

Biodosimetric Studies for Ballast Water Treatment

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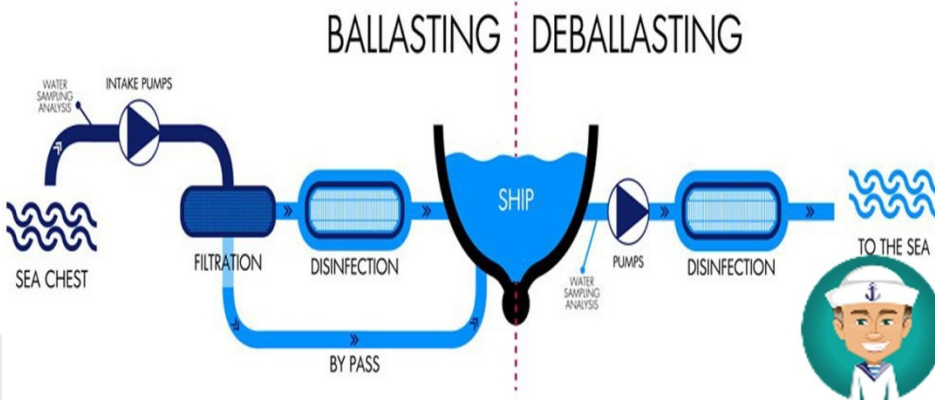
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Contents

- Introduction
- Experimental study
- Numerical simulation
- Results and discussions
- Conclusions

Introduction

What is Ballast Water ?



- Ballast water is usually carried by ships or bulk cargo carriers to improve stability and balance.
- It is taken up when ships or cargo carriers are unloaded or extra stability is needed in bad weather in one region.
- It is usually discharged at the next port, wherever more cargo is loaded.

Introduction

Why does ballast water need to be treated before discharging?

Ten of the Most Unwanted

Marine plants, animals and microbes are being carried around the world attached to the hulls of ships and in ships' ballast water. When discharged into new environments, they may become invaders and seriously disrupt the native ecology and economy. Introduced pathogens may cause diseases and death in humans.

Clonidine
Introduced from Europe to the United States and Japan.
Introduced to South America, East of Mexico and other areas.
Marine brown algaes appear to be being introduced with ballast water. One example is an alga that began colonizing a Pacific island in 1983, spreading across South America, affecting more than a million people and killing more than ten thousand by 1998. This alga was previously been reported only in Europe.

Clonidine Water Bug
Introduced from Europe to North America.
Introduced to North America from Europe.
Large populations that distribute the species to Europe and other regions have been reported only in Europe.

Yellow Crab
Introduced from Europe to North America.
Introduced to North America from Europe.
Large populations that distribute the species to Europe and other regions have been reported only in Europe.

Red Sea Sea Star
Introduced from Europe to North America.
Introduced to North America from Europe.
Large populations that distribute the species to Europe and other regions have been reported only in Europe.

South Island Kelp
Introduced from Europe to North America.
Introduced to North America from Europe.
Large populations that distribute the species to Europe and other regions have been reported only in Europe.

Red Sea Crab
Introduced from Europe to North America.
Introduced to North America from Europe.
Large populations that distribute the species to Europe and other regions have been reported only in Europe.

European Green Crab
Introduced from Europe to North America.
Introduced to North America from Europe.
Large populations that distribute the species to Europe and other regions have been reported only in Europe.

North Pacific Sea Urchin
Introduced from Europe to North America.
Introduced to North America from Europe.
Large populations that distribute the species to Europe and other regions have been reported only in Europe.

North American Comb Jelly
Introduced from Europe to North America.
Introduced to North America from Europe.
Large populations that distribute the species to Europe and other regions have been reported only in Europe.

Yellow Sea Star
Introduced from Europe to North America.
Introduced to North America from Europe.
Large populations that distribute the species to Europe and other regions have been reported only in Europe.

Map: Shows the world with ten red dots indicating the origin of the species. A legend indicates 'Origin of the species'.

Footer: The species presented here are for illustrative purposes only. Their introduced ranges may be greater than depicted. There are numerous other examples of serious marine bio-invasions around the world.

