Treatment of Ballast Water Using Acoustic Cavitation Techniques Coupled with Advanced Oxidants

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This research investigates the mixing of marine species in different ecosystems. As ships dock in different ports, they exchange water from the ship's ballast tank and the marine environment. The transfer of water seems insignificant until the ship enters a different port and ecosystem and releases foreign organisms from the ballast tank to the marine environment. These organisms are foreign to the environment that they have been placed in, and, as a result, they may over-produce and cause environmental and ecological problems.

To solve this problem, a transducer was found that could create sonic waves at different frequencies through the water and reach the ships' hulls. The sonic waves inactivated foreign organisms in the hulls of ships. This research's objective is to test the effectiveness of this device and the sonic waves at a frequency of 1.4 KHz, also searching to find an optimum length of time for sonication. In addition, the effectiveness of sonication coupled with an advanced oxidant, hydrogen peroxide, was tested in comparison to sonication alone to determine if advanced oxidants can effect the eradication of foreign organisms in the ballast of ships.

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Methods

Brine shrimp were used as test subjects in these experiments because brine shrimp were found to tolerate a range of pH and salinity environments. Moreover, brine shrimp were small and easy to maintain and grow. In these experiments, time was the independent variable, and the number of shrimp killed were the dependent variable. The wavelength and frequency of the waves were kept constant.

Sonication was conducted after the brine shrimp were allowed to hatch for 24 hours. The marine habitat was placed on a stirring tray and stirred constantly and, as the habitat was stirred, sonication was conducted with the use of the transducer, which was placed in the water. The marine habitat was sonicated in time intervals of 3, 5, 10, 15, and 20 minute intervals. In the sonication and ozone tests, the pipe creating the ozone was placed in the water as the sonication took place in intervals of 5, 10, 15, and 20-minute intervals.

Following sonication, the brine shrimp were allowed to sit in the habitat for 48 hours. The cysts were then subsampled for counting by mixing the beaker with a glass-stirring rod until a homogenous suspension of cysts was achieved. Following this, 3 sub-samples of 10 mL were quickly removed with a volumetric pipette. The control beakers were pipetted first to avoid introducing traces of treatment chemicals. One hundred percent ethanol was added to the sub-samples so that the final concentration of alcohol was 70%. A dissecting microscope was used to tally the number of hatched juveniles and dead cysts in each sub-sample, where the partially hatched cysts were counted as hatched or unhatched.

Results

The following tables show the percentage of 200 test subjects that were counted as dead or live brine shrimp. The first table shows this percentage of dead and live brine shrimp with sonication alone affecting the brine shrimp cysts organisms, whereas the second table shows sonication coupled with advanced oxidants affecting the organisms.

Table 1. Sonication alone (1.4KHz), brine shrimp cysts

Duration (minutes)	% Active	% Inactive
3 min	64.88	35.11
Control	80.00	20.00
5 min	63.64	36.33
Control	71.00	29.00
10 min	60.00	40.00
Control	90.00	10.00
15 min	57.56	42.44
Control	87.00	13.00
20 min	52.88	47.11
Control	92.00	8.00

Table 2. Sonication plus advanced oxidants (1.4KHz + 100 ppm ozone + 100 ppm hydrogen peroxide), brine shrimp cysts

Duration (minutes)	% Active	% Inactive
5 min	76.67	23.33
Control	85.00	15.00
10 min	57.33	42.67
Control	90.00	10.00
15 min	29.89	70.11
Control	86.00	14.00
20 min	8.67	91.33
Control	89.00	11.00

Under each time duration is the control, which was used to see how under normal circumstances many brine shrimp species would hatch.

As shown from the data, sonication alone had minimal change over time. There was little change in percent inactive from 3 minutes to 20 minutes, whereas with sonication and advanced oxidants, the percentage inactive was noticeably different and continued to increase as time proceeded until 20 minutes. It was found that hydroxyl radicals (OH*) were the primary killer in sonication with advanced oxidants. The hydroxyl radicals, the bubbles from when sonication took place, were created when sound waves went through the water, and also when the advanced oxidants were introduced into the marine habitat. Therefore, since hydroxyl radicals destroyed the brine shrimp in the habitat, it was seen that the combination of sonication and advanced oxidants created more hydroxyl radicals in the water then sonication alone, as shown in the data (percent inactive).