Treatment of the ballast water using the oxidation method

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Abstract: Ships provide pollution in many ways, as: pollution with petroleum products or residues, pollution with noxes, pollution with residual and ballast water. All these kinds of pollution affected the environmental. Recent studies show that maximum pollution is provided in the port area, caused by ships and by the other elements of the port structure and by the operation done for port maintenance and cargo manipulation. In this paper we will try to present some pollution causes and how is possible to avoid them.

Unconfined open water disposal has been traditional method of dredged spoils disposal because it is the most economical option. For the contaminated dredged material we propose the following disposal options: thin layer disposal, confined land disposal, open water disposal with capping, specialized treatment.

Key-Words: ballast water, pollution, advanced oxidation

1 Introduction
PureBallast is fully backed by Alfa Laval’s global network of service and support and incorporates patented Wallenius AOT (Advanced Oxidation Technology). PureBallast system is based on advanced oxidation technology, which is a chemical-free process. In both pilot and onboard tests, the highly advanced method has proven an effective means of meeting the IMO requirements.

2 Experimental
2.1 Description of the method
The AOT units contain titanium dioxide catalysts, which generate radicals when hit by light. The radicals, whose lifetime is only a few milliseconds, break down the cell membrane of micro-organisms – without the use of chemicals or the creation of harmful residuals.

Depending on a ship’s ballast water volume, PureBallast involves one or more AOT units. AOT units treat the water during ballasting and deballasting operations as we see in figures below.

Fig. 1 How Wallenius AOT action

Fig. 2 Ballast water operation

Fig. 3 Deballasting water operation
2.2 The general mathematical model of cost calculations

To calculate the costs for implementing the ballast water treatment method we have to define the units of measurements: [Eur/tons of cargo transported], [Eur/m3 ballast transported] or [Eur/year] we want to use. The total cost is studied per annum. The cost formula contains three terms, as follows [1, 2]:

\[ C_T = C_I + C_C + C_{OM} \]  

Where:
- CT - the total cost, [Eur/year];
- CI - the investment cost, [Eur/year];
- CC - the consumption cost, [Eur/year];
- COM - the operation-maintenance cost, [Eur/year];

The cost per unit will be expressed by [Eur/m3] (Eur per ton of ballast water).

The total cost obtained in [Eur/year], will have to be divided by the total quantity of ballast exchanged / treated during one year [m3/year], in order to obtain a cost per unit [Eur/m3].

\[ C_U = \frac{C_T}{VT} \]  

The total quantity of the take in ballast water during one year is VT-Ex=123345[m3/year]. If the ballast water has been treated in a treatment equipment installed on board, was not need exchange and the total quantity of ballast water take in was VT-T = 92484[m3/year].

3 Results and discussion

The investment costs are represented by the acquisition costs. Alfa Laval sold the system including the installation cost.

\[ C_I = C_{AQ} \]  

For the acquisition costs [CAq] I considered 500000 [Eur] the equipment's total purchase price having life expectancy 10 [years], the annum rate is CAq [Eur/year].

\[ C_{AQ} = \frac{X[Eur] \cdot \frac{1}{T_{ani}}}{} = 500000[Eur/year] \]  

The consumption cost comprises of the energy costs (used by the ballast pumps and treatment plants), and the costs of consumption for Pure Ballast system. The producer has estimated the consumption cost, including annual service at 0.07[Usd/m3] (~ 0.0515[Eur/m3]). To calculate the energy costs Cen [Eur/year] I consider the price for 1 kWh = 0.125 [Eur].

\[ C_C = C_{ballast - system} + C_{Pure - Ballast} \]  

Furthermore we need the followings:
- The electrical power used by the equipment P [kW];
- The total volume of ballast treated per year VT [m3/year];
- The treatment capacity of the equipment RT [m3/h];

The total electrical power consumption per year will be NT [kWh/year] and the cost of the electrical power consumed will be Cen [Eur/year].