Ballast water contains plants, animals, viruses and bacteria

Non-native and exotic species can cause ecological damage to aquatic ecosystems, even human death.

Introduction

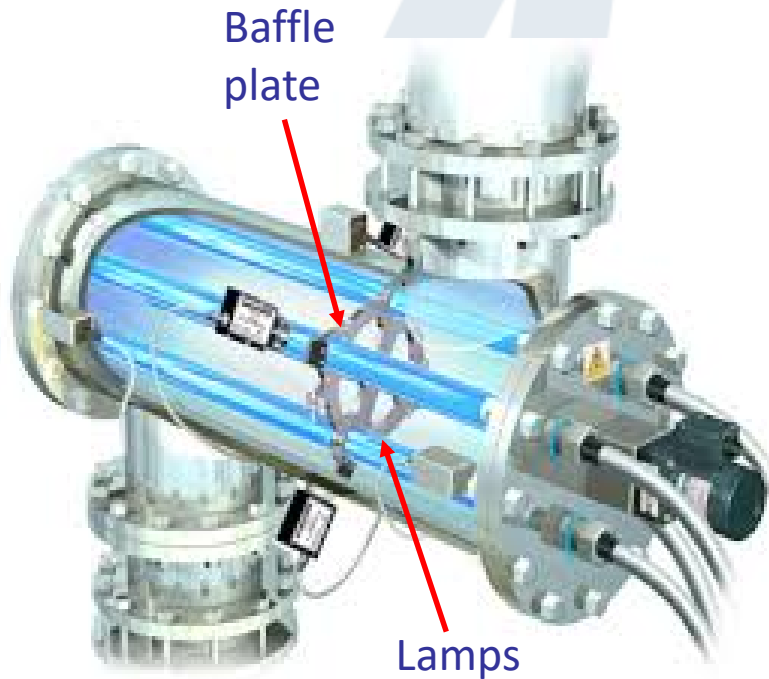
Ballast Water
Management
Convention/
National
Regulation

Mechanical--separation and filtration

Physical--ozone, electrical currents
or UV radiation

Chemical--biocides or a form of
chlorination

Introduction

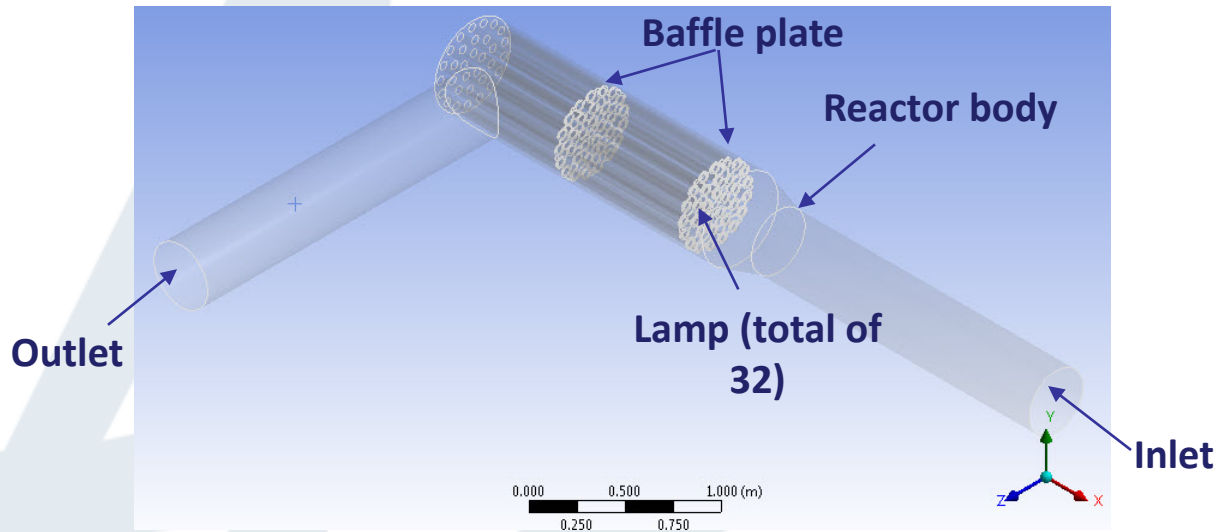


Picture of a UV reactor

UV reactor for ballast water treatment

- UV light can disrupt the structure of DNA or RNA of the microorganism.
- UV light energy is absorbed by DNA or RNA and it results in the photochemical damage.
- The damaged DNA or RNA cannot copy during replication. This inactivates the microorganism.
- It does not introduce any by-product during the procedure.

