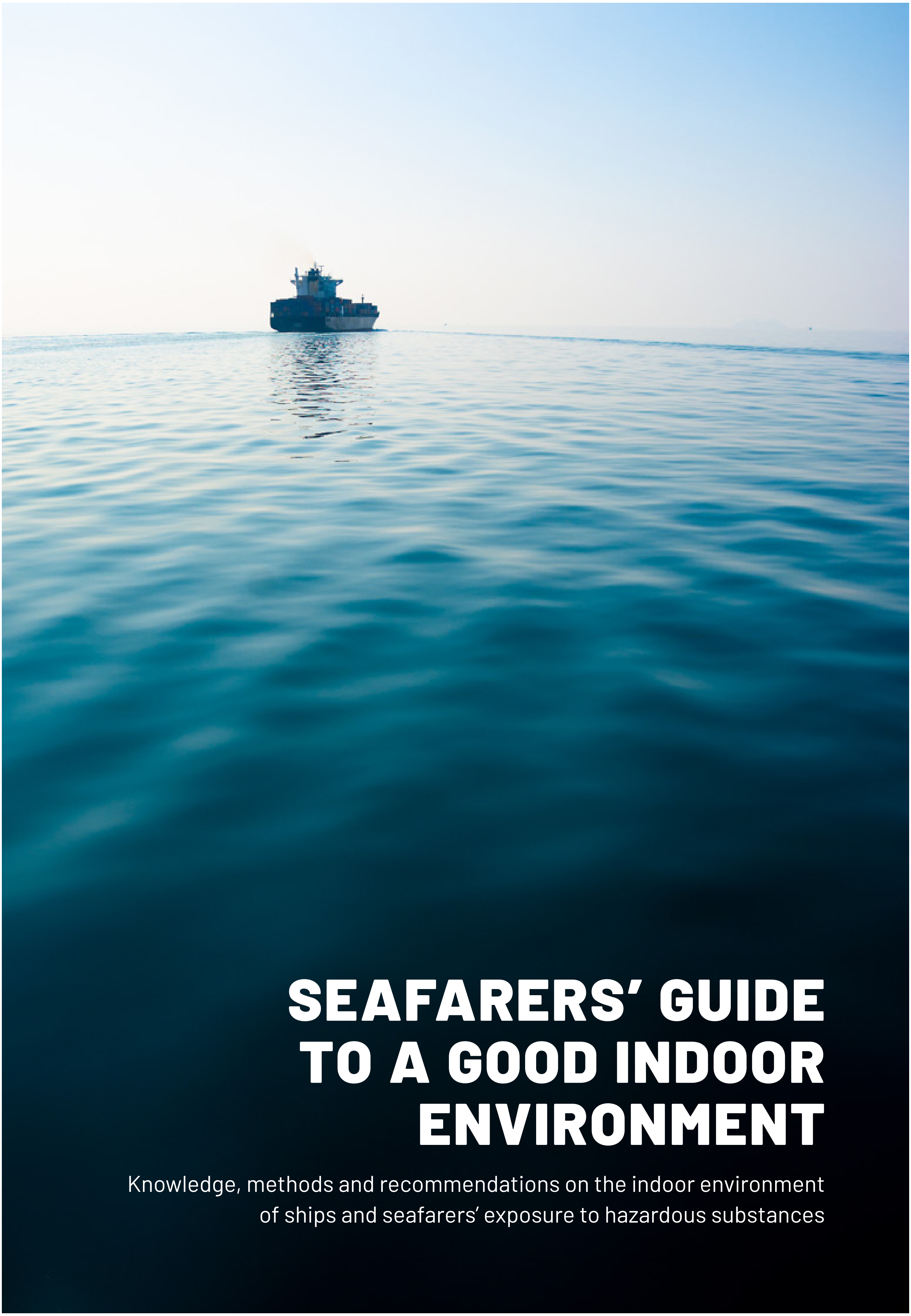

SEAFARERS' GUIDE TO A GOOD INDOOR ENVIRONMENT

Knowledge, methods and recommendations on the indoor environment of ships and seafarers' exposure to hazardous substances

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Produced with support from the Swedish Mercantile Marine Foundation, sjomanshus.se
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CONTENTS

FROM RESEARCH TO PRACTICE

The Seafarers' Guide to a Good Indoor Environment provides practical advice and tips on how to assess and evaluate the indoor environment on ships and how to reduce exposure to hazardous substances in different types of work.

The purpose of this guide is to provide an overview of the hazardous substances that may be present in the indoor environment of ships, the health risks associated with these substances, what you can do to reduce the risks, and what regulations apply to the working environment. The information is based on findings from three previous research projects carried out by Sarka Langer, IVL Swedish Environmental Research Institute, and Cecilia Österman, Linnaeus University, during 2013-2022. We hope that the material will be useful both to those affected by the indoor environment on board and to others with responsibilities and tasks in the ship's working environment and safety work.

Links to project reports and scientific publications can be found in the section References and further reading.

SHIP'S INDOOR ENVIRONMENT AND AIR QUALITY

As seafarers often work long hours on board with little opportunity for variety and change of scenery, the indoor environment and air quality of ships are important for both health and well-being.

The links between air pollution and health

People spend most of their time indoors, either at home, at work or in vehicles. In homes and offices, the most common sources of air pollution are related to building materials, furniture, paints and cleaning products. For example, formaldehyde is emitted from particle boards and textiles, organic compounds from solvents, paints and glues, plasticisers and aldehydes from flooring materials and carpets. It is mainly new materials that emit volatile substances into the air, but some substances can emit for several years. Even at low levels, the chemicals can be odour-intensive and irritating.

Dust and particles are also always present in indoor air. Much of the indoor pollution comes from people themselves and from our personal hygiene products such as deodorants, shampoos and cosmetics. Other substances, such as ozone and nitrogen dioxide, come from outdoor air and are brought in through ventilation systems.

The relationship between the indoor environment and health is complex, with many different factors at play. How dangerous it is to be exposed to a particular substance depends on how harmful or toxic the substance is and how large a dose is needed to cause adverse health effects. Health effects can be either local or systemic. Local health effects on the body can be, for example, skin corrosion, eye and respiratory tract irritation after a direct contact with a substance. Systemic health effects can occur when exposure has been caused by the substance being absorbed into one or more organs through the skin, respiratory tract or by ingestion. This can lead to acute poisoning or long-term damage such as allergies or cancer.

Indoor air quality on ships

As seafarers often work long hours on board with little opportunity for variety and change of scenery, the indoor environment and air quality of ships are important for both health and well-being. Seafarers are one of the occupational groups most exposed to hazardous substances from fuels and exhaust gases. The confined environment also poses a risk of spreading infectious diseases on ships, particularly in the respiratory tract.

The indoor environment and air quality on board are largely influenced by the type of fuel and the design of the ship's ventilation system. These factors affect the chemical pollutants and particulates in the indoor air, but also thermal comfort, which is how we experience the temperature and draught in a workplace or cabin.

Indoor air on board is drawn in from the outside by the ship's ventilation system, where it can be cleaned, heated and cooled. In ports and on busy shipping lanes, pollutants from industry and exhaust from other ships can enter the indoor environment. Inside the ship, other air pollutants are added. These are mainly substances emitted from fuels, lubricating oils and engine exhaust, but also from activities such as cleaning, painting, welding and cooking. Air pollutants may be present in gaseous form or as particles of various sizes. Detailed analyses show that indoor air on ships contains a complex mixture of mainly carbon dioxide, carbon monoxide, sulphur dioxide and nitrogen oxides, but also aromatic hydrocarbons such as benzene, toluene, xylenes, straight aliphatic hydrocarbons and polycyclic aromatic hydrocarbons, known as PAHs.