- ballast pump capacity \( R_p = 500 \) \([m^3/h]\); consumption \( N_{en}^{pp} = 45 \) \([kWh]\);

\[ N_{en}^{PP} = \frac{VT}{R_p} \]  

- ANTI-Fouling \( R_{a-f} = 1870 \) \([m^3/h]\); electrical power consumption \( = 5 \) \([kW]\);

\[ N_{en}^{a-f} = \frac{VT}{R_{a-f}} \]  

The total consumption cost will be:

\[ C_c = C_{ballast - system} + C_{Pure - Ballast} + 0.0515[Eur/m^3] \]  

The operation-maintenance cost comprise of the spare parts, the equipment maintenance, the training courses if is necessary and the salary for crewmembers.

\[ C_{OM} = C_{SP} + C_{TC} + C_S \]
To calculate the spare parts cost [CSP], I need the number of replacement parts per year. In order to do that I calculate the number of running hours of the treatment equipment per year and I consider that the spare parts Bi will be replaced at \[\text{nrh/SP}\] hours per part. The individual cost per spare parts is Bi [Eur/SP].

The number of Bi replacement parts per year (X - the number of parts of Bi kind) is NSP [SP/year] and the cost of Bi spare parts per year is CSP-Bi [Eur/year].

\[
N_{SP} = \frac{N_r \text{[h/year]}}{\text{nrh/SP}} \times X
\]

(12)

\[
C_{SP-Bi} = N_S \left(\frac{\text{SP}}{\text{year}}\right) \times \text{Bi}[\text{Eur}/\text{SP}] = N_S \times \text{Bi}[\text{Eur}/\text{year}]
\]

(13)

The total cost of spare parts will be [3]:

\[
C_{SP} = \sum_{i=1}^{N_S} C_{SP-Bi} \approx 400[\text{Eur/year}]
\]

(14)

To calculate the salary for crewmembers we need the followings: the salary per hour and the number of operation hours of equipment. The salary per hour is Dh [Eur/h] and annual payment for this job is CS [Eur/year].

\[
D_h[\text{Eur/h}] = \frac{D[\text{Eur/month}]}{30[\text{h/month}]} = \frac{D[\text{Eur/month}]}{30[\text{h/month}]} \times \frac{30[\text{h/month}]}{240[\text{Eur/h}]}
\]

(15)

C_S [Eur/year] = N_r[\text{h/year}] \cdot D_h[\text{Eur/h}] = 1500[\text{Eur/year}]

(16)

For the treatment equipment which need special operating I consider needful to train two crewmembers for every ship (Cost of training courses).

\[
C_{TC} = 2\text{courses} \times 300[\text{Eur/Course}] = 600[\text{Eur}]
\]

(17)

The operation-maintenance cost is:

\[
C_{OM} = C_{SP} + C_{TC} + C_S = 2500[\text{Eur/year}]
\]

(18)

The total cost for implementing on board this method for treating ballast water by Advanced Oxidation Technology is:

\[
C_T = C_I + C_C + C_{OM} = 54611.79[\text{Eur/year}] + 0.0515[\text{Eur/m}^3]
\]

(19)

The cost in [Eur per unit] of treated ballast [m³] will be:

\[
C_U[\text{Eur/m}^3] = C_T[\text{Eur/year}] \div 0.642[\text{Eur/m}^3]
\]

(20)

4 Conclusion

The cost of treating ballast water by Advanced Oxidation Technology is more expensive than other methods that can be applied on board.

<table>
<thead>
<tr>
<th>Method</th>
<th>Cost in Eur per unit of treated ballast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential method</td>
<td>0.014 – 0.30</td>
</tr>
<tr>
<td>Flow through method</td>
<td>0.019 – 0.171</td>
</tr>
<tr>
<td>Cyclonic separation +UV</td>
<td>0.149 – 0.528</td>
</tr>
<tr>
<td>Filtration</td>
<td>0.065 – 0.177</td>
</tr>
<tr>
<td>Advanced Oxidation Technology</td>
<td>0.642</td>
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</tbody>
</table>

VTT Industrial Systems, Finland Own results

The method that will be choose for treating ballast water on board depends on the cost per unit but more important depends on the requirements of International Maritime Organization.

References:


