Review of ultraviolet light, ultrasound and ozone technologies

Executive Summary

Different treatment methods have been proposed for onboard ballast water treatment options, among those also ultraviolet light (UV), ultrasound (US) and ozone treatments. The literature survey that was made in the beginning of the project indicated that all the methods have potential for ballast water treatment and numerous reports were available presenting the research activities carried out around the world. The technology that has been studied widely appears to be UV, whereas US seems to have very limited applications in terms of ballast water treatment. In addition to the single technologies also the combinations of US + UV and UV + hydrogen peroxide (H2O2) were tested as a part of the hurdle experiments.

UV treatment is well established in various onshore applications such as different water treatment plants and aquaculture. It achieves disinfection by breaking chemical bonds at the DNA and RNA molecules and proteins in the cell. Regarding the ballast water treatment option various laboratory scale tests has been completed and few full scale onboard applications are under evaluation. Many studies suggest that UV treatment requires a primary treatment in order to perform efficiently but in this project only secondary treatment options were included in the test programme.

The US applications in ballast water treatment are rather new. US is generated by transducer which converts the mechanical or electrical energy into high frequency vibration. The effect of US treatment is based on physical and chemical changes resulted from cavitation. US technology has been utilized in water treatment and food industry to control the growth of micro-organisms.

Ozone has been widely utilized in onshore applications such as water disinfection, aquaculture and power plants cooling systems. Ozone must be generated onsite since it is unstable in atmospheric pressure. The ozonisation of seawater differs from ozonisation the fresh water mainly due to the presence of bromide and elevated pH of sea water. Contact time is essential when ozone disinfection will be utilised.

In the first phase the methods were tested in the laboratory scale both in Finland and in the UK. After the evaluation of the laboratory scale test results the onshore trails were carried out in Tvärminne, Finland, in order to confirm the proper operation of the devices and to obtain information about the efficiency of the treatment options against the organisms in the Baltic Sea marine environment. The effects on phytoplankton and bacteria were not studied.

The results from laboratory trials were partly confusing due to the various scale effects related to the test system and thus the results were difficult to explain. The results from Tvärminne onshore trials with considerable reliability for UV varied between 78-100 %, for US treatment between 80-99 % and for ozone treatment 95-100 % depending on the organism group, flow rate and ozone dosages. The combination of US and UV achieved mortality rates between 97-100 % and the combination of UV + H2O2 between 94-100 %. Even in those cases where 100 % mortality was observed, the requirements for maximum allowable number of viable organisms per water volume set by IMO were not necessarily confirmed due to the relatively small sampling volume. It must be also emphasized that only moderate (200-1,600 l/h) flow rate were used. During the trials in the UK also possibly modification of ballast water properties and contents by the treatments was identified. Ozone treatment causes a significant increase of the Redox potential with possible consequences on metal corrosion, coatings and gaskets. However, these effects can be minimised by careful material selection.

Costs evaluations were carried out in order to provide rough estimations of treatment costs for each treatment option in two different case study ships. It appears that for UV treatment the costs for treated ballast water varies between 0.045 - 0.11 €/m^3, for US 0.28 - 0.43 €/m3 and for ozone 0.20 - 0.24 €/m^3. The effect to the shipping costs due to the treatment varies between 1 - 14 % per voyage for the case study ships. These values represent the cost evaluation for full scale application based on current level of treatment technology available. It is more likely that treatment costs would drop down when new test configuration are developed. It must keep in mind that different source and background information has been available for each study and therefore reasonable comparison between the methods is difficult.

In most of the cases the treatment processes are not predictable due to the different water properties and operational aspects. Therefore further studies and full scale trials are required in order to optimise the process conditions for each treatment technology. One option for testing and evaluation of various treatment methods could be container installations, where treatment processes would be designed for full scale flow rates and water volumes. This option would also enable different marine environments to be included in the test programme. In addition to the secondary treatment options also primary treatment options, i.e. filters and cyclons, should be included since many secondary treatment options require primary treatment in order to perform efficiently. In addition to the treatment technologies also the sampling and analysing methods needs to be developed in order to ensure reliable results and easyto- use samplers for the ship crew.