Report for 2003PA11B: Using Crumb Rubber Filtraton for Ballast Water Treatment

- Conference Proceedings:
    - Xie, Yuefeng; Peng Chen, 2004, Crumb Rubber Filtration for Ballast Water Treatment: A Preliminary Study, in Proceedings of the 2nd International Ballast Water Management Conference and Exhibition, Singapore.
- Dissertations:
    - Chen, Peng, 2004, Ballast Water Treatment Using Crumb Rubber Filtration, Environmental Pollution Control Program, Penn State Harrisburg, Middletown, PA, 65.

Report Follows

Abstract:

Ballast water is an important way of transferring aquatic nuisance species (ANS) all over the world. Due to the lack of natural predators in the new environment, they are often able to thrive and outgrow the native species. Their domination can cause massive ecological, economic, and public health problems. Currently the only ballast water treatment option is mid-ocean ballast water exchange. Due to the safety concern and low efficiency, alternative options such as filtration, ultraviolet irradiation, biocides/chemicals, and heat treatment are under study. Crumb rubber, a scrap tire-derived material, is an innovative filter medium that can be used to treat ballast water. Millions of scrap tires are generated in the United States each year. These discarded tires present both health and environmental problems.

A side-by-side comparison between a crumb rubber filter and a sand/anthracite filter was conducted with water from Swatara Creek at a local water treatment plant. Experiments were conducted with different filtration rates and with/without polyaluminum chloride. The filter performance was evaluated by head loss, turbidity removal, particle removal, zooplankton and phytoplankton removal. The backwash performance was also studied.

The results show that the performance of the crumb rubber filter for turbidity, suspended particle, phytoplankton, and zooplankton removal was similar to that of the sand/anthracite filter. However, the crumb rubber filter allowed a greater filtration rate and longer filter run. Both filters were effective in removing larger particles (>10 µm). Adding 10 mg/L polyaluminum chloride did not improve the removal of large particles (>10 µm) but did significantly increase the filter head loss and reduced the filter run time.

The crumb rubber filtration is a potential shipboard technology for ballast water treatment because of its low head loss, high filtration rate, light-medium weight, and low expensive. Further study should be conducted at much higher filtration rates to investigate the removal of large particles (>10 µm and >50 µm) in ballast water. Our group has been awarded a grant by National Oceanic and Atmospheric Administration to investigate the crumb rubber filtration for ballast water treatment in a pilot scale study.

Statement of Critical Need:

Ballast water is an important way of transferring aquatic nuisance species (ANS) all over the world. ANS include algae, shellfish, developing larvae, eggs and other microorganisms. Due to the lack of natural predators in the new environment, they are often able to thrive and outgrow the native species. This domination can cause massive ecological, economic, and public health problems such as degradation of habitat, alteration of water quality, blockage of flow in drainage and irrigation canals, or even transition of diseases to humans. One of the most notorious ANS is the Zebra Mussel, which caused great damage in the Great Lakes. The International Maritime Organization (IMO) regards the introduction of harmful aquatic organisms and pathogens to new environments via ballast water, as one of the four greatest threats to the world’s oceans.

Currently, ballast water exchange is the only method which is practiced to reduce the risk of ballast-mediated invasion. Ballast water exchange involves replacing coastal water with open-ocean water during a voyage. This process reduces the density of coastal organisms in ballast tanks that may be able to invade a recipient port, replacing them with oceanic organisms with a lower probability of survival in near shore waters. However, conducting ballast water exchange at open sea puts many ships at risk especially in bad weather conditions. Therefore, less than 50% of ships are practicing ballast water exchange. In addition, ballast water exchange achieves only 65 to 95% effectiveness in the exchange of the original ballast water. Conventional sand/anthracite water filtration is an effective process for removing organisms. However, it is not economically and technologically feasible for ballast water treatment because of its heavy weight, low filtration rate, and large space requirement. A cost effective treatment technology is needed for ballast water treatment.

Crumb rubber, a scrap tire-derived material, is an innovative filter medium. Millions of scrap tires are generated in the United States each year. These discarded tires present both health and environmental problems. Scrap-tire reuse or recycling is an effective way to reduce these problems. Crumb rubber is currently used in highway pavement, athletic track surfaces, landfill lines, compost bulking agents, energy recovery and artificial reefs for aquatic life. As a filter medium, crumb rubber allows the porosity of the filter bed to decrease through the filter, resulting in the smallest pore size at the bottom and largest pore size on the top, which is ideal for down-flow filtration. The crumb rubber filter allows greater depth filtration and it then allows a greater filtration rate. In addition, the relatively low density of crumb rubber allows a lower filter back wash rate and simple back-wash procedure. The significantly light weight of crumb rubber filters make this an ideal on-board treatment technology for ballast water filtration.

Statement of Results of Benefits:

The proposed project will demonstrate a treatment technology for ballast water treatment that can be used to protect the precious coastal water resources in Pennsylvania and the nation. Because of its high filtration rate and light weight, the crumb-rubber filter could be used as an in-vessel treatment facility in cargo ships or cruise ships. The crumb-rubber filters could also be mounted on a barge as a mobile treatment unit. For land based treatment facilities, using crumb rubber filtration could significantly reduce the land requirements and the capital and operational cost for ballast water treatment. This technology could also be developed for storm water and combined effluent treatment. The use of the crumb rubber will also minimize the waste tire piles and promote green technology concepts.

