

# SYNERGISTIC UV DISINFECTION OF BALLAST WATER FLOWS

R. Duthie\*, R. Baier\*\*, R. Forsberg\*\*, S. Patel\*\*, and A. Meyer\*\*

\*Synergina, Inc., 155 Blake Hill, East Aurora, NY, 14052, USA

\*\*Industry/University Center for Biosurfaces

University at Buffalo, Buffalo, NY 14214-3007, USA

e-mail: baier@acsu.buffalo.edu

Tel.: 716-829-3560

FAX: 716-835-4872

## Introduction

Synergistic Inactivation and Disinfection (SIAD) is a method of attenuating potentially invasive and pathogenic organisms pumped into harbors with water, suspended sediments, and shed slimes from ballast tanks of overseas vessels. These biocomplex and often-turbid suspensions carry diverse species accumulated in the tanks of global voyaging ships, and enormous volumes (many thousands cubic meters) must be de-ballasted/discharged in short periods.

It would be beneficial to inactivate potentially infective microbes and exotic, nonindigenous species at each deballasting site, and perhaps during re-ballasting operations as well. This benefit can be obtained only if a rapid high-flow disinfection technique with low-space requirements can be made available in maritime facilities or aboard ships.

Experience with SIAD for sterilization of dental and medical implants (1), and more recently for nonthermal pasteurization of fruit juices, has provided operating experience that favors extension of this technology to ballast and "grey water" treatment.

## Methods and Materials

The devices used in these studies were SIAD Models LQ 4000, GEN II, and SL4000 (Prototype), all from Synergina, Inc., East Aurora, NY, USA, and based on U.S. Patents 5,547,635 and 5,688,475 (2,3). The devices expose static or flowing samples to simultaneous bursts of broad band ultraviolet light and rapid local heating, producing an effect called "dynamic sterilization" by Delgado and Schaff (1) on the basis of the rapid and complete sterilization shown with *Bacillus subtilis* (heat sensitive) as well

as *Bacillus stearothermophilus* (heat resistant) strains seeded to complex implants.

The SIAD device employed by these authors was operated at 1500 watts, producing complete sterilization in 10-16 seconds exposure to a Synergina process lamp # 200-305 S, with a life of approximately 200,000 active cycles. This device was utilized for the ballast water studies reported here. Related, higher-power units were used as cited below for the proof-of-principle studies performed with apple juice and high-pulp-content orange juice flows.

The ballast waters and suspended sediments tested were derived from removable ballast-tank indwelling devices called BOB (ballast organic biofilm) samplers, after a transAtlantic voyage of the collier HADERA (4,5) and after Mediterranean-Atlantic-Pacific-Atlantic-Mediterranean multi-port round trips of the commercial vessels ZIM CHINA and ZIM PACIFIC. The ballast water and sediment slurry testing was based on cultivation of suspended microorganisms on marine agar as well as tryptic soy agar, exposing one set of sample duplicates to 6 seconds of SIAD illumination while the other remained in ambient lighting. Prior filtration of the ballast water/sediment suspensions through 50-micrometer metal screen sieves and fiber glass plugs also was utilized to remove potential zooplanktonic aquatic nuisance organisms before SIAD treatment, in some trials.

## Results

There was uniform and total "kill" of all microbial life contained in the SIAD-treated ballast water specimens, as evidenced by the "no-growth" condition on marine and fresh water agars. At this writing, the experiments with heavy sediment

slurries and with pre-filtered ballast water specimens are still in progress, as are experiments at different flow rates.

Instructive results, predicting good flowing system performance, were obtained with the flow of apple juice at 3-5 gallon/minute past 4 of the SIAD lamps. The apple juice, deliberately pre-seeded with the pathogenic microbe *E. coli* O157:H7, was reduced to "no-growth" from a control count of 75,000 colony forming units per milliliter with a temperature increase of only 20C.

Using a SIAD unit with 2 SIAD lamps, Tropicana Grovestand pulp-rich orange juice, inoculated with *E. coli* ATCC 25922, was treated at 10 gallon-per-minute (gpm) flows for increasing periods and at increasing lamp power from 2000 W to 3140 W. Complete sterilization was obtained at an exposure time of 7.5 minutes to 3160W, with a juice temperature increase from 32 to 36C.

