

THE FATE AND BIOAVAILABILITY OF FUEL SPILLS IN POLAR MARINE ENVIRONMENTS: EFFECT OF EVAPORATION AND DISSOLUTION

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The Antarctic coastal marine environment harbours a unique ecosystem of marine organisms that are adapted to living under extreme conditions. A key concern for this ecosystem is of pollution resulting from anthropogenic activities, including fuel spills from marine vessels and accidental release during resupply operations and fuel storage at research stations. The risk of a fuel spill incident along the Antarctic coastline is growing with the increase in maritime traffic during recent years from tourism, research and support operations and both legal and illegal fishing in Antarctic waters. Antarctic marine life may be particularly vulnerable to the impacts of fuel spills due to environmental conditions that influence the fate and effect of contaminants. Data on the fate and bioavailability of fuel spills in the Antarctic marine environment is scarce, making assessments of the risk posed by fuel spills difficult. In this study the weathering rates and partition ratios were examined for three fuels commonly used in Antarctic waters, Special Antarctic Blend (SAB), Marine Gas Oil (MGO) and Intermediate Fuel Oil 180 (IFO-180). The main focus was on the evaporation and dissolution rates of the fuels, since evaporation is the process responsible for the majority of weathering loss, while dissolution determines the bioavailable fraction of the fuel. Other processes considered were natural dispersion of the fuels into the water column, and depletion of hydrocarbons from the water column, as these factors also influence the exposure duration of marine biota to the pollutants.

The results show that evaporation is the process most influenced by the cold Antarctic conditions (0°C), with initial evaporation rates 3.5 to 4.1 times slower compared to more temperate conditions (15°C, Fig. 1A, B). The slower evaporation rate allows more hydrocarbons to enter the water column, since the solubility and dissolution rates are affected to a lesser degree by the cold Antarctic conditions. Specifically, 95.1%, 79.9% and 63.2% greater masses of hydrocarbons are expected to enter the water column from SAB, MGO and IFO-180 fuel spills, respectively, in comparison to the same fuel spills under more temperate conditions. The evaporation coefficients that were determined have been incorporated into an oil-spill evaporation model developed by Kotzakoulakis and George (in prep.) that takes into account the diffusion forces inside the body of the oil phase, and the concentration gradient that develops between the surface and the inner part of the spill. The predictions of the oil-spill evaporation model are in close agreement with experimental evaporation data from fuels and crude oil under both polar and temperate conditions (Fig. 1A, B).

The aromatic fraction of a fuel is the main contributor of hydrocarbons dissolved in the water phase, due to the polarity of these molecules induced by the aromatic ring (Fig. 1C). The dissolution of hydrocarbons into the water phase accounts for a minor fraction of the mass loss due to weathering of the fuels, which at 0°C is equal to 1.53‰, 0.67‰ and 0.77‰ of that attributed to evaporation for the SAB, MGO and IFO fuels, respectively. Despite this, the absolute amount of hydrocarbons that are dissolved in the water column at 0°C is 95.1%, 79.9% and 63.2% higher than that at 20°C for SAB, MGO and IFO-180, respectively, because the evaporation rate drop is roughly double that of dissolution. This is an important observation since the dissolved hydrocarbons, together with the dispersed hydrocarbons, are responsible

for the bioavailability of the fuel to marine organisms in the water column. This observation, combined with the slower metabolic rate of the Antarctic marine organisms compared to those in temperate regions, highlights the necessity for measurements of the bioavailability and toxicity of the WAFs produced by commonly used fuels to Antarctic organisms.

