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16. Abstract (MAXIMUM 200 WORDS)

Large-scale dockside experiments were conducted to evaluate the treatment efficiency of commercially available unit processes for preventing the transfer of unwanted species via ships' ballast water. The project was conducted at the University of Miami (UM) Rosenstiel School of Marine and Atmospheric Science on Virginia Key, Florida. Test system water with natural assemblages of organisms was pumped from Biscayne Bay, Florida, at a flow of approximately 5.7 m^3 min^{-1} (1,500 gpm). Unit processes included a hydrocyclone, a self-cleaning 50 µm screen, and a UV treatment unit. In addition to these unit processes, a mixing and injection system was fabricated to add suspended solids or dissolved coloring agents to the water stream to explore the effect of increased suspended solids (turbidity) or water color on UV treatment efficacy.

The results showed that screening of the test water at 50 µm was effective at removing most of the zooplankton and a small percentage of the microphytoplankton. In contrast, hydrocyclonic separation was not effective for treatment. Initially, UV treatment was able to reduce the count of viable microorganisms to an undetectable level; however, significant regrowth of bacteria was observed. The impact of increased turbidity on all unit processes was considered negligible. Hence, if UV treatment units are to be utilized, removal of suspended solids prior to irradiation may not be necessary if initial design dosage is high enough. At relatively low UV doses, as would be seen in waters of high color, however, the dose was insufficient to inactivate natural assemblages of microorganisms.

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EXECUTIVE SUMMARY

Large-scale dockside experiments were conducted to evaluate the treatment efficiency of commercially available unit processes for preventing the transfer of unwanted species via ships' ballast water. The project was undertaken utilizing U.S. Coast Guard Research & Development Center funding at the University of Miami (UM) in Coral Gables, Florida. The treatment system was located at UM's Rosenstiel School of Marine and Atmospheric Science on Virginia Key, Biscayne Bay, Miami, Florida. Water with natural assemblages of organisms pumped from Biscayne Bay flowed through the test system at approximately 5.7 m^3 min^{-1} (or 1,500 gpm). Unit processes included a hydrocyclone, a self-cleaning 50 μm screen, and an ultraviolet (UV) treatment unit. In addition to the unit processes, a mixing and injection system was fabricated to add suspended solids or dissolved coloring agents to the water stream to explore the effect of increased suspended solids (turbidity) or water color on UV treatment efficacy.

Treatment efficiency was monitored by evaluating a broad spectrum of biological and biochemical effects. Planktonic organisms, both algae and zooplankton, were monitored to determine any effects due to treatment schemes. In addition, biochemical analyses such as ATP (adenosine triphosphate) were undertaken to determine viability effects of treatment. Also microbial analyses were undertaken to determine effects of UV treatment on the microflora. These analyses were performed to evaluate a wide spectrum of possible effects of treatment on the indigenous organisms.

The results of the analyses showed clearly that hydrocyclonic separation was not effective for treatment at any level in the test water. In addition, it was clear that screening the water stream at 50 μm was effective at removing most of the zooplankton and a small percentage of the micro phytoplankton. The UV treatment was able to reduce the count of viable microorganisms to an undetectable level immediately after treatment. However, regrowth was observed in samples analyzed after 18-hour storage to the level where effectively no net treatment occurred due to UV exposure. In contrast, regrowth was not observed in samples analyzed after longer storage periods (6-day dark storage and 6-day dark storage followed by 24-hour ambient light exposure). It was noted that bacterial abundance in these samples decreased regardless of UV dose indicating that factors other than UV treatment (such as natural causes or grazing by maturing copepods) were responsible for decline in these bacterial numbers over time. There was some indication that the UV treatment affected phytoplankton, although no trends were apparent with respect to destruction of a monitor of phytoplankton biomass (chlorophyll *a*), with either increasing or decreasing UV treatment. This indicates that longer-term grow-out experiments will be required to define these phenomena. Zooplankton viability was not quantified in any of the experiments; however, qualitative microscopic observations of zooplankton groups immediately after UV treatment contained lively specimens regardless of dose, suggesting that UV treatment utilized was not sufficient to rapidly kill mesozooplankton groups present.

Statistical evaluation showed essentially no effect due to increased turbidity throughout the treatment regime, even on the UV treatment unit. The turbidity was varied from

approximately 5 NTU (nephelometric turbidity units) to greater than 90 NTU, representing the spectrum that would be encountered in ballasting operations. While the dose delivered by the UV system decreased due to the increased suspended solids loading, its reduced value (approximately 25,000 $\mu W \cdot s\ cm^{-2}$ minimum dosage) was sufficient to inactivate microorganisms, even with the increased turbidity. It appears, therefore, that if UV treatment units are to be utilized in ballast water treatment schemes, turbidity removal or suspended solids removal prior to irradiation will probably not be necessary if initial design dosage is high enough. At relatively low UV doses (approximately 10,000 $\mu W \cdot s\ cm^{-2}$) as would be seen in waters of high color (approximately 20 mg L^{-1} humic materials), however, the dose was insufficient to inactivate natural assemblages of microorganisms.

Media filter experiments were also conducted, independent of the large-scale treatment system experiments, using the same water source without altering turbidity or color. These experiments were designed to determine effects of flow rate on particle size distribution (indicative of organism removal) of filtrate. Media of different grain size was used for each of five test runs. It was observed that at increased flow rates, lower percentages of particles were removed, with media type and grain size having little effect. It is evident that for media filters to be utilized in treatment of ballast water, research and optimization of their primary characteristics is needed.

In summary, it was observed that the 50 μm screen contributed appreciably to removal of organisms, especially zooplankton in the test water of the facility. The hydrocyclone was observed to be not effective in removing organisms in the test water. The UV treatment, at doses delivered in these tests, was observed to be not effective at facilitating meaningful treatment of bacteria in test water due to grow-back phenomena observed after 18 hours. Observations indicate that longer-term experiments will be required to define overall effectiveness of UV treatment on phytoplankton and zooplankton.

This research documented performance of selected unit processes in controlled, large-scale tests, and used well-defined analytical methods to obtain statistically based results. Results of these tests provide useful information for development of a defensible scientifically based ballast water treatment standard and also illustrate test methods that should be considered for use in tests and evaluations of ballast water treatment technologies that may be performed in the future.