RULES AND GUIDELINES

The work environment rules that apply on board depend on where the ship is registered. For Swedish-flagged ships, the Swedish Transport Agency and the Swedish Work Environment Authority's rules and limit values for air pollution apply. Many ships are also subject to other types of guidelines from classification societies, cargo owners and industry organisations. For general indoor environments, there are health-based guideline values for air pollution. These have not been developed specifically for ships but can be used for comparison.

The UN's maritime body The International Maritime Organisation (IMO), based in London, develops international rules and recommendations for shipping. These are then implemented through the national legislation of flag states. This means that health and safety rules may differ depending on where the ship is registered. Two ships of the same shipping company registered under different flags may therefore be subject to different health and safety rules.

Many ships are also subject to other types of guidelines and instructions from classification societies, cargo owners and industry organisations. These types of guidelines often place higher demands on the work environment and safety than the law prescribes. For tankers, for example, there is ISGOTT, the International Safety Guide for Oil Tankers and Terminals, a comprehensive international industry-wide recommendation for how ships and quayside facilities should be designed and how they should interact in terms of safety, health and the environment in connection with the handling of petroleum products.

Work environment rules for Swedish-flagged ships

Swedish-flagged ships are the only workplaces in Sweden where the Swedish Work Environment Authority is not the supervisory authority. Instead, the Swedish Transport Agency has the right to issue rules for the work environment on board and to ensure that the rules are complied with. This means that there are some differences between the work environment rules on board and those that apply to workplaces on land. Sometimes it takes time before new work environment rules also apply to the crew on board.

The work environment on Swedish-flagged ships is regulated by the Swedish Transport Agency's regulations and general advice on the work environment on ships. These regulations bring into force a selection of the Swedish Work Environment Authority's regulations, including the rules on chemical risk sources, limit values for respiratory exposure in the work environment, and the parts of the rules on the design of workplaces that concern ventilation and air quality.

The management of the shipping company has overall responsibility for the health and safety of its employees. The master is generally responsible for the work environment on board. Both international requirements for a functioning safety management system and Swedish requirements for systematic work environment management (SAM) mean that the work environment must be regularly examined and risk assessed, and that risks of ill health and accidents must be addressed and followed up.
The requirements apply to all parts of the work environment –physical, organisational and social – and these parts often interact.

Chemical risks in the work environment should be addressed as far as possible

The Work Environment Act means that all employers are obliged to regularly examine and risk assess the work environment to determine what measures are needed to ensure that work is safe. The Work Environment Act states that measures to reduce chemical risks in the workplace should be based on a 'ladder of action'. This means that risks should be prevented or limited as far as possible by common technical or organisational measures. The last step in the ladder of action is personal protective equipment. It should be used when it is not possible to limit the risk further with other measures.

Workplaces should have satisfactory air quality in the occupied zone. As far as possible, the air should be free from pollutants that are harmful to health or cause unpleasant odours. Ventilation systems should be provided to supply sufficient outside air and to remove air pollutants from the indoor spaces. Indoor workplaces should have an appropriate thermal climate. The temperature and air velocity must be adjusted according to whether the work is light or heavy, mobile or sedentary. If different tasks are performed in different parts of the room, they may require different thermal climates.

Limit values for respiratory exposure at work

The Swedish Work Environment Authority's occupational exposure limit (OEL) values for hazardous substances specify the highest acceptable average level of a substance in the air at the workplace, measured as personal exposure and calculated as a time-weighted average. Swedish and international OEL values are based on scientific evidence of known dose-response effects, i.e. how high doses of a substance people can be exposed to without suffering acute or long-term health effects. OELs form the basis for decisions on how long it is acceptable to work in a particular atmosphere, depending on the type of substance and concentration, and are expressed as threshold time-weighted average limit or short-term exposure limit.

Threshold limit value, time-weighted average (TLV-TWA): limit value for respiratory exposure during a working day, usually 8 hours. Threshold limit values are mandatory and *must not be exceeded*. At sea, working days longer than 8 hours are common. In this case, a standardised method can be used to calculate the level by multiplying the limit value by 8/x, where x is the length of the working day in hours. Longer working hours mean a lower limit value.

Threshold limit value, short-term exposure limit (TLV-STEL): limit value for respiratory exposure during a reference period of 15 minutes (5 minutes for some substances). Exposure equivalent to a 15-minute exposure limit should not occur for more than 15 minutes per hour.

The OEL values apply on the assumption that the exposed persons do not carry out physically demanding work that increases respiration and thus the absorption of air pollutants.

General indoor air quality guidelines and recommendations

The expert group of the WHO's International Agency for Research on Cancer (IARC) has classified nearly 1,000 agents (active ingredients) into five groups according to their perceived carcinogenicity. IARC risk group 1 means that the substance is a known human carcinogen, group 2A that it is probably a human carcinogen and group 2B that it is possibly a human carcinogen.

OEL levels are adapted to industrial workplaces where workers are typically present for eight-hour shifts. The situation is slightly different on ships, where workers both work and live on board for longer periods than is typical in a land-based workplace.
To get an idea of how the measured levels compare with other environments, they can be compared with the World Health Organisation's health-based guideline values for indoor air (WHO, 2021). These guideline values were developed for outdoor air, but they also apply to residential and other non-industrial environments. The guideline values are significantly lower than OEL values and *should not be exceeded*.
Measured concentrations can also be compared with measurements carried out in homes or offices and for other relevant occupational groups.

The Public Health Agency of Sweden has issued general advice on the thermal indoor environment in homes and public buildings. The advice includes recommendations for temperature, relative humidity and draughts at which most people experience good thermal comfort. The advice also includes guideline values for when the indoor climate may be detrimental to human health. Although the advice is not specifically aimed at the living environment on board, it gives an indication of the quality of the indoor environment that should be maintained to provide good comfort and not pose a direct or indirect health risk.

Summary of air pollutants

Tables 1-3 provide a summary of the air pollutants included in the Seafarers' Guide. The tables provide information on the substance's IARC risk group, occupational exposure limit values, World Health Organization health-based guideline values and, for comparison, previously measured concentrations in general indoor environments such as homes and offices. Table 1 shows OEL values and guideline values for gaseous air pollutants and Table 2 for dust and particles. Table 3 summarises the thermal climate parameters.

Table 1. Overview of gaseous substances.