Using the same unit with pulp-rich orange juice pre-seeded with *E. coli* ATCC 11229, complete sterilization was obtained at 10 gpm flow rate in 6 minutes, at a lamp power of 3116 W, again with just a few degrees temperature increase.

### Discussion

Given the long history of generally unsuccessful attempts to obtain reliable, rapid UV sterilization and disinfection of particle-rich fluids, it is necessary to further examine the promising results obtained with the SIAD process. Recognizing that ballast water, sediment, and biofilm "exotics" are entirely untreated at present, it will be worthwhile to consider further development of this hardy, "small-footprint" technology even it proves to be only partially effective in real dockside situations.

The general relationships between bacterial effects and specific illuminating wavelengths are well known (6,7), with 90% kill usually obtained at 254nm for a variety of bacterial and viral species (8-11).

It is unlikely that the sole mechanism of microbial inactivation is the known dimerization of adjacent thymines in DNA molecules. Interference, from numerous other stress-provoking wavelengths emitted in the SIAD process, with protein synthesis

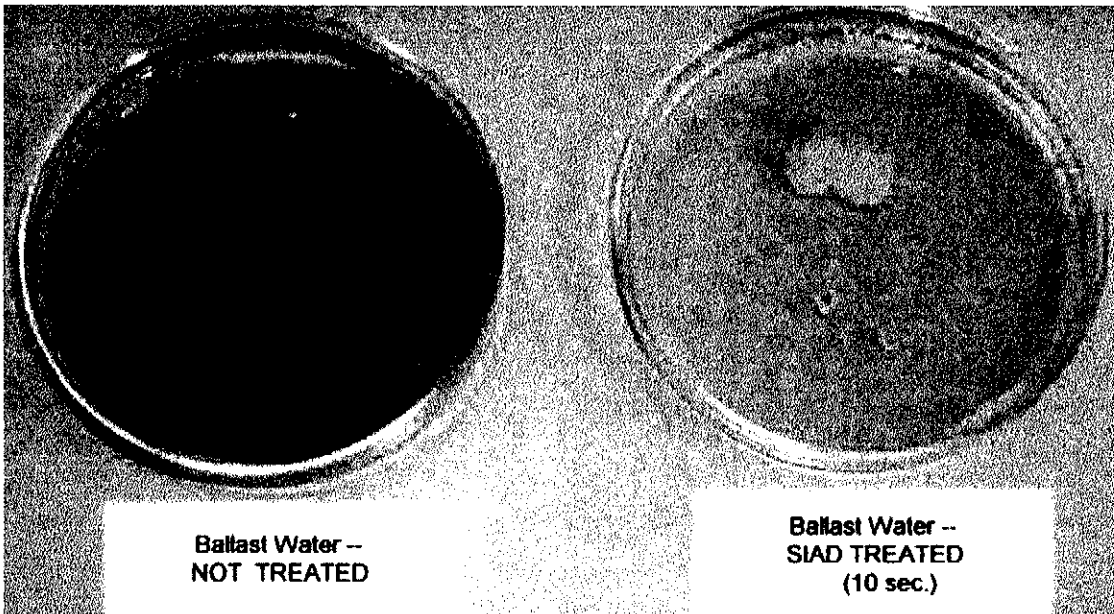
and expression is a likely alternative pathway now under investigation (12).

Specifically, the combined "dynamic" influences of the multi-wavelength, high-heat-pulse SIAD lamps seem to overcome the screening, shielding, and shadowing effects that limit conventional germicidal UV treatment to line-of-sight treatment. The SIAD excitation phenomena may include a variety of non-sterilizing photonic and thermal events not dependent on line-of-sight irradiation, since they operate in the entire range from about 100nm to more than 500nm.

A unique synergism seems, from the mostly empirical data so far acquired, to exist with regard to very rapid inactivation of a multitude of biological organisms in flowing, turbid fluids-- the effect sought for metric tonnes of ballast water now released untreated into the world's ports and harbors.

