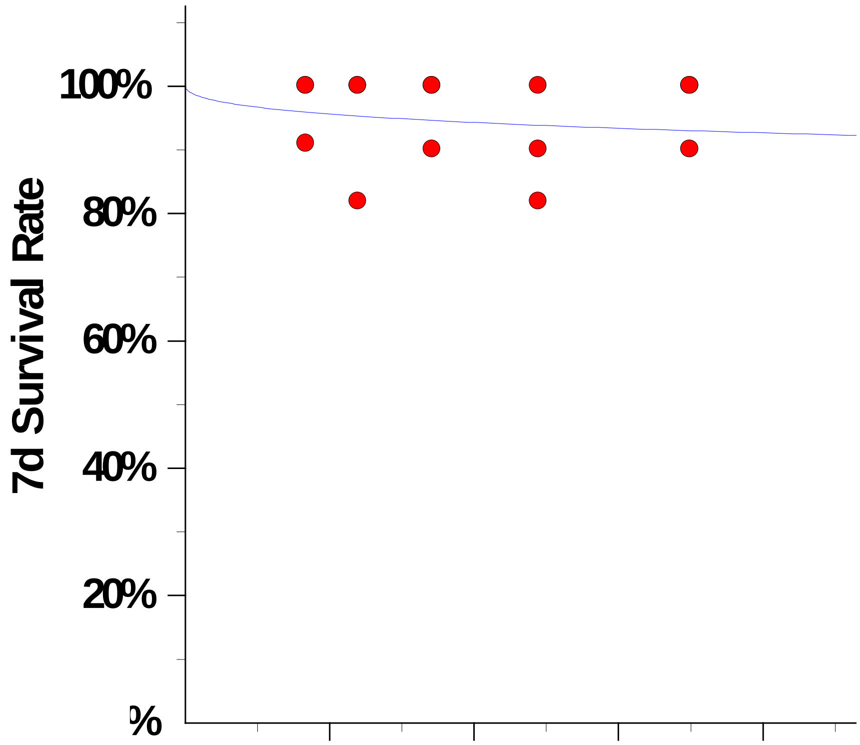


Figure 3a

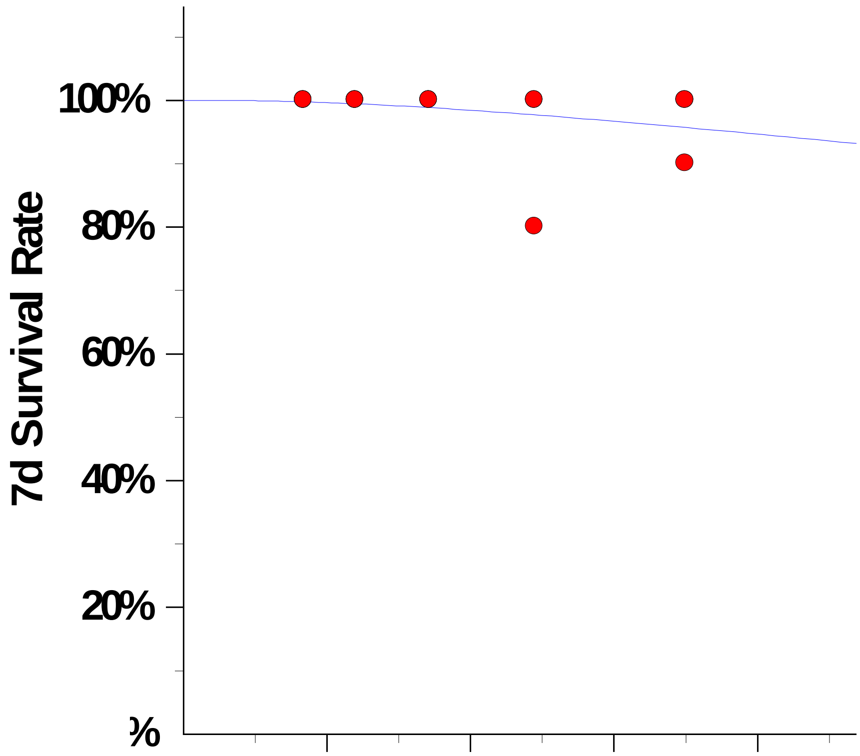