Introduction



Schematic diagram of LBW850e UV reactor

- Fluid flow ---- highly turbulent.
- Microorganisms trajectories ---- complex and unpredictable.
- Radiation ---- difficult to measure.
- Numerical simulations plays important role in understanding various processes involved in the reactor.

Introduction

- UV Transmittance (UVT)--- The measure of UV energy at a particular wavelength or frequency which is actually transmitted through water from the UV lamp.
- UV dose---the amount of UV radiation to which a bacterial is exposed.

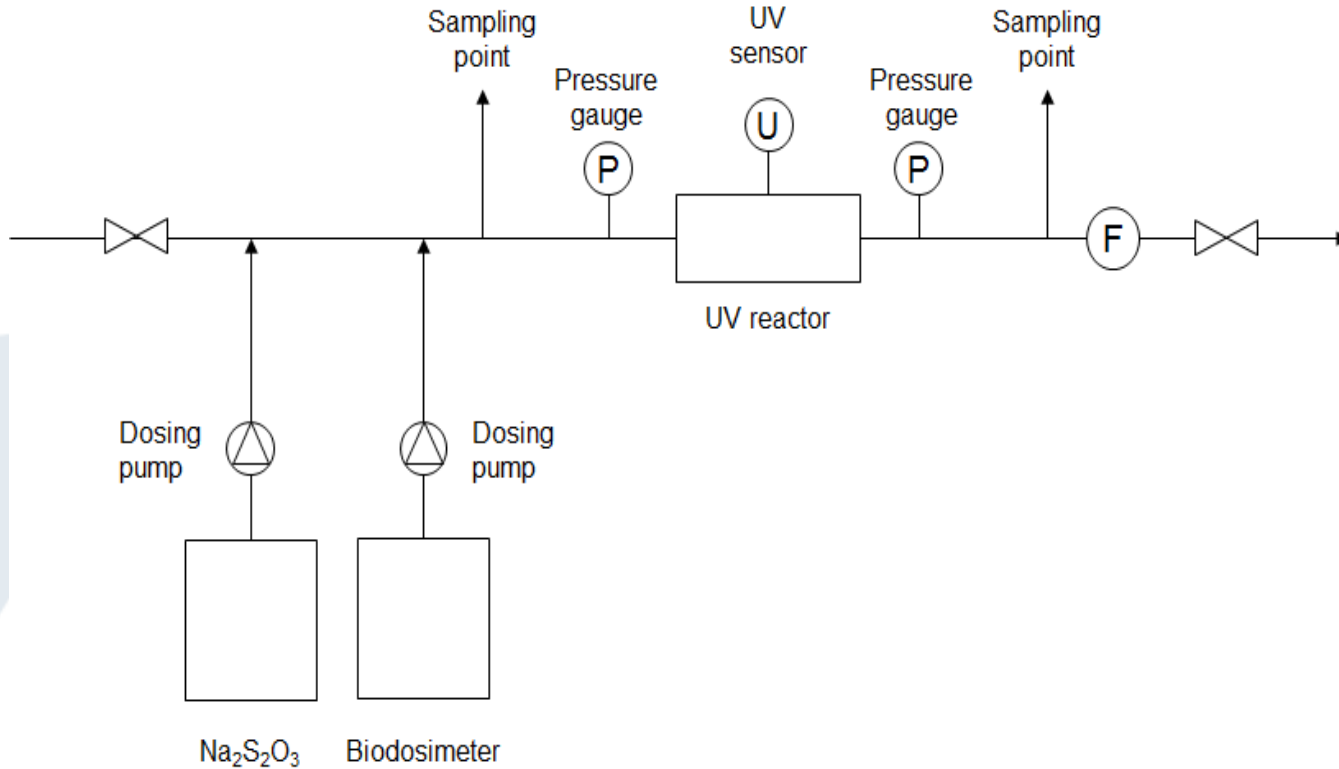
$$D = \int_0^t E dt$$

- Log inactivation---the number or percent of microorganisms inactivated (killed or unable to replicate) through the disinfection process.
- RED---reduction equivalent dose

$$RED = k \log \left(\frac{N}{N_0} \right)$$

Experimental study

Full scale test



Schematic diagram of the experimental set-up

Numerical simulation

Three steps for simulation

1. Flow simulation

- Steady state simulation
- κ - ε model for turbulent flow
- SIMPLE method for coupling of the pressure and velocity
- 2nd upwind scheme for convection term in the N-S equation
- 1st order upwind scheme for κ - ε equations.

