Ballast Tank Biofilms Resist Water Exchange but Distribute Dominant Species

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Abstract

It has been established that aquatic invasive species can be introduced to the Great Lakes and transmitted among the ballast tanks of localized lake freighters, or "lakers", as well as the international ships entering through the Saint Lawrence Seaway. Much research has been conducted on ways to treat ballast water, thereby mitigating the threat of non-indigenous species invasions from ships that are within the Great Lakes. No efforts are yet being put into treatment of the unremoved biofouling of the interior walls and sediments within ships' ballast tanks. Such biofilms can re-seed the ballast tanks' volumes during re-filling and thus put the Lakes under further threat of invasion. We propose a ballast exchange procedure while the ships are docked that will also include a ballast biofilm and sediment cleaning regimen, with an option for ballast compartment re-painting with corrosion-resistant, easy-release coatings.

Introduction

Current surveys approximate that there are 111 ships on the Laurentian Great Lakes at any given time in the operating season. Together they can hold a total of 362,335,415 cubic meters of ballast water within their tanks and the amounts of biofilms in all of these ships is approximately138 meters cubed by volume, or, conservatively, about 150 tons by weight. This matter, spread thinly across the surfaces of ballast tanks and sediments, from all these ships provides much opportunity for even once-treated water to be re-seeded by any one of the 7.4 trillion colony forming units of bacteria and even 100X that amount of viruses and virus-like particles (VLPs) that each of these ships thus carries despite prior volumetric emptying.

The bacteria and VLPs contained within the biofilms from already contaminated water can be re-dispersed. One such way is in a bioaerosol phase caused by biological plumes of water spray that rise up and cause dangerous health issues to anyone downwind of the de-ballasting event. Seawater-dwelling *Vibrio alginolyticus* has been found inland, in Cleveland, Ohio, to ear-infect an individual in this manner. The means for retention of desirable natural biodiversity, as well as ways to treat, eradicate, and prevent the spread of biofilm contamination is through application of successful Navy-developed surface-active displacement solutions (SADS), as well as corrosion-resistant easy-release preventative coatings. Because of it's accommodating infrastructure and facilities required for ballast water exchange and treatment, the Port of Buffalo is an obviously favorable location for such a facility.

Methods

In order to determine the traffic that circulates within the Great Lakes and from the St. Lawrence seaway, a survey was conducted using the Great Lakes and Seaway shipping and vessel passage maps (July 11th 2013 through December 31, 2013). The number of freighters was recorded and the average was taken. Additional information was recorded on the first day such as ship names, ballast tank sizes and ship types in order to regularly assess the threat that might be posed to the Great Lakes. From the data gathered, the amounts of bacteria, viruses and biofilms needed to be cleaned away, on average, were determined.

The proposed method of removing of the biofilms is to use the technique of the earlier Navy-developed surface-active displacement solutions (SADS). This approach has been successfully used in the removal of organic materials from sensitive equipment that conventional alkali solutions and bleaches would damage, and it is still used today for removing toxic residues from military equipment.
The solution contains a safe surfactant with both hydrophobic and hydrophilic properties making it amphipathic and also uses a film-penetrating component such as agriculture-derived n-butanol. When applied to a contaminated surface such as that of the inside of a ballast tank, the solution would theoretically penetrate the organic biological layer completely. Once it reaches the non-biologic surface, it will expand across that surface to displace any of the organic layers it comes in contact with. The removed "biowaste" will collect at the bottom of the tank, along with biofilms that will be similarly sloughed from the sediments and can be removed by re-suspension into the cleansing fluid, leaving behind a monolayer-coated dehydrated surface ready for painting. The waste can, itself, be further remediated.

Results

A survey taken on 7/11/2013 showed the following:
-Bulk carriers were the majority of ballast-carrying watercraft consisting of 64.4% of all vessels underway.
-Their average ballast tank size was 23,800 meters cubed while the overall average tank size was 21,071 meters cubed.
-The combined ballast capacity of all ships was 2,335,415 meters cubed.
-Each ship carried approximately 5,000 square meters of biofilms providing a potential 100 trillion-propagule risk per ship.
-Stripping and reduction of the biofilm mass using the SADS formulation would result in about 150,000 kilograms of disinfected biowaste that could be converted into useful building products following SADS procedures.