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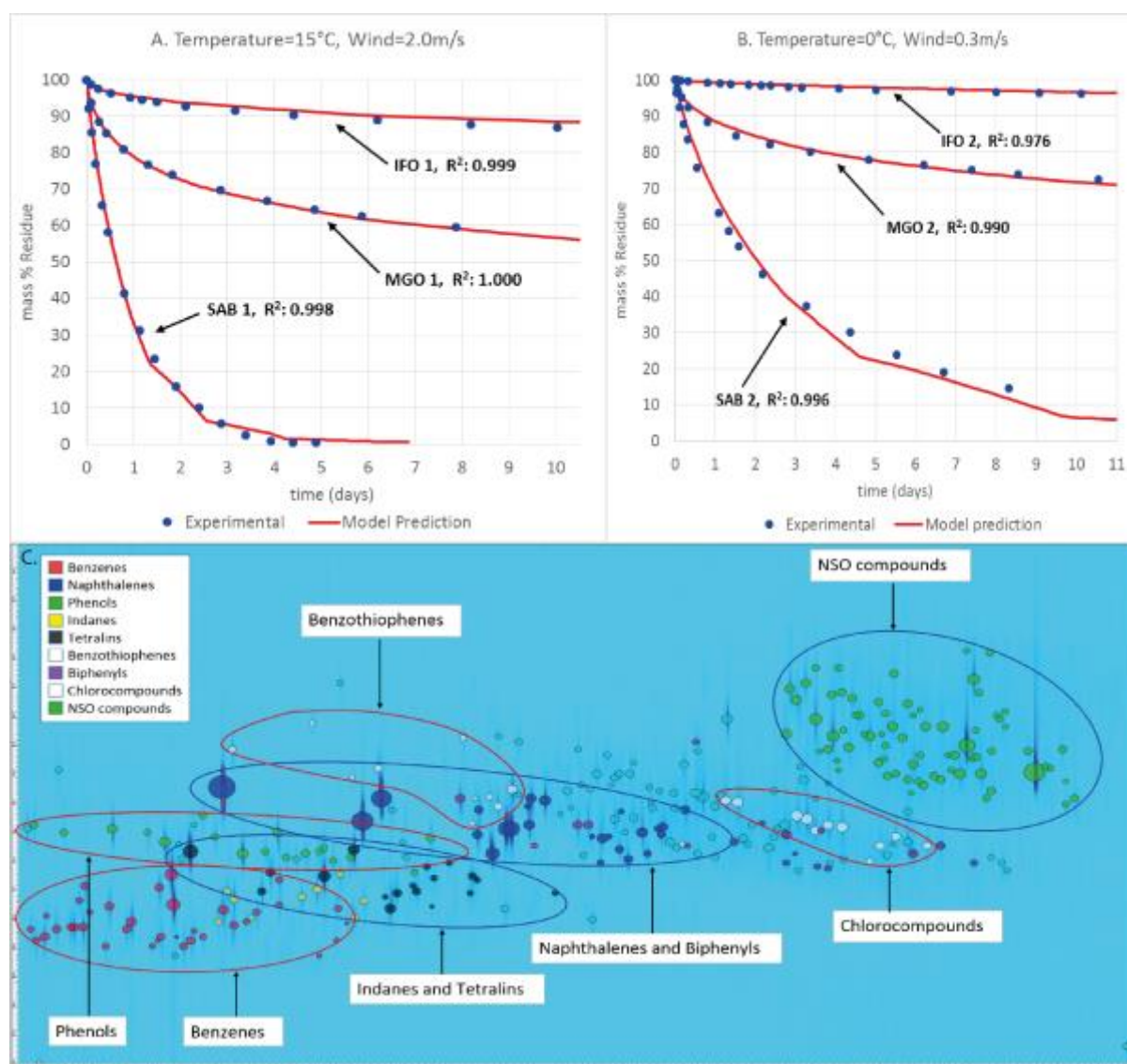


Figure 1 The experimentally determined evaporation extent (blue symbols) of the three fuels (SAB, MGO and IFO-180) at (A) temperate (15°C) and (B) polar (0°C) environmental conditions, and the predicted evaporation curves (red lines) derived from the evaporation model developed by Kotzakoulakis and George (in prep.). (C) Comprehensive two dimensional chromatographic map of the location of the hydrocarbon and NSO groups in the IFO-180 water accommodated fraction. A large amount of heavy NSOs are present in the IFO-180 WAF that are absent from the other two fuels.