Numerical simulation

Three steps for simulation

2. Radiation simulation

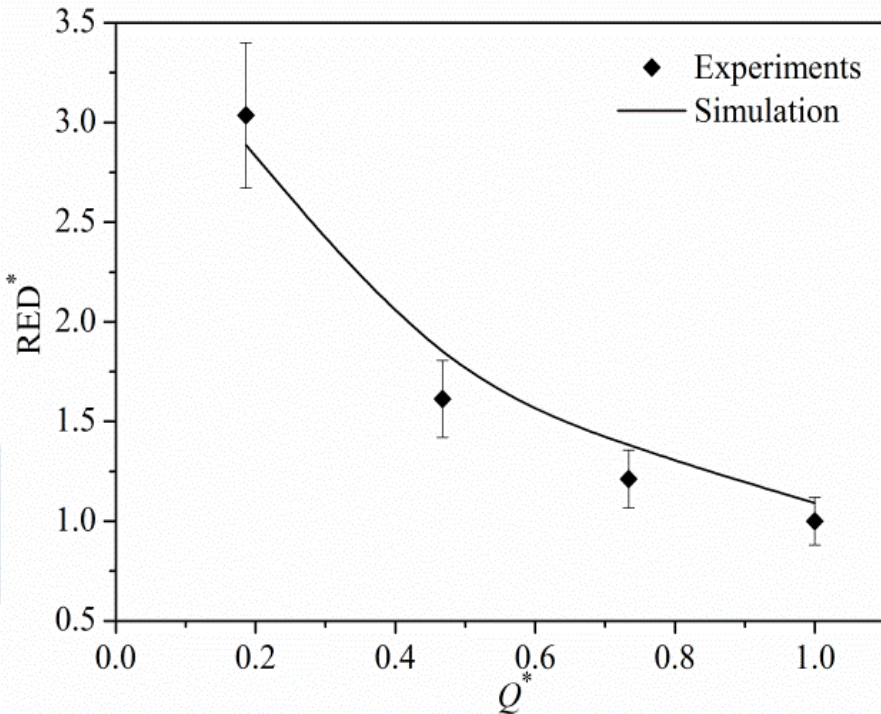
- Discrete Ordinates (DO) model

$$\nabla \cdot (I \cdot \vec{s}) + aI = an^2 \frac{\sigma T^4}{\pi}$$

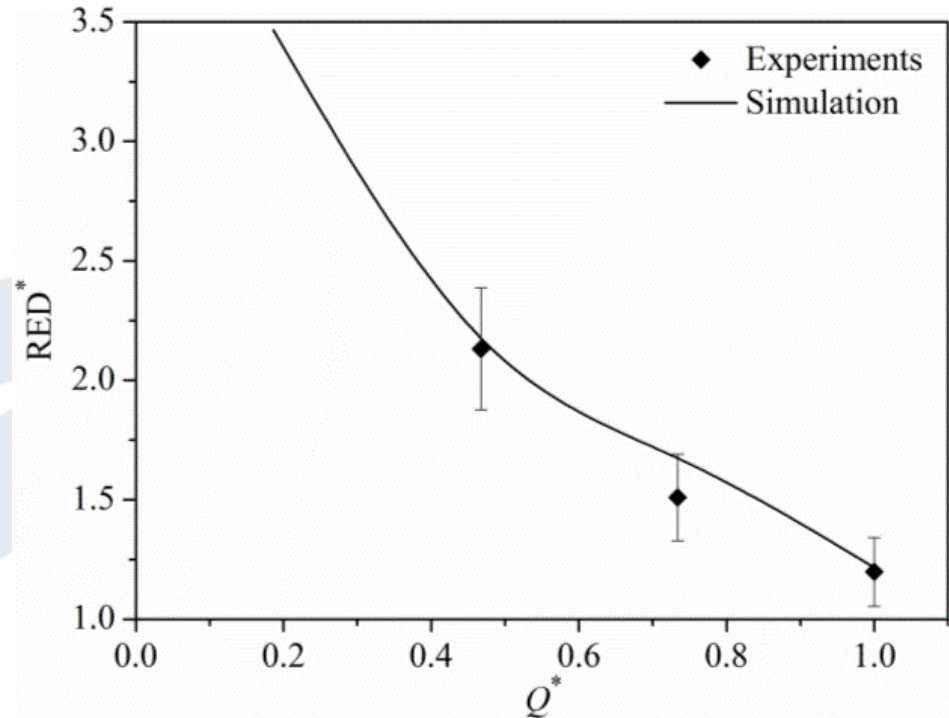