Pollutant	*IARC risk group*	*TLV-TWA (8h)*	*TLV-STEL (15 min)*	*WHO guidelines for indoor air quality*	*Indoor environments (homes, offices)*
Benzo(a) pyrene	1	2 µg/m³	20 µg/m³	0.0012 µg/m³	0.0000005 - 0.0005 µg/m³
Benzene	1	1 500 µg/m³ (0.5 ppm) From April 026: 660 µg/m³ (0.2 ppm)	9 000 µg/m³ (3 ppm)	1.7 µg/m³	0.6 – 25 µg/m³
Formaldehyde	1	370 µg/m³	740 µg/m³	100 µg/m³ 30 minutes 10 µg/m³ long-term average	4 – 160 µg/m³
Carbon monoxide	–	23 mg/m³ (20 ppm)	117 mg/m³ (100 ppm)	4 mg/m³ (3 ppm) daily average	Not usually measured in homes and offices
Carbon dioxide	–	9 000 mg/m³ (5 000 ppm)	18 000 mg/m³ (10 000 ppm)	1 000 ppm instantaneous value	400 – 2 000 ppm
Nitrogen dioxide	–	960 µg/m³	1 900 µg/m³	25 µg/m³ daily average 10 µg/m³ annual average	3 – 40 µg/m³
Naphthalene	2B	50 000 µg/m³	80 000 µg/m³	10 µg/m³	<0.00001 – 26 µg/m³
Ozone	–	200 µg/m³	600 µg/m³	100 µg/m³ 8h mean value	0.1 – 97 µg/m³
Sulfur dioxide	–	1 300 µg/m³ (0.5 ppm)	2 700 µg/m³ (1 ppm)	40 µg/m³ daily average	Not usually measured in homes and offices
TVOC	–	–	–	200 – 300 µg/m³	40 – 420 µg/m³

Table 2. Summary of dust and particles.

Pollutant	*TLV-TWA (8h)*	*TLV-STEL (15 min)*	*WHO guidelines for indoor air quality*	*Indoor environments (homes, offices)*
Inorganic dust, respirable	2.5 mg/m³	–	–	Not applicable
Inorganic dust, inhalable	5 mg/m³	–	–	Not applicable
$PM_{2.5}$	–	–	15 µg/m³ daily average 5 µg/m³ annual average	2 – 430 µg/m³
PM_{10}	–	–	45 µg/m³ daily average 15 µg/m³ annual average	2 – 1 200 µg/m³
Elemental carbon	50 µg/m³	–	–	0.5 – 7 µg/m³

Table 3. Summary of thermal climate parameters.

Parameter	*Working environments*	*General indoor environments*	*Indoor environments (homes, offices)*
Temperature	20–24 °C wintertime 20–26 °C summertime during sedentary work	20–24 °C	19–24 °C
Relative humidity	–	25–60 %	25–57 %

GASEOUS AIR POLLUTANTS

Many air pollutants are normally present in our indoor air, but concentrations can be elevated by work and processes taking place nearby. This section describes some important and common gaseous indoor air pollutants. For each substance, it explains where it is found on board, the acute and long-term health effects of unhealthy exposure, and the limits and guidelines available.

Diesel exhaust

Where does it occur on board?

The main source of diesel exhaust in indoor environments is from ships' combustion engines. Diesel engine exhaust is a complex mixture of gases and particles. The main components of diesel exhaust are nitrogen oxides, carbon dioxide, carbon monoxide and hydrocarbons. Diesel exhaust also contains ultrafine particles from incomplete combustion. These particles contain elemental carbon (EC), organic matter, metals and other substances. Health effects, limit values and guidelines are presented separately for the most important of these substances.

Health effects

Diesel exhaust is known to cause inflammatory changes in the lungs, lung cancer and cardiovascular disease. In 2012, the World Health Organisation's (WHO) International Agency for Research on Cancer (IARC) placed diesel exhaust in risk group 1A, which also includes asbestos and arsenic. This decision is based on strong scientific evidence linking diesel exhaust to an increased risk of lung cancer (IARC, 2012).

OEL values and guidelines

As knowledge of the risks has increased, international and Swedish OEL values and health-based guidelines have been lowered several times in recent decades. For many years, nitrogen dioxide has been used as the signal substance for exposure to diesel exhaust in the workplace. From February 2023, the exposure limit value for diesel exhaust must be assessed by measuring elemental carbon (EC). The limit value for elemental carbon is 50 µg/m^3. Elemental carbon is mainly found in diesel exhaust and is more specific as a limit value because there is less risk of interference from other sources.

Nitrogen dioxide

Where does it occur on board?

In the environment, nitrogen oxides (NOx) - nitrogen monoxide (NO) and nitrogen dioxide (NO_2) - are formed by combustion at high temperatures. The main source of nitrogen oxides in the indoor environment is exhaust gases from internal combustion engines. Nitrogen dioxide is also produced during gas welding when the flame is directed directly into the air. Exposure to nitrogen dioxide caused several deaths in Swedish shipyards in the 1940s after gas welding in confined spaces.

In Sweden, emissions of nitrogen oxides to outdoor air have been more than halved between 1990 and 2020 as a result of reductions in emissions from industry and private transport, mainly through catalytic exhaust cleaning.

Health effects

Nitrogen oxides are corrosive gases with low water solubility. Any exposure to NOx can be harmful to health, depending on the concentration, duration and route of exposure. Inhalation of nitrogen oxides can cause poisoning and skin exposure can cause corrosive damage. Lung and respiratory effects include dilation of the blood vessels in the lungs, which can lead to more severe asthma attacks in asthmatics. Similarly, severe chest pain and acute shortness of breath can be symptoms of exposure to nitrogen oxides. The low water solubility of nitrogen oxides means that they can penetrate into the alveoli of the lungs without the high levels of exposure being noticed. It may take several hours for symptoms of pulmonary oedema to appear, leading to acute respiratory distress and, in the worst case, death.

Nitrogen dioxide is an irritant to the eyes and respiratory tract and can cause inflammation of the airways, reduced lung function and a weakened immune system with increased susceptibility to respiratory infections (WHO, 2010). Even levels around half the exposure limit can be irritating to the airways and eyes. Nitrogen dioxide affects asthma and allergy sufferers by increasing sensitivity to allergens (substances that cause allergy or hypersensitivity). Tests have been carried out in which allergy sufferers reacted to a very low dose of an allergen that would not normally affect them after exposure to nitrogen dioxide.

OEL values and guidelines

In 2019, the Swedish Work Environment Authority's occupational exposure limit values for nitrogen dioxide were significantly reduced. The OEL time-weighted average over an 8-hour working day has been reduced from 4 mg/m^3 to 0.96 mg/m^3 and the short-term exposure limit during a reference period of 15 minutes from 10 mg/m^3 to 1.9 mg/m^3. The OEL value for nitrogen dioxide is intended to consider the cumulative effect of the substances present in diesel exhaust.

The World Health Organisation's health-based guideline for indoor nitrogen dioxide is 10 µg/m^3 as an annual average and 25 µg/m^3 as a daily average (WHO, 2021). In previous Swedish studies, mean indoor levels and mean population exposure to nitrogen dioxide have usually been below 20 µg/m^3.

	IARC risk group	*TLV-TWA (8h)*	*TLV-STEL (15 min)*	*WHO guidelines for indoor air quality*	*Indoor environments (homes, offices)*
Nitrogen dioxide	-	960 µg/m^3	1 900 µg/m^3	25 µg/m^3 daily average 10 µg/m^3 annual average	3 – 40 µg/m^3

Sulfur dioxide

Where does it occur on board?

Sulfur dioxide (SO_2) is formed during the combustion of sulfur-containing fuel and is not normally formed in indoor environments. The level of sulfur dioxide indoors is largely determined by the concentrations in the outdoor air and is brought in with the ventilation supply air.

Health effects

Sulfur dioxide is a colourless gas with a pungent odour. It causes coughing, irritates the eyes and can cause inflammation of the respiratory tract, impaired lung function and a weakened immune system. In high concentrations (above 400–500 ppm), sulfur dioxide can cause respiratory problems and death in sensitive individuals.

OEL values and guidelines

The OEL time-weighted average over an 8-hour working day for sulfur dioxide is 1.3 mg/m³ (1 300 µg/m³). However, it does not protect asthmatics. Studies have shown that levels below half the limit value are required to prevent asthmatics from reacting. The World Health Organisation's health-based guideline for indoor sulfur dioxide is 40 µg/m³ as a daily average (WHO, 2021).