Figure 3b

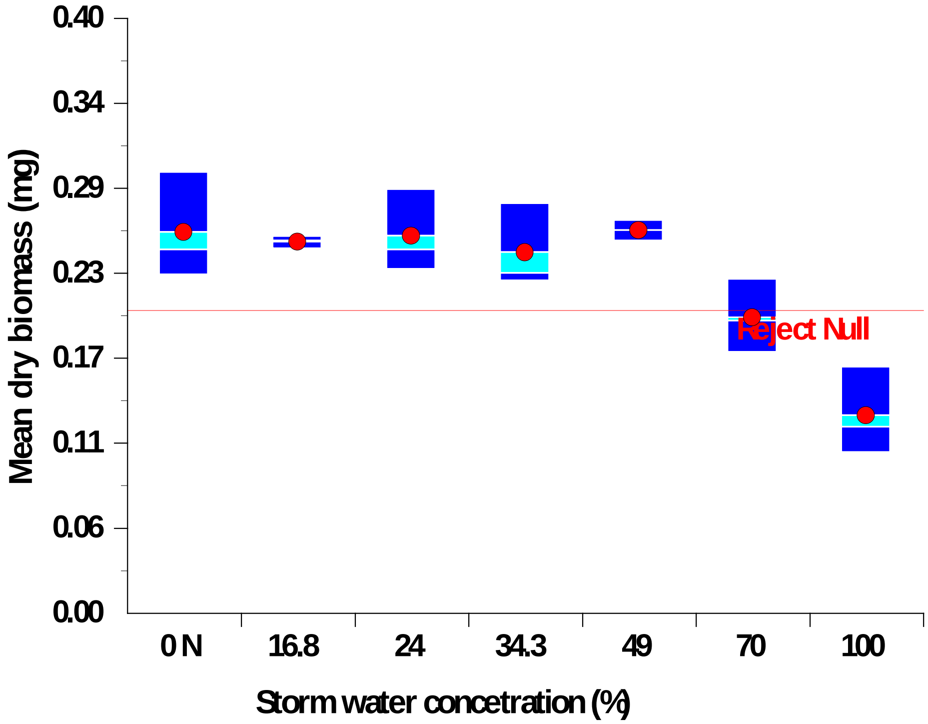


Figure 4a

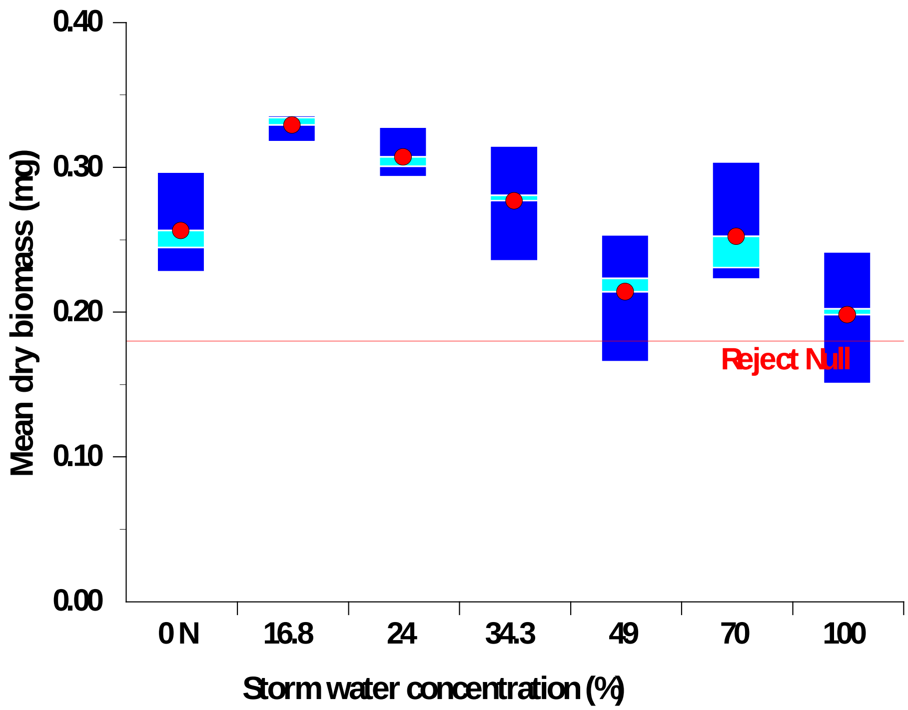


