Leakage rate of the nerve agent tabun from sea-dumped ammunition

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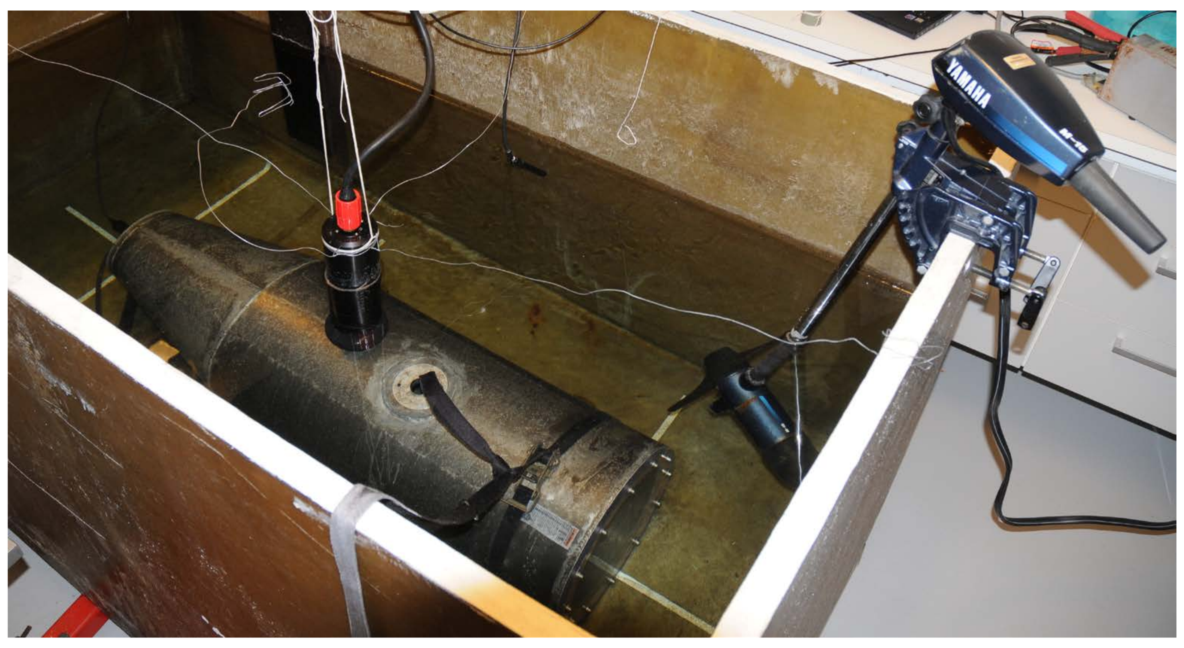
Corroded bomb shell and sediment sampler in Skagerrak in 2002 (Photo:FFI)



Laboratory experiments with a bomb model (Photo:FFI)

Key observations

- The leakage rate from an opening in a bomb shell depends on the area and position of the opening
- As soon as an opening appears, sea water will start leaking into the shell and enhance the hydrolysis
- If the opening is facing upwards, the leakage rate of the nerve agent tabun is very low and most is hydrolysed before it leaks out
- If the opening is facing downwards, the leakage rate is much faster, but pictures from dumped ammunition show predominantly corrosion on the part facing upwards

INTRODUCTION

Large amounts of chemical ammunitions were dumped at sea in many locations worldwide just after the Second World War. Much of the German chemical ammunitions were loaded on to condemned ships and sunk in the deepest part of Skagerrak, outside the Norwegian and Swedish territorial waters. Norwegian authorities gave permission to dumping at 600-700 m depth, 25 nautical miles southeast of Arendal between 1945 and 1947.

The Norwegian Research Establishment (FFI) carried out investigations of some of the scuttled wrecks south-east of Arendal by remotely operated vehicles in 1989 and in 2002. Aerial bombs pierced through by corrosion with the content already leaked out were observed close to the wrecks, both in 1989 and in 2002.

