Air under the Surface – Particulate Concentrations in a Submarine Work Environment

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The submarines of the Gotland class can operate submerged for many weeks. During this time the air will be filtered through particle- and charcoal filters, carbon dioxide will be eliminated and oxygen added. Still, air contaminants will be present in the air and need to be investigated. The studies made public on submarine environments are few. In this study the dining area which is close to the kitchen and the machinery room where the diesel engines are placed were assessed. Portable measurement instruments were brought on board during a 11 day long sailing. During the sailing, the submarine was operating both on the surface and submerged.

A collection of particles suspended in a carrier gas is called an aerosol. Usually, aerosols are measured by their mass concentration. The mass concentration is typically given in micrograms per cubic meter (μg/m^3). The mass concentration of particles below 2.5 micrometer in diameter is abbreviated $PM_{2.5}$. The World Health Organization (WHO) has concluded that $PM_{2.5}$ is a major risk to health and therefore this parameter is measured both in outdoor and indoor environments. The $PM_{2.5}$ was measured on board, close to the kitchen and the concentrations peaked during cooking activities. When there were no cooking activities the $PM_{2.5}$ was low. The $PM_{2.5}$ was also analysed in the machinery room where the mean concentration was higher than in the dining area. The level in the machinery room was similar to a residence indoor environment.

Another parameter that was measured close to the kitchen on board was volatile organic compounds (VOCs). VOCs are commonly present especially in indoor air and there are numerous of different VOCs. VOCs can give the apprehension of bad air quality, for example by smell and irritation in eyes. The mean concentration of VOCs was increased on board during submersion.

Additionally, black carbon was measured in the dining area. Black carbon is the carbonaceous part of soot and absorbs electromagnetic radiation (light) in the infrared to UV spectrum. It is commonly measured due to the possibly carcinogenic abilities. This was measured close to the kitchen and it was found that soot from the diesel exhaust could infiltrate the dining area through the hatch to the atmosphere during surface operation. For the rest the black carbon concentration was lower than concentrations found in home environments.

Concentrations of different polycyclic aromatic hydrocarbons (PAHs) were analysed in both the dining area and the machinery room. The total concentration was the highest in the machinery room. The toxicity of the total PAH concentrations was lower than previous studies on a submarine and ships.

In the machinery room also ultrafine particles were analysed. These are particles smaller than 100 nanometers in diameter and are measured in number concentrations. There could be seen increases due to possibly exhausts in the machinery room from the diesel engines. The ultrafine particle mean level was similar to an urban environment.

A recommendation for improving the air quality in the machinery room is to prevent leakages and exhaust infiltration even further. Additionally, closing of doors and avoid occupancy in this part if possible when some sort of leakage or exhaust is detected in the air is recommended. In the dining area the air quality could be improved by increasing the fan power during cooking.

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