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Relative bioavailability and toxicity of fuel oils leaking from World War II shipwrecks

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ABSTRACT

The Norwegian Authorities have classified 30 WWII shipwrecks to have a considerable potential for pollution to the environment, based on the location and condition of the wreck and the types and amount of fuel. Oil thus far has been removed from eight of these shipwrecks. The water accommodated fractions of oils from two British wrecks and two German wrecks have been studied with special emphasis on chemistry and biological effects (algae growth (*Skeletonema costatum*) and copepod mortality (*Calanus finmarchicus*)). Chemical analyses were also performed on three additional German wreck oils. The results from these studies show that the coal based oils from German WWII shipwrecks have higher toxicity to marine organisms than the mineral oils from the British shipwrecks. The potential for higher impact on the marine environment of coal based oils has resulted in an altering of the priority list for oil recovery from WWII wrecks by the authorities.

1. Introduction

There has been increased awareness and concern about the oil-pollution risks posed by sunken wreck, both recent and relic. Especially shipwrecks from World War II (WWII) are becoming a major problem for many nations. In a previous international survey, Michel et al. (2005) identified over 8500 sunken shipwrecks around the world, which posed a significant risk for oil pollution. Efforts have been made to compile data on WWII shipwrecks, such as the South Pacific Regional Environment Programme (SPREP WWII shipwreck database) containing over 3800 vessels lost in the Pacific and East Asia (Monfils et al., 2006), and the Atlantic, Mediterranean and Indian Ocean (AMIO) database, that contains information on the location and ownership of nearly 4000 WWII shipwrecks (Monfils, 2005). The wrecks that date back to WWII have been submerged for approximately 70 years, so there is a growing concern that corrosion will lead to that these wrecks will eventually leak oil to an extent that may cause potential impacts to the environment.

In USA, the National Oceanic and Atmospheric Administration (NOAA) maintains a large database (The Resources and Undersea Treats (RUST)), which includes approximately 20,000 shipwrecks in US waters, most of them unlikely to be of substantial threats to the marine environment. Recently, a list of the most ecologically and economically significant potentially polluting wrecks in U.S. waters have been prepared by NOAA and U.S. Coast Guard (NOAA, 2013). The objective with the NOAA report was to filter an overwhelming list of potentially polluting wrecks, leaving a shorter list of 87 high and medium priority wreck that can realistically be used for regional and area contingency planning. NOAA (2013) concluded that the U.S. coastlines are not littered with "ticking time bombs" containing oil, although there are definitely wrecks of concern that should be further assessed and monitored. The vast majority of potentially polluting shipwrecks lost in U.S. waters can be tracked to a four-year period between 1941 and 1945 when Japanese and German submarines sought to destroy tankers and freighters along the U.S. coasts. WWII resulted in the majority (53 of the 87) of the shipwrecks in the final list.

Norway has a long weather-beaten coastline, and our sea-faring traditions and war history have resulted in a considerable number of shipwrecks along the Norwegian coast. In the 1990s, Norwegian Authorities registered more than 2000 shipwrecks larger than 100 DWT along the coast, and about 80% of these were classified as likely to pose no environmental risk (Idaas, 1995). The wrecks were categorized based on the estimated amount of oil products and cargo they contained, and the vulnerability of the marine environment they were located in. However, about 30 wrecks, all of from the World War II era, were classified to have considerable pollution

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Fig. 1. Location of shipwrecks that were classified to have considerable pollution risk to the environment. The oil has been removed from the wrecks marked with a circle. Map from the Norwegian Coastal Administration.

risk (see Fig. 1). Priorities for offloading fuel from the wrecks were established (described in Bergstrøm, 2014) and the oil has now been removed from eight of them.

Oil is a complex, highly variable mixture of hydrocarbons and other trace components. Bunker fuel oils can vary greatly in chemical composition, depending on the type and origin of the oil, the refining process, and the production process (NRC, 1989). Exposure to hydrocarbons may cause a variety of adverse effects in marine organisms, including narcosis, reduction in growth and reproduction, as well as death (Boyd et al., 2001). In order to cause an effect, oil components must be bio-available to the organisms being exposed. Many of the components in oil are potentially toxic to marine organisms, but have limited bio-availability in the environment due to their low solubility. Toxic effects depend on the duration of exposure and the concentration of the oil components involved and can be lethal (causing death) or sub-lethal, e.g. disorientation, reduced growth and reproduction (Rand et al., 1995). Toxic effects can be classified as acute caused by short-term exposure to a high concentration (such as following an acute oil spill) or chronic caused by long-term exposure to a lower concentration (such as release of produced water).

Norway is a fishing nation and both the commercial fishing waters and the aquaculture industry are crucial for many coastal communities. As a large number of the shipwrecks are located in areas popular for fishing and recreation, seafood safety and bathing restrictions are significant practical considerations. Therefore, the objective has been to study the potential for environmental impact from leaking wrecks by preparing low energy water accommodated fractions (WAFs) of oils from four WWII shipwrecks to characterize their chemical composition and acute toxicity. Two species representing different trophic levels, the primary producer *Skeletonema costatum* (algae) and the primary consumer *Calanus finmarchicus* (copepod) were used as test species for acute toxic effects. The WAF of an oil is of special interest because components dissolved from an oil slick or from rising oil droplets in the water column are known to be bioavailable to marine organisms and therefore have a potential for causing acute toxic effects (Neff and Stubblefield, 1995). Chemical analyses have been performed on three additional German WWII wreck oils, as the oil volumes available of these oils were not sufficient to prepare WAFs.

2. Materials and methods

2.1. The shipwreck oils

The oils studied were from the British sloop HMS "Bittern", the British carrier tanker RFA "Boardale", the German destroyer "Erich Giese", and the German cargo ship MS "Nordvard". In addition, chemical analyses of the oils from the German cargo ship MS "Welheim", the German heavy cruiser "Blücher", and the German submarine "U-864", have been performed. Completion of recovery of oils from three of the wrecks were performed in 2011–2012; all of them sank during April, 1940: HMS "Bittern" after a German air strike near Namsos, RFA "Boardale" grounded and sank outside Vesterålen, and "Erich Giese" during strike with British forces outside Narvik. The recoveries from these three shipwrecks are documented in Framo (2012). In 2007 the oil was removed from M/S "Nordvard", which sank after a British air strike in December in 1944 in the Oslo fjord, and MS "Welheim", which was sunken by a Norwegian MTB outside Florø in 1944. The oil from "U-864" was removed in March 2013, but it still contains 67 tons of metallic mercury. "U864" was detected and sunk by a British submarine in February 1945 outside Fedje. The cruiser "Blücher" was hit by land based batteries, caught fire, and sank in the Oslo Fjord in April 1940. Most of the oil was removed in 1994. More details regarding the recovery operations are given in Bergstrøm (2014).