3. Particle simulation

- Discrete phase model (DPM)
- One way coupling
- Particle diameter: 30 μm
- Three different kinds of particle numbers: 5000, 10000, 20000
- UDF to calculate UV dose

Results discussions



(a)

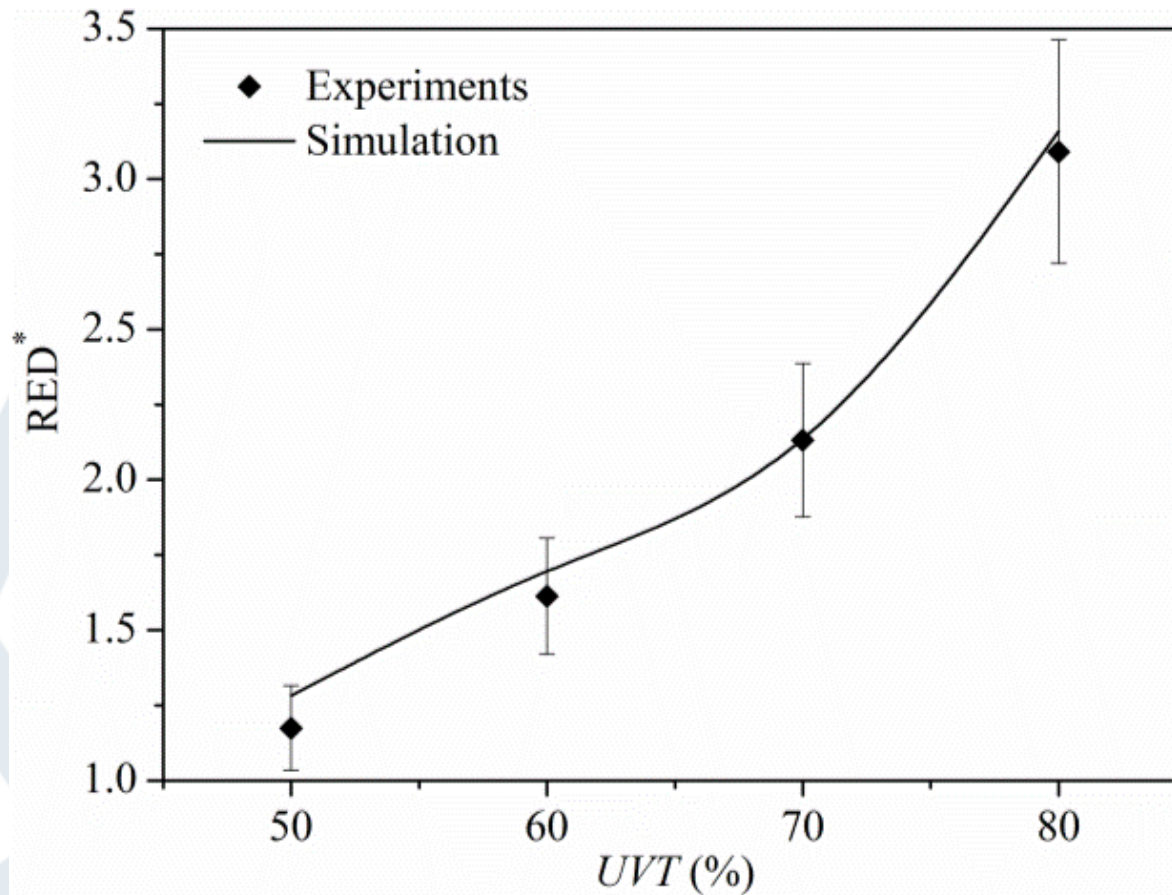


(b)