Carbon monoxide

Where does it occur on board?

Carbon monoxide (CO) is produced by incomplete combustion. Carbon monoxide is colourless and odourless, making it difficult to detect. Measurements carried out on ships during the projects constituting the base for 'Seafarers' guide' show that there are rarely detectable levels, either in engine rooms or in other spaces. The levels of carbon monoxide measured outdoors are likely to come from exhaust plumes from the ship itself and from other ships in the vicinity.

Health effects

Carbon monoxide blocks the ability of haemoglobin to bind oxygen. Exposure to high levels can cause symptoms of angina or even death. A study of the health effects of long-term exposure to carbon monoxide in steel workers also showed cognitive impairment, including fatigue and short-term memory problems. Carbon monoxide is a so called ototoxic substance. This means that exposure, even at levels just below the exposure limit, increases the risk of hearing damage from noise.

OEL values and guidelines

The OEL values for carbon monoxide have been lowered in line with increased knowledge of its health risks. The time-weighted average over an 8-hour working day is 20 ppm (23 mg/m³) and the short-term exposure limit is 100 ppm (117 mg/m³).

The World Health Organisation considers that long-term exposure to carbon monoxide levels must be well below the occupational exposure limit value to be considered 'safe'. The World Health Organisation's guideline for indoor environments is 4 mg/m³ (3 ppm) for 8 hours exposure (WHO, 2021).

Carbon dioxide

Where does it occur on board?

Carbon dioxide is produced by the combustion of fuel oil and the decomposition of organic matter. On ships, for example, it can be found in the cargo holds of wood, pellets or grain, and in sewage systems. Humans also breathe out carbon dioxide. Measurements of carbon dioxide levels can therefore be used to assess how well ventilation is working. The lower the airflow, the higher the carbon dioxide content.

Health effects

Carbon dioxide is a colourless, odourless gas. It is not poisonous, but because it is heavier than air, it can cause asphyxiation. The highest levels of carbon dioxide are usually found at the lowest point in a room. Levels above 50,000 ppm of carbon dioxide in inhaled air can cause unconsciousness and higher levels can cause suffocation.

OEL values and guidelines

Carbon dioxide is used as an indicator of good indoor ventilation. If the carbon dioxide level in a room under normal use regularly exceeds 1,000 ppm, it is an indication that the ventilation is inadequate.

Ozone

Where does it occur on board?

In outdoor air, ozone is formed by photochemical reactions initiated by sunlight. In indoor environments, ozone is introduced from outdoor air through ventilation, but there are also processes in the working environment that can produce ozone, such as welding. Because ozone is a highly reactive gas, it is used for decontamination, odour removal and duct cleaning in commercial kitchens and restaurants.

Health effects

Ozone irritates the eyes, nose and throat, causes respiratory problems and lung disease, impairs lung function and can trigger asthma. Very high exposures can cause acute damage in lungs that can lead to long-term respiratory diseases such as asthma or chronic bronchitis.

OEL values and guidelines

The time-weighted average over an 8-hour working day is 0.2 mg/m³ (0.1 ppm) and the short-term limit value is 0.6 mg/m³ (0.3 ppm). When ozone generators are used for duct cleaning in catering environments, the Swedish Work Environment Authority recommends that there should be sensors in the kitchen that warn of high ozone levels. The ozone generating unit should also be interlocked with the exhaust air fan and cleaning hatches. All units, ducts and cleaning hatches should be labelled if they may contain ozone.

	IARC risk group	*TLV-TWA (8h)*	*TLV-STEL (15 min)*	*WHO guidelines for indoor air quality*	*Indoor environments (housing, offices)*
Sulphur dioxide	-	1 300 µg/m³ (0.5 ppm)	2 700 µg/m³ (1 ppm)	40 µg/m³ daily average	Not usually measured in homes and offices
Carbon monoxide	-	23 mg/m³ (20 ppm)	117 mg/m³ (100 ppm)	4 mg/m³ (3 ppm) daily average	Not usually measured in homes and offices
Carbon dioxide	-	9 000 mg/m³ (5 000 ppm)	18 000 mg/m³ (10 000 ppm)	1 000 ppm instantaneous value	400–2 000 ppm
Ozone	-	200 µg/m³ (0.1 ppm)	600 µg/m³ (0.3 ppm)	100 µg/m³ 8h meansvärde	0.1–97 µg/m³

Volatile organic compounds

Where does it occur on board?

The main sources of volatile organic compounds (VOCs) are indoor environments. They are emitted from building materials, furniture, office equipment and cleaning chemicals, but also during cooking. On a ship, the main sources of VOCs are the ship's fuel, both through evaporation and as a component of exhaust gases, as well as paints and solvents.

To give an indication of the concentration of VOCs in indoor air, it is often given as the sum of all VOCs analysed, known as Total Volatile Organic Compounds (TVOCs).

Health effects

The ability of organic substances to cause health effects varies greatly depending on the substance, from those with no known health effects to those that are highly toxic. VOCs contribute to odours that reduce the perceived quality of indoor air. This can lead to headaches, eye irritation, respiratory problems and reduced performance. As with other pollutants, health effects depend on many factors. Acute symptoms include nose, throat and eye irritation, headaches, nausea, dizziness and allergic skin reactions. In addition, some VOC compounds can damage internal organs such as the liver and kidneys, leading to chronic health risks.

Benzene is a volatile organic compound commonly found in fuel oils. It is easily absorbed into the human body, either by inhalation or through skin contact. Benzene can irritate the mucous membranes of the eyes and respiratory tract, cause tiredness and, in the worst case, damage the heart. Benzene is classified as risk group 1, carcinogenic to humans and may cause leukaemia.

OEL values and guidelines

There are no limit values for TVOC because it includes a large number of different VOCs with different properties. However, there are recommended guideline values for indoor environments (UBA, 2018). TVOC levels in indoor environments should be kept to a maximum long-term average of 200–300 µg/m^3 or lower if possible. According to the UBA, the concentration in the range between 1,000 and 3,000 µg/m^3 should not be exceeded in indoor environments where people are permanently present.

The OEL value for benzene is set on the basis of its carcinogenic effect. From April 2026, the Swedish Work Environment Authority will further reduce the limit value for benzene.

	IARC risk group	*TLV-TWA (8h)*	*TLV-STEL (15 min)*	*WHO guidelines for indoor air quality*	*Indoor environments (housing, offices)*
TVOC	-	Not specified	Not specified	200–300 µg/m^3	40–420 µg/m^3
Benzene	1	1 500 µg/m^3 (0.5 ppm) From April 2026: 660 µg/m^3 (0.2 ppm)	9 000 µg/m^3 (3 ppm)	1.7 µg/m^3	0.6–25 µg/m^3
Naphthalene	2B	50 000 µg/m^3	80 000 µg/m^3	10 µg/m^3	<0.00001–5.4 µg/m^3
Benzo(a) pyrene	1	2 µg/m^3	20 µg/m^3	0.0012 µg/m^3	0.0000005 –0.0005 µg/m^3
Formaldehyde	1	370 µg/m^3	740 µg/m^3	100 µg/m^3 for 30 minutes 10 µg/m^3 long-term average	4 – 160 µg/m^3

Polycyclic aromatic hydrocarbons

Where does it occur on board?

