# Sulfur in marine archaeological shipwrecks -- the 'hull story' gives a sour aftertaste

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Advanced chemical analyses reveal that, with the help of smart scavenging bacteria, sulfur and iron compounds accumulated in the timbers of the Swedish warship Vasa during her 333 years on the seabed of the Stockholm harbour. Contact with oxygen, in conjunction with the high humidity of the museum environment, causes these contaminants to produce sulfuric acid, according to a new doctoral thesis in chemistry from Stockholm University.

The Vasa sank in Stockholm's harbour on her maiden voyage in 1628 and was salvaged in 1961. The impressively restored ship is, after conservation, on display in the Vasa Museum in Stockholm. At present over 2,000 acidic sulfate salt precipitates have been registered in the timbers of the wreck as a result of the sulfuric acid formation. In her doctoral thesis from Structural Chemistry at Stockholm University, Yvonne Fors indicates that sulfur contaminants are a common conservation concern for marine archaeological wood. Her thesis presents the background, consequences and some remedies for these processes.

The seawater at the Vasa's wreck site became heavily polluted over the course of time and bacterial degradation of organic waste from the growing city consumed most of the oxygen in the water. Malodorous hydrogen sulfide was produced by scavenging bacteria, resulting in the accumulation of different sulfur and iron compounds in the wreck's timbers during 333 years on the seabed.

“In the Vasa high sulfur concentrations are found only in the surface layers of the timbers, while for other shipwrecks such as the Mary Rose in Portsmouth, England, sulfur has penetrated throughout the hull. There are more than two tonnes of sulfur in each of them”, says Yvonne Fors, who has studied how sulfur passes from seawater into the timbers. Advanced x-ray spectroscopic analyses at international research facilities in USA and France were used to map the distribution of the sulfur and iron compounds in the wood cells of the timber. Through contact with oxygen and high humidity conditions sulfur and iron compounds may develop sulfuric acid. Presently, there is approximately two tonnes of sulfuric acid in the Vasa’s wood.

“It is essential to find out as much as possible about how and where the different compounds are bonded in the cell structure of the timber in order to be able to predict their reactivity and the possibility of removing them,” says Yvonne Fors. It appears that the sulfur and iron contaminants can only be partially extracted, without seriously damaging the fragile wood.

“It is important to keep a stable climate in the museum to slow down the processes,” says Yvonne Fors. High acidity can have a long-term detrimental effect on the strength of the timber, and this must be limited. Yvonne Fors has carried out some promising initial experiments neutralising the acid in loose pieces from the Vasa by means of ammonia gas. However, any possible side effects on the wood must be carefully evaluated. The discoveries and conclusions in this thesis are an important first step in prolonging the expiration date of this national treasure.

Source: Swedish Research Council