Investigation and risk assessment of ships loaded with chemical ammunition scuttled in Skagerrak

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Content

• Dumping operations in Skagerrak after World War II
• Earlier investigations carried out in Skagerrak
• New investigation to locate the shipwrecks
• Fate of chemical agents in sea water
Chemical warfare agents produced in Germany before and during WW2

<table>
<thead>
<tr>
<th>Agent</th>
<th>Type</th>
<th>Boiling point (°C)</th>
<th>Amount (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur mustard</td>
<td>Blistering</td>
<td>216 (solid/liquid)</td>
<td>25 000</td>
</tr>
<tr>
<td>Organoarsenic agents</td>
<td>Vomiting</td>
<td>233-410 (solid)</td>
<td>13 000 – 25 000</td>
</tr>
<tr>
<td>Tabun</td>
<td>Nerve</td>
<td>240 (liquid)</td>
<td>12 000</td>
</tr>
<tr>
<td>Chloroacetophenone</td>
<td>Tear</td>
<td>247 (solid)</td>
<td>7 100</td>
</tr>
<tr>
<td>Phosgene</td>
<td>Choking</td>
<td>8 (liquid/gas)</td>
<td>5 900</td>
</tr>
<tr>
<td>Nitrogen mustard</td>
<td>Blistering</td>
<td>230 (liquid)</td>
<td>2 000</td>
</tr>
</tbody>
</table>

Ref: Stock T (1996) and Arison H L (2013)

Organoarsenic agents: Adamsite, clark I, clark II, arsine oil (mixture of several different organoarsenic agents)

Most of the nerve agent tabun was initially dumped in Little Belt between Jutland and Funen, raised in 1959-1960 and redumped in Bay of Biscay.

One convoy (3 ships) with tabun is reported sunk in Skagerrak.
The scuttling was done in condemned ships

- In Skagerrak almost all CW were sunk loaded on old condemned ships
- Seven British and seven American convoys with a total of 38 ships is presumed scuttled outside Arendal in 1945-1947
- We do not know which agent was loaded on each convoy
- In addition, some ships were scuttled in deep water (more than 1000 m depth) in the Norwegian Sea
Dumping in Norwegian waters

- The Norwegian authorities gave in 1945 permission to scuttle ships loaded with captured chemical ammunition on board at 600-700 m depth in an area approximately 14 km X 4 km in size, 19 – 25 nautical miles south-east of Arendal.
- The dumpsite is marked on navigational charts.
- Due to heavy protests, dumping after 1947 was done in deep water the Norwegian Sea.
Previous investigations

• 15 possible wrecks were located by FFI in a 16 km x 8 km area in 1989 by use of a side-scan sonar

• Five of those wrecks were inspected in 1989 by ROV. Water samples were collected and analysed

• Four of the same wrecks were inspected again in 2002 by ROV. Water and sediment samples were collected and analysed

• About 1/3 of the area was searched for more wrecks by an autonomous underwater vehicle in 2009. No water or sediment samples were collected
Possible wreck positions

- The exact wreck positions have not been known
- “SESOSTRIS” was for example located in 2002 at a distance of 12.6 km from the reported position (Arison 2013)
- The reason for inaccurate reports might be poor navigational systems and bad weather at the time of scuttling
Investigation in 2002

- Field work to inspect four of the known wrecks by a ROV

- Laboratory analysis of sediment and water samples
  - Identification of chemical warfare agents
  - Some degradation products
  - Elemental arsenic

- Risk assessment
  - Of what has been seen
  - Theoretical release scenarios
Wreck at 570 m depth in 2002
Wreck at 560 m depth in 2002
Wreck at 560 m depth in 2002
Wreck at 650 m depth in 2002
Wreck at 640 m depth in 2002: SESOSTRIS
An intact wreck located at 665 m depth in 2015

In 2015 FFI carried out the first part of a new survey with the HUGIN AUV. The aim is to locate all wrecks dumped in Skagerrak outside Arendal. The second part will be carried out in 2016. A sonar picture is shown.
A broken wreck at 554 m depth in 2015

Sonar picture of wreck at 554 m
A wreck split in two parts with debris at 644 m

Sonar picture of wreck at 644 m
## Stability of chemical agents in sea water

<table>
<thead>
<tr>
<th>Agent</th>
<th>Density</th>
<th>Solubility in water</th>
<th>Stability in water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nerve agents (tabun)</td>
<td>As water</td>
<td>Good</td>
<td>Breaks down quickly</td>
</tr>
<tr>
<td>Phosgene</td>
<td>Heavier than water</td>
<td>Good</td>
<td>Breaks down quickly</td>
</tr>
<tr>
<td>Mustard agents</td>
<td>Heavier than water</td>
<td>Poor</td>
<td>Poorly soluble, what is solved decomposes quickly</td>
</tr>
<tr>
<td>Chloracetophenone</td>
<td>Heavier than water</td>
<td>Poor</td>
<td>Reacts slowly</td>
</tr>
<tr>
<td>Organoarsenic agents</td>
<td>Heavier than water</td>
<td>Poor</td>
<td>Stable</td>
</tr>
</tbody>
</table>

- Tabun is the most toxic compound dumped in Skagerrak. It is quickly diluted and decomposed to less toxic compounds in water.
- Mustard agent will stay on the seabed for decades and form lumps with a hard cover. Will still contain active mustard inside.
- Organoarsenic agents do not break down. Will stay on the seabed and could be taken up and accumulated in marine organisms.
Conclusions

• Observations
  – 36 wrecks have been localised in 2015 in part of the search area
  – The rest of the area will be searched in 2016

• Fate/toxicology
  – Chemical warfare agents are very toxic to marine organisms
  – When the agents leak into water, most of them are quickly decomposed to less toxic compounds
  – Some agents, like mustard gas and organoarsenic compounds will stay on the seabed for decades, but direct contact is necessary to cause any harm to humans or marine organisms
  – No damage to fish has been reported in the Baltic Sea or in Skagerrak
  – Arsenic compounds could pose a risk to bottom-living organisms

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