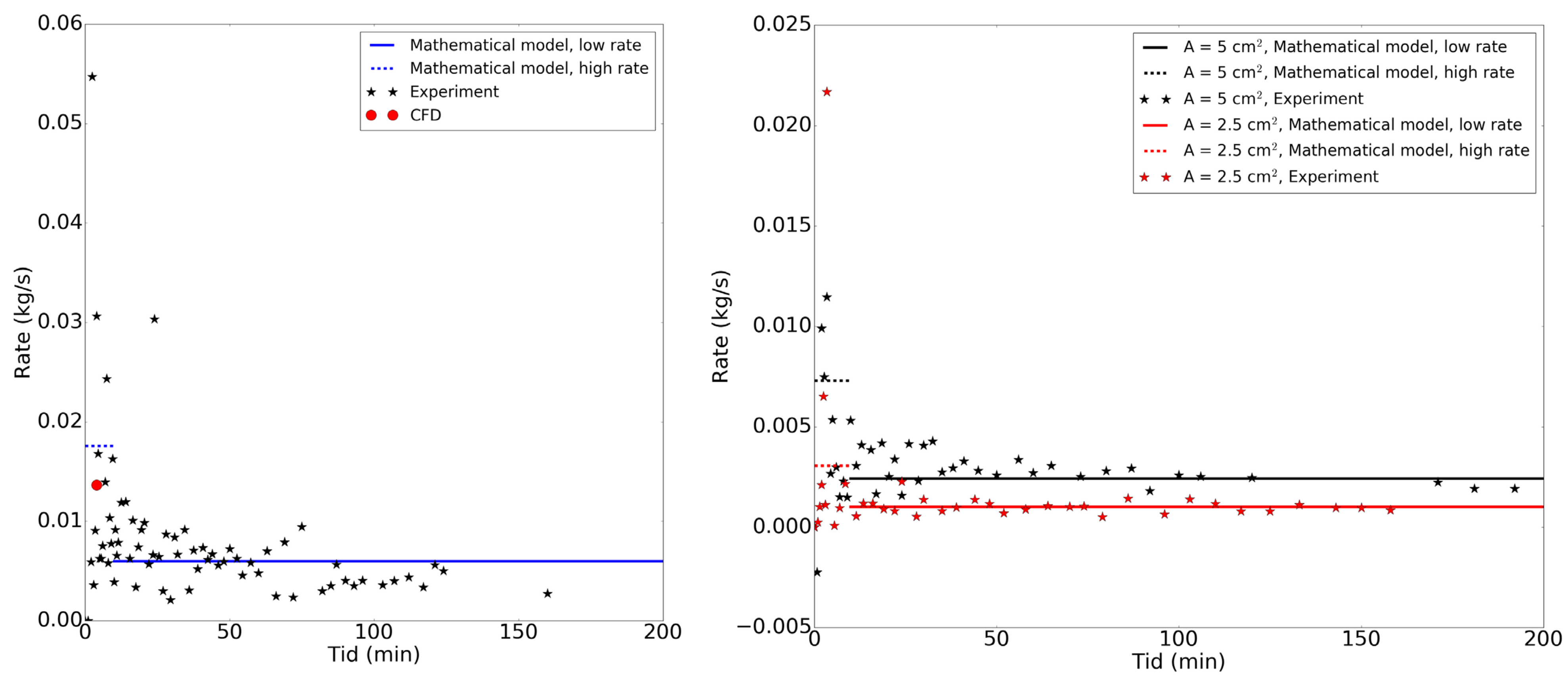
The nerve agent tabun has a density close to water and is the most acute toxic compound dumped in Skagerrak. Experiments to find the leakage rate of a tabun simulant (a solution of table sugar in water with a density of tabun) and fresh water into sea water through a corroded hole have been conducted.

LEAKAGE RATE EXPERIMENTS

A full size model of a K.C.250 III Gr. aerial bomb was made in aluminium with Plexiglas in one end. The bomb model had circular openings with different sizes (2.5 cm^2, 5 cm^2 and 10 cm^2).