Polycyclic aromatic hydrocarbons (PAHs) are a group of several hundred substances found in many fuels. They are formed when organic materials are heated or incompletely burned in the absence of oxygen. PAHs can be present in exhaust gases drawn in by the ship's ventilation system. They can also evaporate from fuels and are present in tobacco smoke.

Health effects

The acute and long-term health effects of PAHs depend mainly on the route of exposure (inhalation, skin contact or ingestion), the duration and the level of exposure. It also depends on the toxicity of the particular PAH compound and the general health status of the exposed person. Short-term exposure to high levels of PAHs can cause skin and eye irritation, nausea and reduced lung function in asthmatics. Long-term exposure to low levels of some PAHs, including benzo(a)pyrene, can cause lung cancer. Like diesel exhaust and benzene, benzo(a)pyrene is classified as risk group 1. It is one of the oldest known carcinogens for occupational exposure. As early as the 18th century, it was discovered that chimney sweeps suffered from a specific type of cancer linked to their exposure to soot, and in 1933 benzo(a)pyrene was identified as the substance in soot and exhaust gases that causes cancer.

Naphthalene, another PAH found on board, is classified as possibly carcinogenic to humans (IARC Group 2B). Naphthalene is mainly produced by combustion processes. Exposure to naphthalene is usually through inhalation of exhaust gases, and also solvents, lubricants, tobacco smoke or consumer products such as hairspray.

Exposure to naphthalene can be irritating to the eyes and mucous membranes and can cause haemolytic anaemia, a condition in which red blood cells break down.

OEL values and guidelines

Because PAHs are made up of many substances with different health effects, there is no guideline value for total PAHs. Since the 1970s, methods have been established to measure and analyse 16 priority PAHs identified by the United States Environmental Protection Agency (US EPA). This list has long been a basic reference for determination of the levels and health risks of PAH exposure. In recent years, more substances have been added to the list of PAHs that should be analysed to further improve assessment of exposures and potential health effects. Which PAHs are specifically analysed depends on the aim of a particular investigation. However, it is common to include naphthalene and benzo(a)pyrene in all methods, as they are major contributors to the health effects of PAHs. Indoor air quality guidelines can be found in the WHO Guidelines for Indoor Air Quality (WHO, 2010).

Formaldehyde

Where does it occur on board?

Formaldehyde comes mainly from various indoor sources, such as building materials and furnishings. Formaldehyde is a component of adhesives used in the manufacture of particleboard and other wood-based composites. Formaldehyde is a common product of the transformation of other hydrocarbons in the atmosphere or in combustion processes. For example, it can be produced by the combustion of methanol in methanol-fuelled engines.

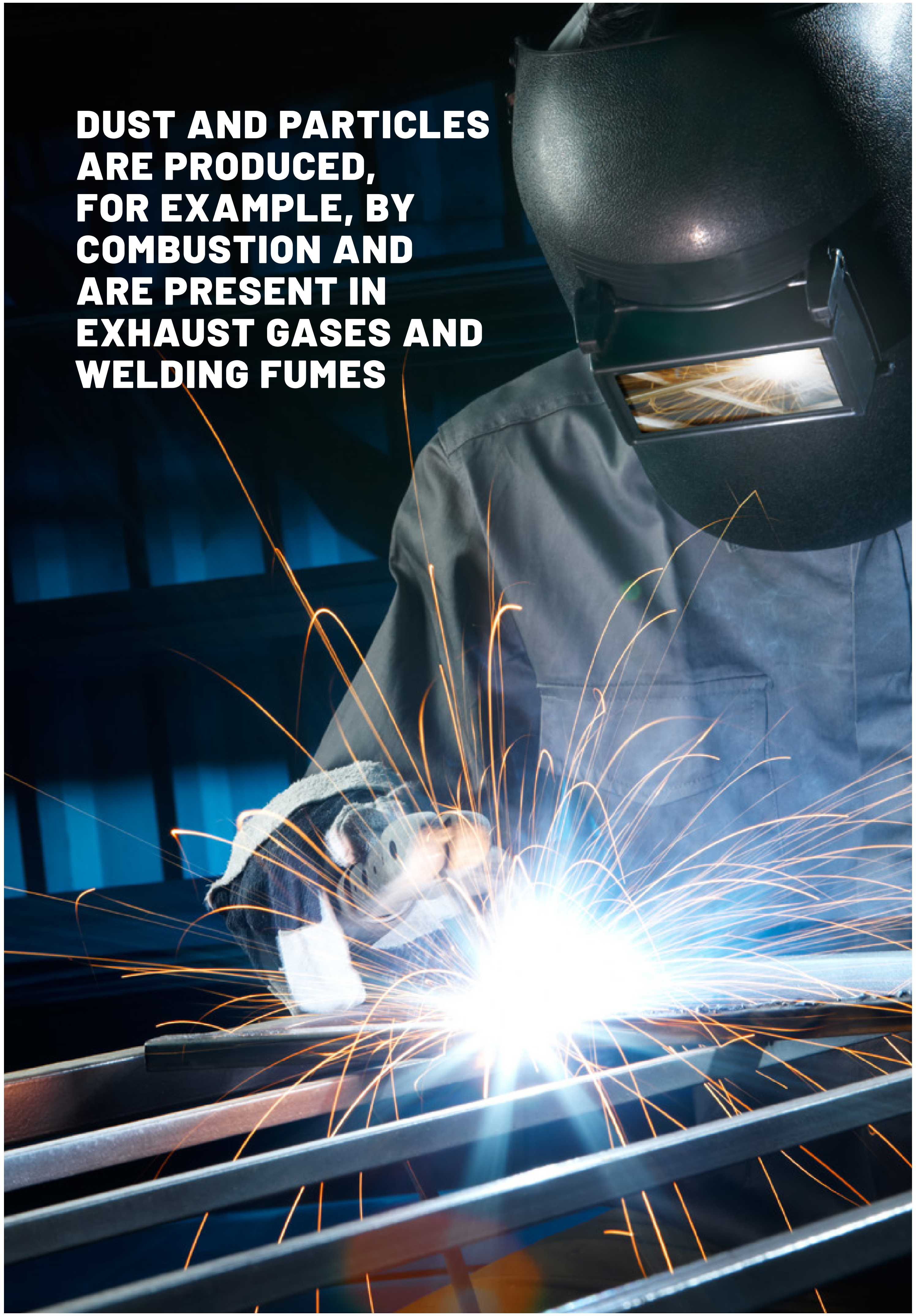
Formaldehyde has not been shown to be a problem on ships because working and living environments are much better ventilated than, for example, homes and offices.

Health effects

Formaldehyde is an irritant and is classified as risk group 1, carcinogenic to humans.

OEL values and guidelines

The OEL time-weighted average over an 8-hour working day for formaldehyde is 370 µg/m^3 and the 15-minute short-term limit value is 740 µg/m^3. The WHO recommends a guideline value of 100 µg/m^3, averaged over 30 minutes. Other sources indicate a health-based long-term average (1 year) of 10 µg/m^3 (Public Health England, 2019).



DUST AND PARTICLES

Dust is air pollutants in the form of particles. Many of the particles we breathe in can affect our health, for example by irritating the nose, throat and airways and aggravating asthma. Particles containing allergenic substances can cause sensitisation or allergies. The risk of adverse health effects depends on the particle size, the concentration of particles, their chemical composition and the time of exposure.

Dust and particles in the workplace

Dust is a generic term for very small solid particles found in the air and deposited as a layer on floors, furniture and other indoor surfaces. Dust can be made up of many different types of material. Some particles are of natural origin, while others are released by various mechanical, heating and combustion processes.