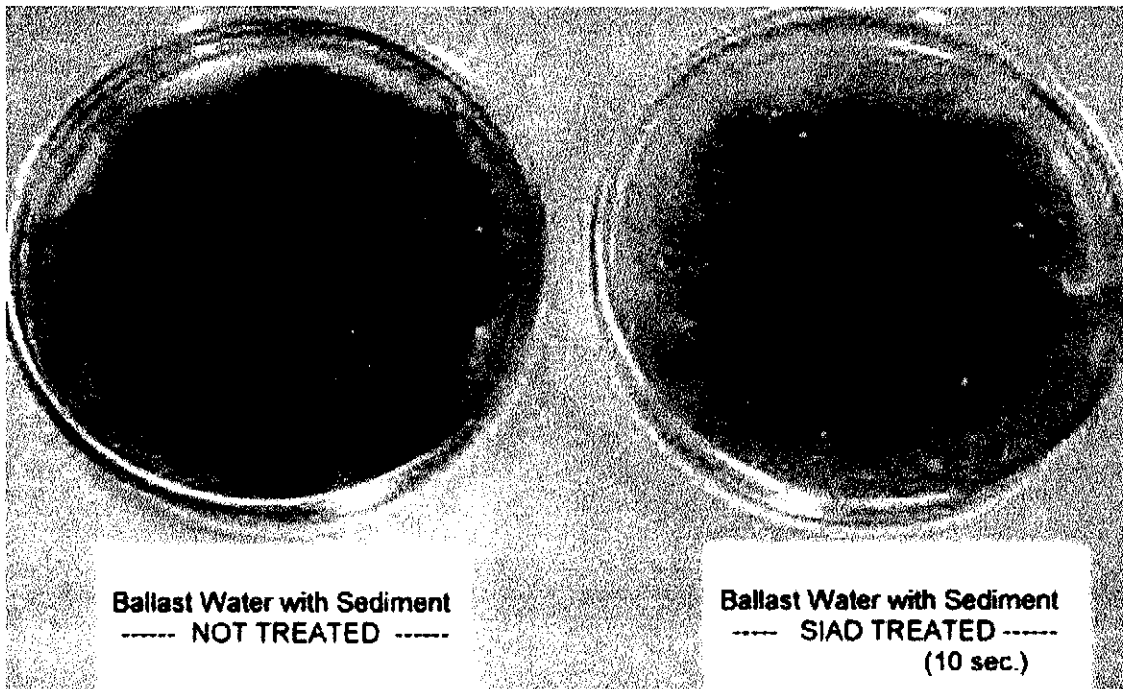
### References

1. Delgado AA and Schaaf NG. *Int J Oral Maxillofac Implants*, 1990, 5:117-125.
2. Duthie R. U.S. Patent Number 5,547,635 (1996).
3. Duthie R. U.S. Patent Number 5,688,475 (1997).
4. Meyer AE, Baier R, Hulsmann N, Galil B, Friedmann D, and Forsberg R. Abstracts Book, American Society of Limnology and Oceanography, Aquatic Sciences Meeting, June 5-9, 2000, Copenhagen, abstract #SS08-p22.
5. Drake LA, Ruiz GM, Galil BS, Mullady TL, Friedmann DO and Dobbs FC. *Marine Ecology Progress Series* (in press).
6. Kroller LR. *Ultraviolet Radiation*, John Wiley & Sons, New York, 1965.
7. Mpelkas CC. "Germicidal and short-wave ultraviolet radiation", *Sylvania Engineering Bulletin* No. 0-342, 1980, pp 1-14.
8. Chang JCH, Ossoff SF, Lobe DC, Dorfman MN, Dunais CM, Qualls RG and Johnson JD. *Appl Environ Microbiol* 1985, 49:1361-1365.
9. Hill WF, Hambelt FE, Benton WH, and Akin EW. *Appl Microbiol* 1970, 19:805-813.
10. Collins FM. *Appl Microbiol* 1971, 21:411-413.
11. Hart D and Durhan NC. *JAMA* 172:1019-1028.
12. Svensater G, Sjogreen B, and Hamilton IR. *Microbiology* 2000, 146:107-117.



**Ballast Water --  
NOT TREATED**

**Ballast Water --  
SIAD TREATED  
(10 sec.)**



**Ballast Water with Sediment  
----- NOT TREATED -----**

**Ballast Water with Sediment  
----- SIAD TREATED -----  
(10 sec.)**