Task 4.3 – Biological de-oxygenation. Sea trials.

Executive Summary

Biological de-oxygenation is based on the fact that addition of nutrients to ballast water will stimulate the growth of the indigenous bacteria in the water. The solubility of oxygen in water is low, and the bacterial growth will consume the dissolved oxygen. When the ballast water becomes anoxic, organisms that require a steady supply of oxygen will die. The aim of the studies reported here was to test biological de-oxygenation in full scale onboard a ship.

The study was performed on the car truck carrier MS Don Quijote owned by the Swedish shipping company Wallenius Lines, on a transatlantic voyage from Southampton in England to Manzanillo in Panama (20^{th} – 30^{th} June, 2003). The weather was nice and calm throughout the voyage.

Four ballast tanks were used in the experiments. Nutrient solution was added to two tanks with volumes of 285 m^3 and 326 m^3, respectively. Two other tanks, both with a volume of 513 m^3, were used as untreated controls. The ballast water in the tanks was exchanged with new water from the English Channel during the early hours of the 21^{st}. The nutrient solution was added to the treated tanks through the sounding pipe after they had been emptied, and new seawater was pumped into the tanks immediately after the addition. The experiment was terminated after 7 days (28^{th}).

The temperature in the ballast water increased from 16-18 ºC immediately after filling of the tanks to 28-29 ºC at the end of the experiment.

In the treated water, the concentration of viable bacteria increased within the first 48 hours from around $1 \cdot 10^4$ to $6 \cdot 10^7$ GU (growth units)/ml. The final concentration is comparable to what was observed in previous laboratory studies. As a result of the bacterial growth, pH decreased from around pH 8 to around pH 6.5. The dissolved oxygen measurements gave a more ambiguous result, and only on the last day of the study (day 7) did they clearly indicate that the ballast water was anoxic. This may be due to practical problems with the dissolved oxygen measurements. The biological results indicate that the treated water became anoxic no later than 2-3 days after start. In the control tanks the dissolved oxygen concentration was high throughout the experiment.

No significant amounts of H_2S were formed in the treated ballast water.

Due to the treatment the discharged water was enriched in nitrogen (N) and phosphorous (P). The discharged water contained 2-2.5 g inorganic N/m^3, mainly as ammonium, and about the same amount as organic N in bacteria and other organisms, around 70 mg/m^3 (as P) phosphate, and probably around 0.6 g/m^3 organically bound P in organisms and other organic molecules. The concentration of bacteria in the discharged water was estimated to around 20 g (dry weight) per m^3.

The effect of biological de-oxygenation on the survival of phytoplankton is unclear. From start the ballast water contained an average of 879 diatoms and dinoflagellates per litre (12 analyses, range: 124-2450 cells/litre). This is below the most stringent of the suggested IMO (International Maritime Organisation) standards, which has a limit of maximum 1000 viable phytoplankton cells per litre in discharged ballast water. In the treated water the concentration of diatoms and dinoflagellates decreased during the treatment to

around 10 % of the initial concentration. In the controls, the decrease, if any, was much smaller. On the other hand, the concentration of chlorophyll *a* decreased to around 10 % of the initial value in the control tanks, but decreased only slightly in the treated tanks. Because the cell count was restricted to diatoms and dinoflagellates, and the viability of the phytoplankton was not determined, it is not possible to resolve these conflicting results, but the results indicate that the effect of biological de-oxygenation on the viable phytoplankton population is limited. The lack of light in the ballast tanks probably also reduced the viability considerably in the control tanks, so that doing nothing may yield almost the same reduction in the viable phytoplankton population as the de-oxygenation treatment.

Biological de-oxygenation significantly reduced the concentration of zooplankton in the ballast water. From start the ballast water contained an average of 2570 zooplankton per m^3 (12 samples, range 856-10613 org/m^3), mainly copepods and nauplii. This is well above both the suggested IMO standards, which have limits of 1 or 100 viable organisms larger than 50 µm or 80 µm (*i.e.* zooplankton and larger organisms) per m^3 in discharged ballast water. This study counted all organisms above 50 µm. The IMO standard relates specifically to *viable* organisms, but because the sampling via the fire pump killed a substantial fraction of the zooplankton in the samples, sometimes more than 90 %, it was not possible to estimate the viable fraction in the ballast water. However, even the total concentration, *i.e.* both live and dead, in the treated water at the end of the study (6 samples, range 1-89 org/m^3, average 27 org/m^3) was significantly lower than the least stringent of the proposed IMO standards. The concentration of zooplankton decreased during the study also in the untreated water, but the concentration at the end of the study (5 samples, range 329-591 org/m^3, average 411 org/m^3) was still so high that one has to assume a very low viable fraction (<25 %) in order to fulfil the requirement of max 100 viable organisms per m^3. The most stringent suggested standard (max. 1 viable org/m^3) may be difficult to achieve by de-oxygenation: in the current study one has to assume a viable fraction of less than 3 % in the treated water at the end of the study in order to achieve this level.