Airborne particles are classified according to their size. The size fractions relevant to health are the inhalable, thoracic and respirable fractions (EN 481):

- **The inhalable fraction** is the fraction of particles inhaled through the nose and mouth.
- **The thoracic fraction** is the fraction of inhalable particles that pass through the larynx.
- **The respirable fraction** is the inhalable particles that reach the lower part of the respiratory tract, the alveoli (air sacs) of the lungs.

Because particles can have different shapes, the aerodynamic diameter is often used to express the size of airborne particles. The commonly used term is particulate matter, abbreviated PM. PM_{10} comprise the mass of airborne particles smaller than 10 micrometres (μm) and $PM_{2.5}$ particles smaller than 2.5 μm. Compared to the limit values for the working environment, the PM_{10} size fraction is between inhalable and respirable, and $PM_{2.5}$ is smaller than respirable dust.

Very small particles in the size range of 1-100 nanometres (nm) are called nanoparticles. In the past, ultrafine particles were a common term in occupational hygiene and medicine. Because nanoparticles are so small, their mass represents only a small fraction of the mass concentration of PM_{10} and $PM_{2.5}$. Therefore, other methods are needed to measure nanoparticles, which, in simple terms, involve sorting the particles by size and then calculating the number of particles in each size range as the number of particles per cubic centimetre.

Where does it occur on board?
Particles are generated by combustion and are present in exhaust gases and welding fumes. Dust can also be released when handling powdered chemicals and during metal processing operations such as turning, drilling and grinding. Smoke particles from welding, for example, are generally smaller than 1 µm, which means that all such particles can be considered respirable. Studies have shown that the main source of particles in the indoor air of ships is exhaust gases in the supply air.

Health effects
Particulate matter is considered to be the air pollutant with the greatest impact on human health. Several lung diseases are caused by particles that cause inflammation in different parts of the lungs, such as emphysema, chronic obstructive pulmonary disease (COPD), asthma and heart attacks. Particles containing hazardous substances that are released and circulated in the body in the blood stream can also cause other diseases specific to that particular substance. There are also several types of cancer caused by dust and smoke, the most common being lung cancer. Particles can also carry carcinogens and other harmful substances.

OEL values and guidelines
In the context of occupational health and safety, limit values for dust are set for individual chemical substances, mainly metals, or for specific manufacturing processes, such as cotton, graphite, thermosetting plastics, coal, flour, paper, PVC, textiles or wood. In addition, limits are set for so called total dust depending on its chemical nature, whether it is inorganic or organic. If the dust consists of substances that have specific limit values, these values should apply.

For particles in outdoor air, there are binding limit values for PM_{10} and $PM_{2.5}$. The WHO guidelines (WHO, 2021) also use PM_{10} and $PM_{2.5}$ as a metric of size. IARC has classified outdoor particulate matter as a human carcinogen.

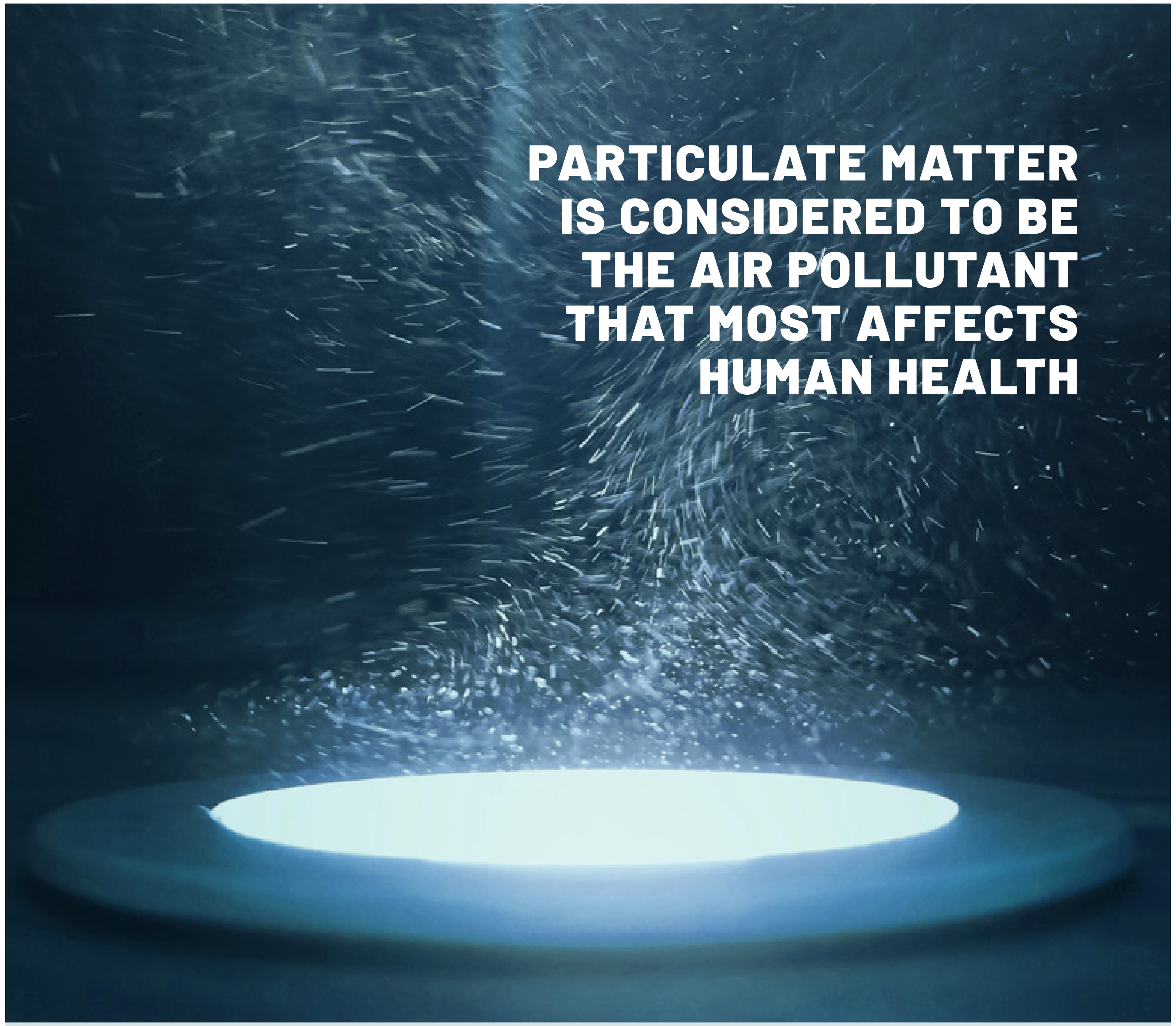
Soot and elemental carbon

Elemental carbon (EC), or soot, is a type of particulate matter produced by almost all types of combustion. In the literature it is also referred to as black carbon.

Where does it occur on board?
Elemental carbon is a component of $PM_{2.5}$ particles, which are mainly produced by incomplete combustion of fossil fuels and biofuels. It is considered a reliable measure of combustion-related particles resulting from incomplete combustion of fossil fuels and biofuels.

Health effects
The health effects are similar to those of exposure to dust and particles, including reduced lung function and cardiovascular disease.

OEL values and guidelines
Elemental carbon is a proxy for exposure to diesel exhaust. The OEL value for elemental carbon is 50 µg/m³.



