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Complying with emissions regulations: calculating the acid plume from ships' desulphurisation equipment

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Marine diesel contains sulphur compounds, which generate sulphur oxide (SO_x) pollution and acid rain. Ships can use mitigating technologies to reduce their SO_x emissions, but these can also have a negative environmental impact. The International Maritime Organization (IMO) introduced stringent legislation to control these, aspects of which are incorporated into EU policy. This study examined the implications of the IMO's policy and recommends a number of design solutions to help ships comply.

Shipping is a significant source of greenhouse gas emissions, accounting for 2.7% of global CO_2 emissions in 2013[1]. Although CO_2 is produced in larger quantities, by-products of fossil fuel combustion like SO_x can have disproportionately large effects on the environment. SO_x emissions acidify soil and water, which negatively impacts biodiversity. Sulphur in fuel also contributes to the formation of secondary particulate matter, which is harmful to human health. Consequently, the International Maritime Organization introduced Regulation 14 to establish SO_x emission limits, which are particularly severe in Emission Control Areas (ECAs), including the Baltic and North Sea areas.

One way for ships to comply with these requirements is to use naturally occurring low sulphur fuel, but this is a scarce resource. Alternatively, fuel can be refined to reduce its sulphur content with an expensive distillation process. Moreover, some ships, depending on their business characteristics, use cheaper, high sulphur fuel alongside exhaust 'scrubbers', which reduce SO_x emissions.

Commonly used 'open loop' marine scrubbers use seawater to spray the flue gas to capture SO_x and subsequently discharge the 'exhaust gas wash-water' back into the ambient. However, SO_x forms sulphuric acid on contact with water and thus locally acidifies the seawater.

IMO resolution MEPC.184(59)[2] is the key regulation on acidic scrubber discharges. While the EU is not a member of the IMO, EU Directive 2012/33[3] discusses emission abatement methods, including exhaust gas cleaning systems, and refers directly to this resolution.

The resolution provides two ways of determining the pH value of the exhaust water plume. The first requires a pH value of no less than 6.5 at the discharge point during operation, a condition that cannot be met, since real scrubber wash water has a pH value closer to 3.

The second option allows for a pH value of 6.5 at a distance of 4 metres from the discharge point, measured when the ship is at rest in port. This is also difficult to achieve, because the main engine needs to operate in order to generate enough SO_x but cannot operate while in port for safety reasons.

Research into the factors preventing ships from meeting the second requirement of the regulation identified several variables which can influence the pH of wash water, including the dilution of seawater. To investigate this further, the researchers carried out a series of titration experiments, in which they acidified samples of seawater taken from Brighton and the River Thames in the UK. The experiments formed the basis for titration curves that can be used to calculate the dilution required to raise the pH of the discharge to 6.5.

Continued on next page.

1. Second IMO greenhouse gas study. See: https://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Second-IMO-GHG-Study-2009.aspx

2. MEPC 59/24/Add.1 Annex 9. Guidelines for exhaust gas cleaning systems. See: http://www.wrsystems.com/wp-content/uploads/2012/08/emsys_mepc_184591.pdf

3. Directive 2012/33/EU amending Council Directive 1999/32/EC as regards the sulphur content of marine fuels. See: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:327:0001:0013:en:PDF

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The study also investigated the impact of flow rate, ship power, dilution prior to discharge, and the size of the discharge port. The findings led to a number of design solutions. For example, the study found that the number and arrangement of port discharge holes (from which the seawater is emitted) can be optimised to ensure a pH of 6.5 at 4 metres distance. The study recommends the use of multiple ports and provides an equation to estimate the number and size of discharge ports necessary for different ships. They concluded that 5, 10 and 15 megawatt (MW) ships should have 9, 18 and 27 outlet ports, respectively.

However, adding several discharge ports can be impractical for large ships and low alkaline waters. In these situations, the study suggests diluting the wash water on board or adding an alkaline agent to reduce overall acidity.

The study also found issues with compliance and enforcement. The current method of testing, which involves travelling out on a boat to collect samples, is unsafe and can lead to estimates of pH that are inaccurate by 1–1.5 units. Instead, the study suggests measuring the temperature at the point of discharge. These temperature measurements could be used to calculate dilution at 4 metres and the titration curves can be used to determine the pH of the seawater.

Since this paper was published, a further Regulation (MEPC.259(58)) has been agreed, which allows for numerical simulation to determine the pH value of the exhaust water plume. The simulation is based on an earlier iteration of the work presented in the present paper.