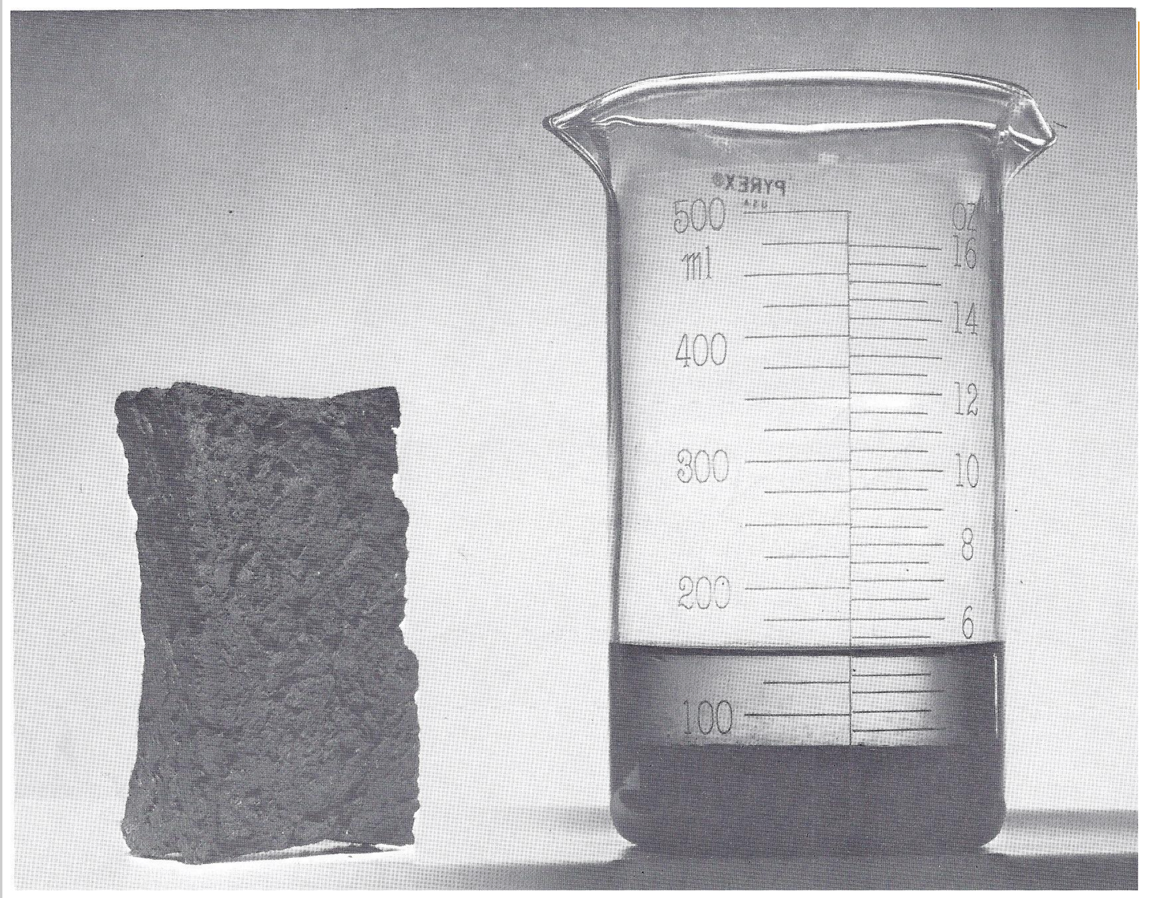

Figure 1. The "sludge brick" is the product of a process that converts the displaced biowaste into an odorless, tasteless, non-toxic, strong building material by using a simple yet inexpensive chemical process.