	IARC risk group	*TLV-TWA (8h)*	*TLV-STEL (15 min)*	*WHO guidelines for indoor air quality*	*Indoor environments (housing, offices)*
Inorganic dust, *respirable*	–	2.5 mg/m³	–	–	Not applicable
Inorganic dust, *inhalable*	–	5 mg/m³	–	–	Not applicable
Organic dust, *inhalable*	–	5 mg/m³	–	–	Not applicable
PM_{10}	1 outdoor air	Not specified	Not specified	15 µg/m³ daily average 5 µg/m³ annual average	2 – 330 µg/m³
$PM_{2.5}$	1 outdoor air	Not specified	Not specified	45 µg/m³ daily average 15 µg/m³ annual average	2 – 210 µg/m³
Elemental carbon	–	50 µg/m³	Not specified	Not specified	0.5–7 µg/m³

THERMAL CLIMATE AND COMFORT

The thermal climate, i.e. air temperature and relative humidity, is of great importance for human well-being. How the thermal climate is experienced depends on air temperature, radiant temperature and humidity. It is also influenced by the type of work performed, whether it is sedentary or mobile, and how well the clothing is adapted to the work to be done.

The importance of a comfortable thermal environment

Cold, heat and draughts can have direct and indirect effects on health. A temperature between 20-24 °C and a relative humidity between 30-70 % is perceived as a good environment by most people. What is perceived as a comfortable temperature is also affected by the speed of the air, i.e. the draught.

Too high or too low a temperature can be uncomfortable and affect both physical and mental performance. Direct effects in hot climates include headaches and fatigue. Cold climates can cause problems with joints and lung disease. Cardiovascular disease is common in both hot and cold climates. Indirect effects include difficulty concentrating, which can contribute to an increased risk of accidents. When the body is exposed to thermal stress, the absorption of airborne pollutants also increases because we have to breathe more.

Indoor relative humidity is linked to temperature. Heating up cold outside air reduces the relative humidity (RH). RH is a measure of how much water vapour the air can hold at a given temperature. At RH levels above 70 %, the risk of mould and mite growth increases. Dry air causes the mucous membranes in the eyes, nose and throat to dry out. This can lead to irritated and dry eyes, dry skin and lips, and nosebleeds. Static electricity can occur when the relative humidity is below 40%. As well as being unpleasant for the person exposed to the discharge caused by the static electricity, it can cause interference in electronic systems.

OEL values and guidelines

There are no exact temperature limits for how hot it may be at work, either indoors or outdoors. The Swedish Work Environment Authority's regulations on the design of workplaces state that indoor workplaces must have a suitable thermal climate, adapted to the activities carried out. The temperature and air velocity must be adapted to the type of work, whether it is light or heavy, mobile or sedentary.

The general advice from the Swedish Work Environment Authority is that the air temperature for light and sedentary work should be within the range of 20-24 °C in winter and 20-26 °C in summer. Otherwise, a more detailed investigation and risk assessment must be carried out. For sedentary work, the air velocity should be less than 0.15 m/s. For more mobile work, or at higher air temperatures, the air velocity may be higher. If different tasks are performed in different parts of a room, they may require different thermal climates.

Permanent outdoor workplaces should be designed to protect workers from the weather. Temporary outdoor workplaces should, as far as possible, be designed to protect workers from the weather. The Public Health Agency of Sweden has issued general advice on indoor temperatures that apply to living spaces and general indoor environments (FoHMFS 2014:17). Recommendations for ventilation, air quality and thermal climate can also be found in international standards.

	Benchmark work environment	*Guideline value indoor environment*	*Indoors*
Temperature	20–24 °C wintertime 20–26 °C summertime Adapted to the type of work	20–24 °C	19–24 °C
Relative humidity	Not specified	25–60 %	25–57 %

MEASUREMENT AND ANALYSES OF AIR QUALITY PARAMETERS

There are several ways to study indoor air pollutants. This section gives examples of how measurements are made, which laboratories can help with the measurement and analyses of various substances, and information on what to include in a measurement report.

Planning the measurements

There are several ways to investigate air pollutants in the indoor environment. The Swedish Work Environment Authority's regulations on limit values for respiratory exposure in the work environment contain rules on which substances may need to be measured depending on the type of air pollution, how the measurement should be planned and how it should be carried out.

If the aim of the investigation is to assess the relationship between the concentrations and the limit values, the measurements must be carried out using personal samplers placed in the breathing zone. The measurements should be planned together with the workers concerned.

Contents of the measurement report

In order for the exposure measurement to be used for an overall assessment of the chemical work environment risks, the results of the measurements must be documented in a measurement report, which must contain at least the following information:

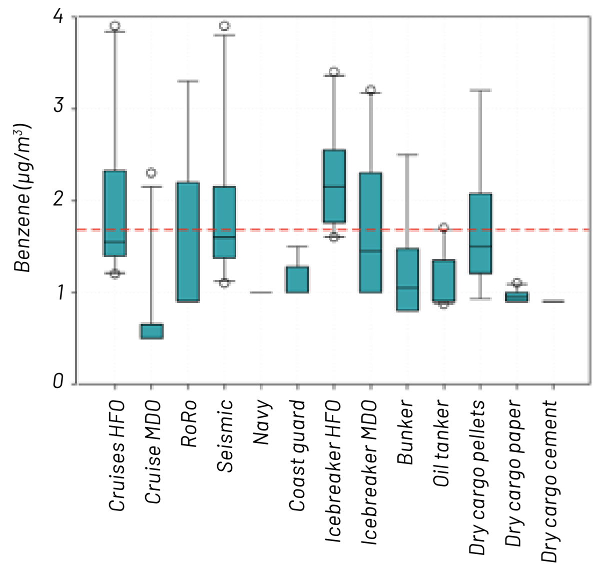
- Where the measurements were carried out in relation to where the workers normally spend their time.
- The conditions at the workplace during the sampling, such as which engines were running at what times and the functioning of the ventilation system.
- How the staff were working in the room, an assessment of the staff's physical workload, which can affect the uptake of hazardous substances, and whether they were wearing personal protective equipment.
- What other exposures occur simultaneously and have a synergistic hygienic effect.
- A comparison with previous surveys or other investigations to put the results into perspective.
- What action is recommended in response to the results of the measurements.

Methods for measuring air pollutants in general indoor environments can also be applied to air quality studies on ships. Measured concentrations can be compared with occupational health and safety limits in work areas or recommended guidelines in living areas.

How to make measurements

Some on-board measurements of air pollutants and indoor climate parameters can easily be carried out using passive samplers or simple sensors. The advantage of passive samplers is that they require no power and are small and quiet. Some other measurements, such as particulate matter, require more sophisticated instruments operated by experienced personnel. Instructions for measuring gaseous and particulate air pollutants commonly found on ships are described in the following sections. The information is categorised according to the type of sampler, sensor or instrument required for the different measurements.

Results for airborne pollutants are given as concentrations in µg/m³ (micrograms per cubic metre). The concentration is an average over the sampling period.



Concentration of benzene on different ships. The red dashed line shows the recommended guideline value for benzene in general indoor environments of 1.7 µg/m³.

Temperature, relative humidity and carbon dioxide

There are several sensors on the market for measuring temperature, humidity and carbon dioxide (CO_2) concentration. We have good experience with the robust and stable sensors from Wöhler. The combination instrument CDL210 measures and records carbon dioxide (ppm), humidity in percent and temperature. The logged data can be transferred via a USB connection and processed in a simple programme supplied with the instrument.