Nature, Scope and Objectives:

This study was a preliminary study on the use of the crumb rubber filtration for ballast water treatment. A side-by-side comparison of the crumb rubber filter and sand/anthracite filter was conducted using a fresh water source. The objective of this preliminary study was to explore the use of crumb rubber filtration in ballast water treatment. The filtration efficiency was evaluated based on head losses, removal of turbidity, particles, zooplankton, phytoplankton and heterotrophic bacteria.

Methods, Procedures and Facilities:

<u>Pilot filters</u>
Two 9 feet × 2 inches (i.d.) transparent polyvinyl chloride (PVC) columns were built and installed in a local water treatment plant. The sand/anthracite filter contained 1 ft of gravel as support media, 1 ft of sand, and 2 ft of anthracite. The crumb rubber filter contained 1 ft of gravel as support media and 3 ft of crumb rubber medium. The filtration rate was controlled by a rotameter installed in the filter outlet pipe. The water from Swatara Creek was taken as ballast water.

<u>Analytical Methods</u>
1. Head loss was measured using a static pressure indicator. The head loss was expressed in inches.
2. Turbidity was measured according to Standard Method 2130 with a Hach 2100p turbidimeter. The level of turbidity was expressed as nephelometric turbidity units (NTU).
3. Particles (size and number) were measured according to Standard Method 2560 using a Hach 2200 PCX particle counter. The particle counting was expressed as number per 100mL.
4. Phytoplankton was measured according to Standard Method 10200 F. A SPENCER microscope with a magnification of 100 and a Sedgwich-Rafter (S-R) counting chamber were used for phytoplankton counting. Two categories of phytoplankton based on sizes (less than 10 µm and larger than 10µm) were identified and counted. The phytoplankton was expressed as number per mL sample.
5. Zooplankton was measured according to Standard Method 10200 G. Each sample was concentrated from 100mL to 10mL using the method suggested by the standard method. The zooplankton was expressed as number per mL sample.

Principal Findings and Significance:

1. Both the sand/anthracite and crumb rubber filters were effective in removing large particles (>10 µm and >15 µm). For the sand/anthracite filter, the removal efficiencies for particles larger than 10 µm and 15 µm were 89.4% and 94.5%, respectively. For the crumb rubber filter, the removal efficiencies for particles larger than 10 µm and 15 µm were 86.8% and 93.6%, respectively.
2. Both the sand/anthracite and crumb rubber filters resulted in a moderate reduction in small particles (>2 µm) and turbidity. For the sand/anthracite filter, the removal efficiencies for small particles (>2 µm) and turbidity were 43.5% and 51.7%, respectively. For the crumb rubber filter, the removal efficiencies for small particles (>2 µm) and turbidity were 23.6% and 47.6%, respectively.
3. Adding 10 mg/L of polymerized aluminum chloride (PACl) significantly enhanced the removal of small particles (50.0%) and turbidity (70.8%) in crumb

rubber filter and sand/anthracite filter (64.3% for small particles and 74.8% for turbidity). However, adding the coagulant did not significantly enhance the removal of large particles (>10 µm and >15 µm).

4. Adding the coagulant dramatically increased the filter head losses and shortened filter runs for both filters. For the crumb rubber filter, adding the coagulant reduced the filter run time at 16 gpm/ft^2 from 24 hours to 6 hours.
5. For particle and turbidity removal, there was no significant difference between the sand/anthracite and crumb rubber filters. In comparison to the sand/anthracite filter, however, the crumb rubber filter had much lower head losses and longer filter run times.
6. For phytoplankton and zooplankton removal, the analytical results were determined to be unreliable because of the small sample size used. Future studies should be conducted by concentrating the samples using 10 and 50 µm plankton sampling nets.
7. This study indicates that the crumb rubber filtration is a potential treatment technology for ballast water. As an on-board treatment technology, however, the water production capacity of the crumb rubber filter needs to be significantly increased. The future study should be conducted at much higher filtration rates (e.g., 80-120 gpm/ft^2) for the removal of large particles (>10 µm and >50 µm) in ballast water.

Students Supported: (name, major, degree)

Chen, Peng, Environmental Pollution Control, Master in Environmental Pollution Control
Tung, Hsin-hsin, Environmental Engineering, PhD in Environmental Engineering
Jain, Anuj, Environmental Engineering, MS in Environmental Engineering

Presentations and Other Information Transfer Activities:

- Chen, Peng and Yuefeng Xie, Ballast Water Treatment Using Crumb Rubber Filtration (poster presentation)**,** the 19th Penn State Graduate Exhibition, University Park, PA, 28 March 2004

- Xie, Yuefeng and Peng Chen, Crumb Rubber Filtration for Ballast Water Treatment: A Preliminary Study (poster presentation)**,** the 2nd International Ballast Water Management Conference and Exhibition, Singapore, 19-21 May 2004

Awards:

Research Grant, National Oceanic and Atmospheric Administration, A Pilot-Scale Study on Crumb Rubber Filtration for Ballast Water Treatment, $156,473, 9/1/2004-8/31/2006.