Figure 4b

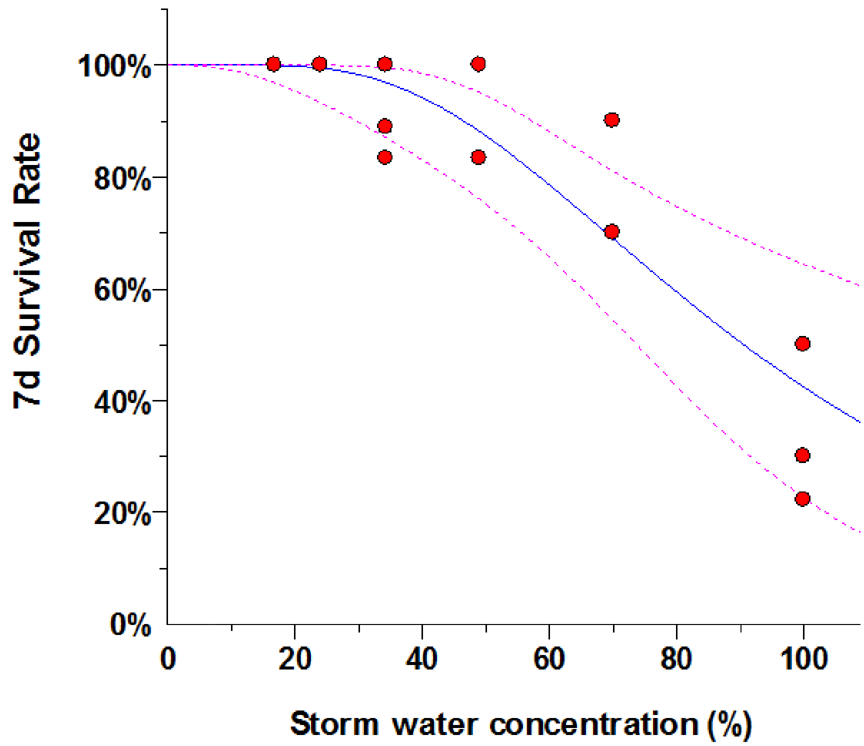
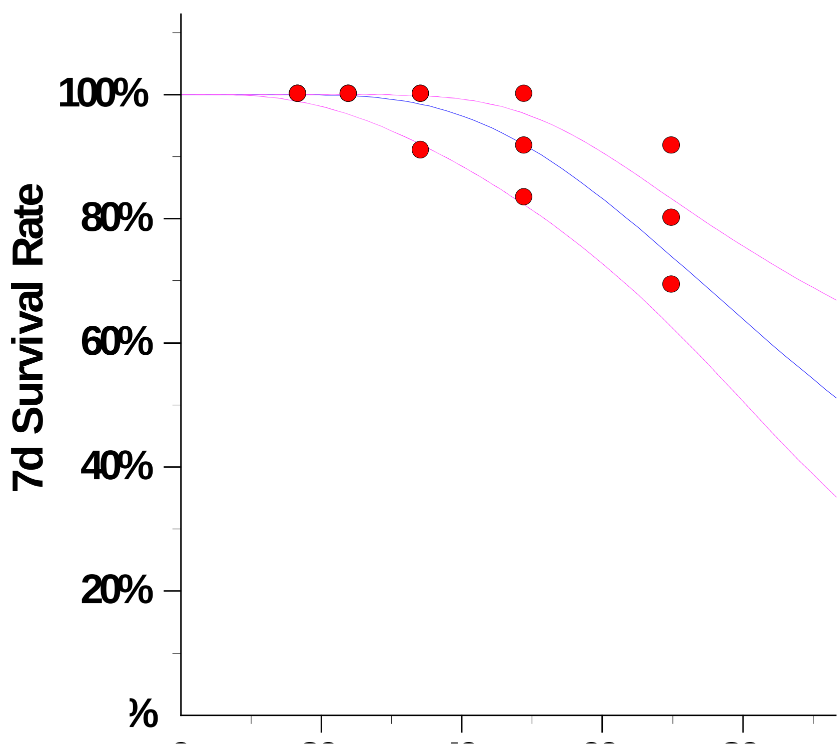