Variation of RED^* under different flow rates for LBW850e at (a) 60% UVT, and (b) 70% UVT

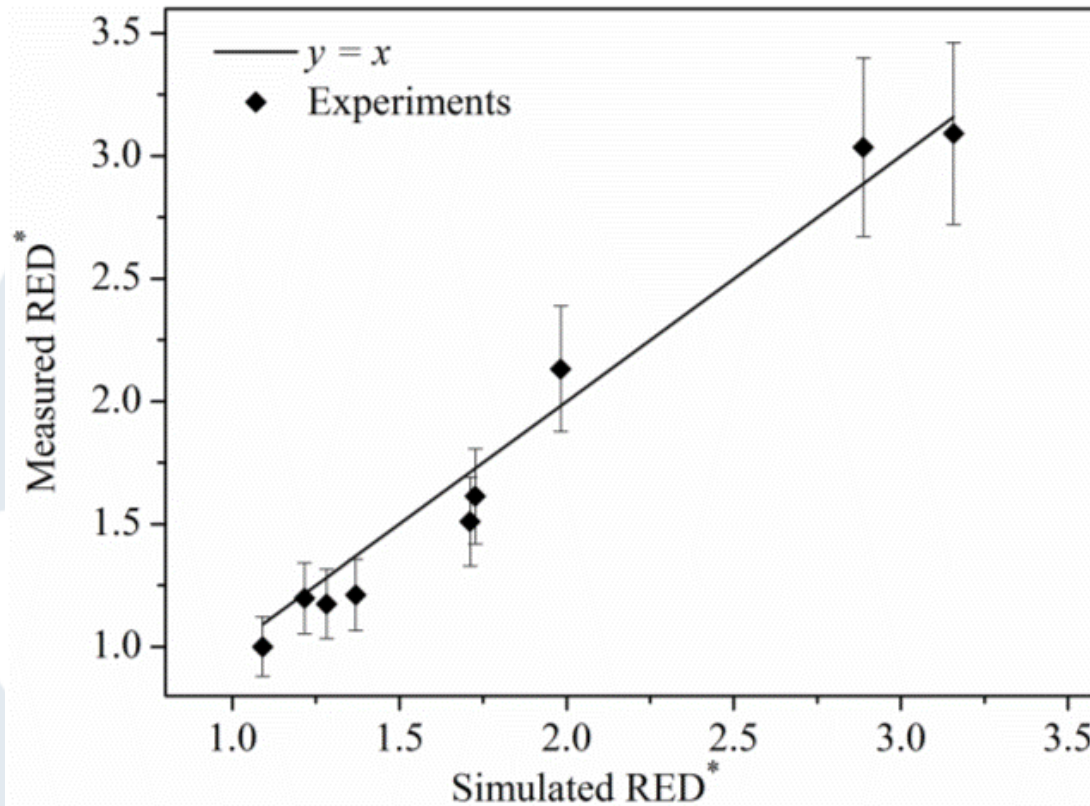
RED^ is dimensionless with the RED under flow rate of $338 \text{ m}^3/\text{h}$ and 60% UVT.*

Results discussions



Variation of RED* under different UVT for LBW850e at $Q^* = 0.47$

Results discussions



The simulated RED* and measured RED* for B. Pumilis

Conclusions

- A numerical model for simulation of ballast water treatment in UV reactor is developed.
- The increase of flow rate decreases the resident time for the microorganism to stay in the UV reactor, therefore, leading to the decrease of RED correspondingly.
- The increase of UVT increases the RED due to the clearance of the water which allows more energy to be transported from UV light to microorganisms.
- With the validation of the numerical model developed for the ballast water treatment, it can then be applied to evaluate some other reactors without doing experimental test. This can help the industry partners to save cost significantly.



Thanks