Discussion and Conclusion

The problems of residual biofilms, and sediments containing viable organisms remains unsolved despite having the potential for becoming an aquatic and bioaerosol nuisance. The Navy has previously developed ways to displace seawater-derived organic debris from ships' components. Suppression of environmental risk is particularly important within the Great Lakes system which has already suffered the invasions of both the zebra and its cousin, the quagga mussels. Both have spread as a result of ship de-ballasting. Mussel veligers have been found to be transported among the various non-native bacteria within the biofilms. Progress has been made in killing organisms suspended within the ballast water, but the issue of removing organisms within the biofilm and sediments has not been adequately addressed.

Using methodologies that were conceived and refined through the past decades, we propose a method with which the ballast tank can be cleaned of all surface-accumulated biological slimes and fouling deposits, that is safe, cheap, environmentally friendly, and is effective. The proposed cleaner would function this way: the dispersed amphipathic component of a low-stability emulsion would readily penetrate the organic residues, while a water spray carrier would serve to flush away the surface contaminants into a volume phase, easily removed and retreated. There will be no flammability issues or health hazards. A monomolecular re-contamination preventing component, adsorbing and replacing the biofilm, will retard secondary fouling, making another fouling event easier to remove and clean.

Discussion and Conclusion (continued)

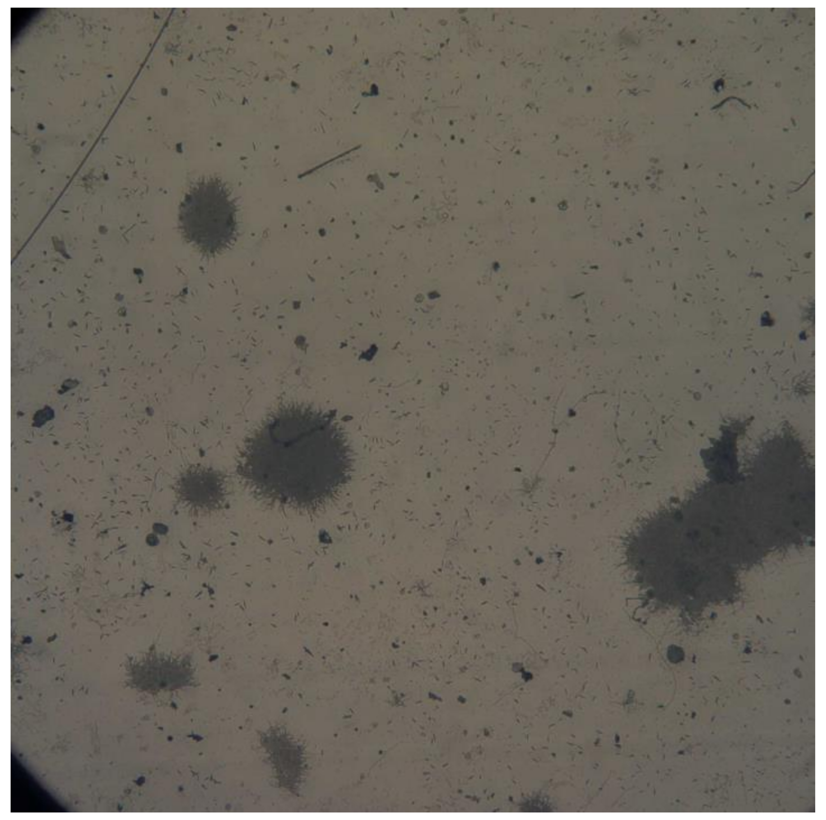

Figure 2.
Typical ballast water biofilm formed on test coupons placed within ballast tanks of around-the-world ships. Scanning electron micrograph at 50X.

Alternatively, a spray coating of a corrosion-resistant fouling release paint could be added to the now-dried interior tank structure.
It is an imperative of economic geography to note the Port of Buffalo's prominence as a transportation hub, at the St. Lawrence Seaway entrance to the upper Great Lakes. The region was once the terminus of the Erie Barge Canal and the mandated transfer port for goods arriving to, and exported from middle America with unexcelled waterborne, rail and highway resources. Environmental health and safety concerns now mandate that the main sources of nonindigenous species transfer, the ballast water, sediments and biofilms are all re-mediated. It is imperative that the nonindigenous species transfer is interrupted through ballast water exchange, sediment cleaning and biofilm removal before ships are allowed to proceed through Lake Erie inland towards other Great Lakes.

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