Figure 5a



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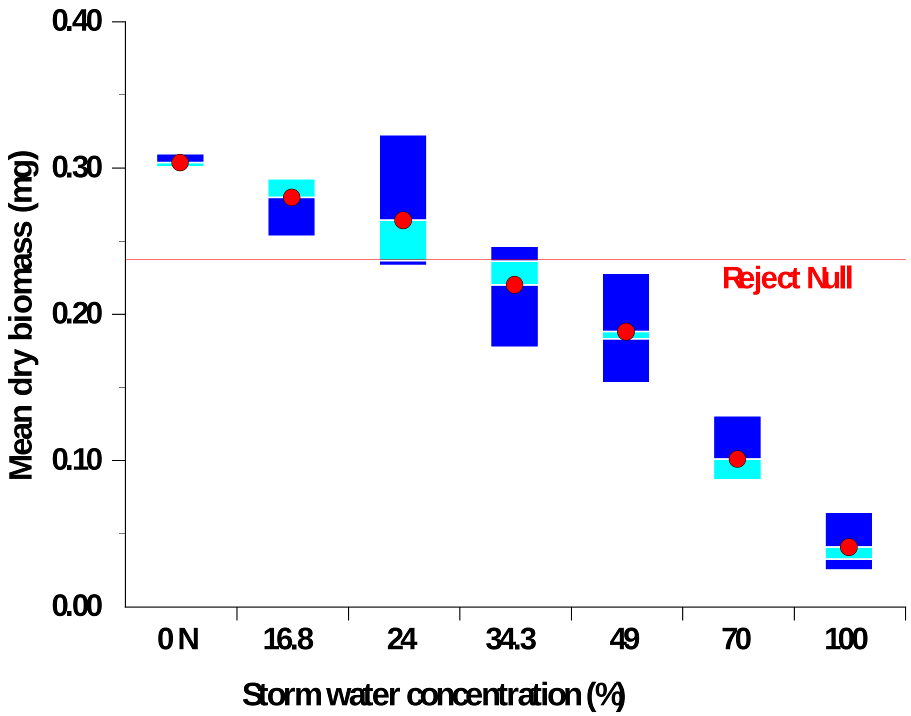

Figure 6a

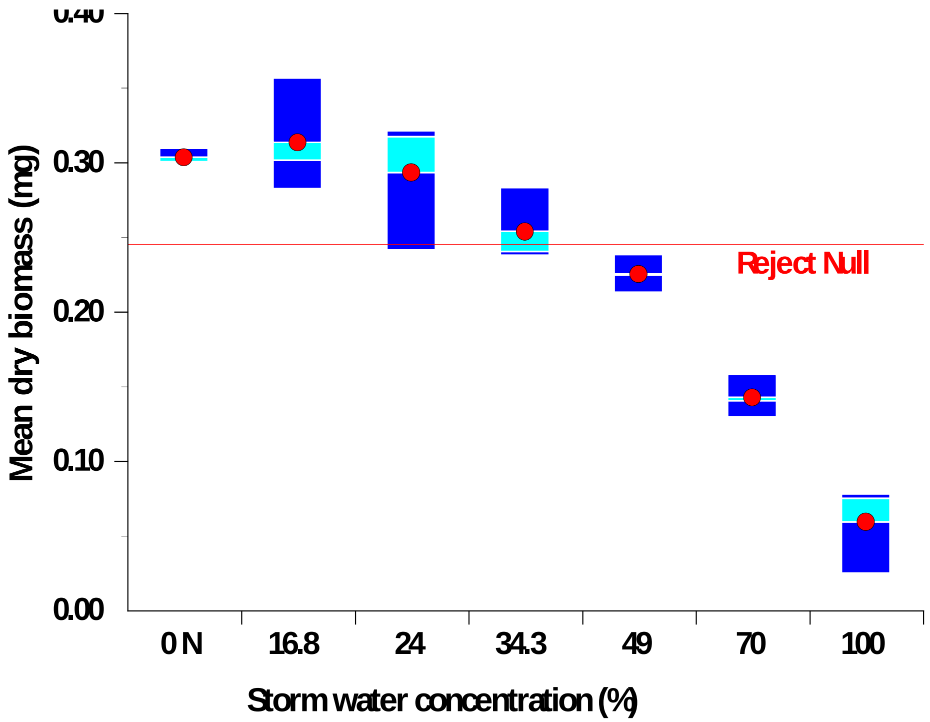

Figure 6b