The bomb model was filled with fresh water or a sugar solution (tabun simulant), immersed in sea water at room temperature with the opening directed upward. Conductivity was used to measure the salt content inside the bomb and thereby the progress of the leakage.

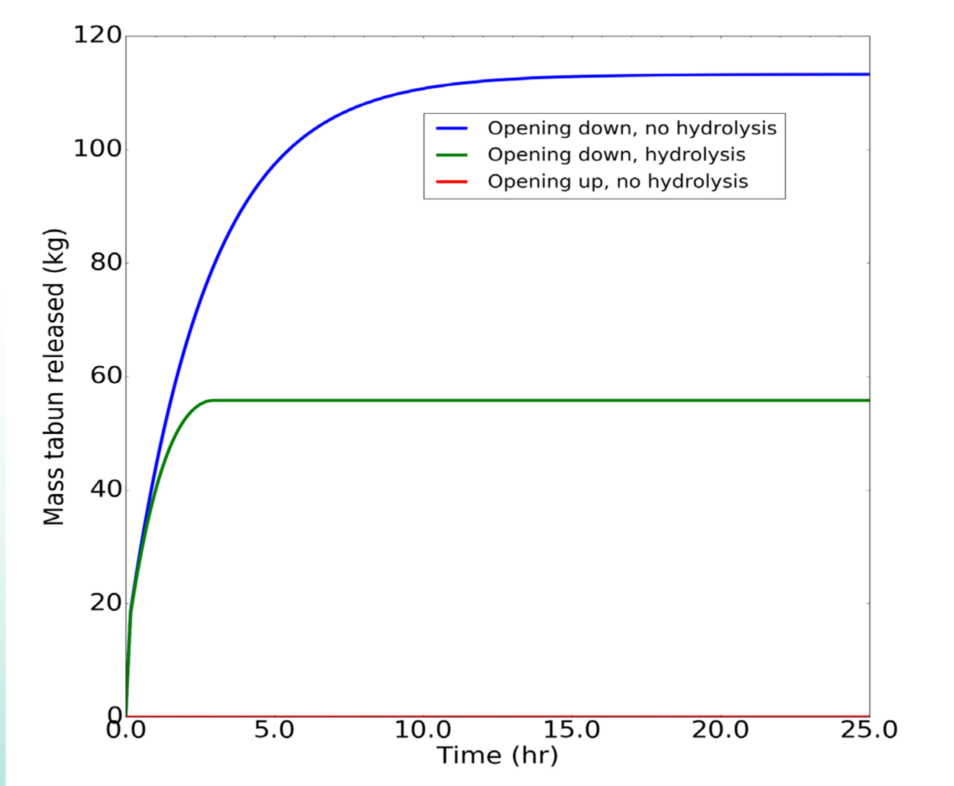
The results from the experiments were compared with a mathematical model using the Buckinghams pi theorem and with Computational Fluid Dynamics (CFD) modelling. Two different initial release rates were used in the mathematical model. The leakage rate from an opening directed downward was also modelled.



Release rates from experiments, mathematical model and CFD with fresh water in the bomb. In the mathematical model, two release rates were used: a high rate for the first 10 minutes and a lower rate after 10 minutes. Left figure: One upward facing opening of 10 cm^2. Right figure: One upward facing opening, 2.5 cm^2 or 5 cm^2.

Opening area (cm^2)	Total mass of tabun released (kg)	Ratio of released mass to initial mass in the bomb (%)	Time until all the bomb contents is released (hours)
1.0	8	7	20
2.5	20	18	13
5.0	36	32	8
10.0	56	49	5

Modelling of the total amount of tabun released from a bomb with different size downward openings. The remaining tabun of the original 113.3 kg will hydrolyse.



Mass of tabun released from the bomb through a hole with area 10 cm^2 as function of time. Opening upward is based on experimental data and downward is based on the mathematical model.

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