The Wöhler KM 410 is a hand-held, battery-operated version of a combination instrument. The KM410 measures and records carbon dioxide, carbon monoxide, temperature and relative humidity, and also calculates and records wet bulb temperature and dew point. The instruments can be purchased from Swema.se, for example.

Nitrogen dioxide, sulfur dioxide and ozone

Nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and ozone can be measured with IVL's passive samplers. The sampling principle is that the air diffuses into the sampler and the pollutants are collected on an impregnated filter. The samplers can be ordered from IVL Swedish Environmental Research Institute. Detailed instructions for handling of the samplers are provided with ordered samplers. The sampling period is 1-2 weeks. After the sampling has been completed, the samplers are sent to the laboratory for analysis. The cost of the sampler and analysis is approximately SEK 500-800.

Volatile organic compounds, formaldehyde and polycyclic aromatic hydrocarbons

Volatile organic compounds (VOCs), formaldehyde and polycyclic aromatic hydrocarbons (PAHs) can also be measured with passive samplers.

For passive sampling of VOCs, tubes containing Tenax® adsorbent medium are used. VOCs are analysed both as the sum of VOCs in the sample (TVOC) and by identifying and quantifying individual substances, such as benzene.

Formaldehyde is measured with a different type of passive sampler. Analyses can be ordered from IVL Swedish Environmental Research Institute. The cost of the sampler and analysis is approximately SEK 2 500-3 000.

PAHs are measured with a special passive sampler made of polyurethane foam (PUF), which is cylindrical, approximately 10 cm long and 2 cm in diameter. During sampling, the PUF sampler is placed in a special protective metal wire container with a mesh size of 1 mm.

Concentraions can be determined for 32 specified PAHs, including the 16 PAHs identified as priority by the US EPA. Naphthalene and benzo(a)pyrene are the PAHs of most concern in the workplace. Samplers, analyses and price information can be ordered from Arbets- och miljömedicin (Occupational and Environmental Medicine) Syd.

Particulate matter, elemental carbon and carbon monoxide

Particulate matter PM_{10} and $PM_{2.5}$ are measured either by collection on filters or by direct reading instruments. Both measurement methods must be carried out by experienced personnel. The measurement can be ordered from IVL Swedish Environmental Research Institute.

Elemental carbon is measured with a special instrument called an aethalometer. The measurement can be performed by Arbets- och miljömedicin (Occupational and Environmental Medicine) Göteborg.

Carbon monoxide is measured with direct reading instruments. IVL Swedish Environmental Research Institute offers this type of measurement.

Laboratories

Arbets- och miljömedicin Göteborg
formaldehyde, elemental carbon, inhalable dust, respirable dust and total dust

Arbets- och miljömedicin Syd
inhalable dust, respirable dust, total dust, naphthalene and benzo(a)pyrene

IVL Swedish Environmental Research Institute
nitrogen dioxide, sulphur dioxide, carbon monoxide, volatile organic compounds (VOC), particles, formaldehyde, carbon dioxide, temperature and relative humidity

Set of samplers for measuring several different air pollutants. Nitrogen dioxide (red button), sulfur dioxide (blue button), ozone (white button), volatile organic compounds (steel tube), polycyclic aromatic hydrocarbons (foam in protective net) and formaldehyde (white tube in the middle). The seal on the steel tube is removed to start the measurement.

ADVICE AND RECOMMENDATIONS

Studies of the indoor environment on ships show that the air quality is generally good, but there is room for improvements. Although the air quality does not pose a direct health risk, it does affect the perception of the indoor environment and the performance of the crew. In this section we propose technical and organisational measures that can be taken to further improve the indoor, working and living environment on ships.

Both Swedish and international OEL values for hazardous substances are based on the scientific basis of known dose-response effects, i.e. how much of a substance people can be exposed to without suffering acute or long-term health effects. OEL values are also set taking into account economic and social impacts and what is technically and practically feasible. It is therefore not possible to say with certainty that air pollutants are completely harmless if they are present at levels below the limit values.

For some of the air pollutants studied, such as benzene and PAHs, the WHO states that no safe levels can be recommended (WHO, 2010). In practice, this means that risks from exposure to hazardous air pollutants should be managed according to the principles of the prevention hierarchy of control, where risks should be eliminated or minimised as far as is economically and technically feasible.

Air quality on ships is important both for the perception of the indoor environment and for the work performance of the crew. The concentrations of various substances in the indoor environment are largely influenced by the type of ship and the type of fuel used. Type of ship and fuel are decisions that are made at a strategic operational level and the crew has little or no control over these decisions. However, with a well thought-out design of the ship's technical equipment and ventilation system, it is possible to reduce the levels of hazardous air pollutants even on tankers and in engine rooms, where the levels are generally the highest.

The duties performed also have a significant impact on the exposure of seafarers to air pollutants. Although service personnel are generally less exposed, they may also have tasks and working conditions that need to be investigated. It is therefore important to identify working situations on board for all categories of personnel that may give rise to an increased risk of illness and accidents, so that appropriate technical, organisational and individual measures can be taken.

Suggested measures for existing ships

This section provides examples of investigations and measures that can be carried out to improve the indoor environment on existing ships. Based on the hierarchy of control, measures should first and foremost eliminate and minimise risks. This may involve technical measures, such as reviewing general ventilation and local exhaust ventilation, or investigating the feasibility of introducing closed processes to reduce exposure. It may also involve organisational measures, such as reviewing how work is organised to see if risks can be reduced by, for example, limiting the time the worker is exposed to the risk or introducing job rotation. The use of personal protective equipment should always be the last step.

Inspection and maintenance of ventilation systems
A ship will normally have several ventilation systems on board. Effective procedures must be in place for regular inspection and cleaning of the systems to ensure that air pollutants are effectively removed and that all spaces have adequate air circulation. This applies to general ventilation systems as well as process ventilation and local exhaust ventilation in workshops, paint shops, galleys, etc.

Staff must also have access to written instructions that clearly explain how each system works, how to service and maintain it safely, and how to troubleshoot it.

To reduce the spread of dust and harmful substances, hand tools such as welding torches, grinders and cutting machines can be fitted with built-in extractors that effectively capture airborne pollutants. Integrated extractors capture pollutants close to the source before they can spread throughout the workplace.

Order and tidiness
In general, it is important to maintain order and hygiene in both working and living areas. Shipboard work means that many people are present in a relatively small area. Previous research has shown that there is an increased risk of infectious diseases spreading. Poor ventilation, lack of maintenance of ventilation systems, inadequate cleaning or incorrect cleaning methods can increase the risk of health problems. Good cleaning practices keep particle levels low because dust acts as a reservoir for particles, from which new particles are constantly generated. Effective procedures for cleaning premises and equipment also make it easier for cleaning staff to do a good job.

Tidiness is facilitated by a clear understanding of the location of equipment, tools, materials, etc. and that 'there is a place for everything'. In workplaces where there is frequent turnover of staff, it is important that these procedures are clear so that they can be applied by everyone, including those who are in the workplace only temporarily.

In office environments, for example, it is advisable to keep computer and other equipment cords in special channels or bound with cable ties, and to keep table surfaces clean so that they can be wiped down and kept clean.

The highest levels of contaminants have been found in ships' engine rooms, particularly in the separator room. It is therefore important to have procedures in place to minimise exposure to vapours from the ship's fuel and lubricating oils. Tank tops and spillways must be regularly cleaned and leaks sealed. Even small leaks from valve stems, pump shaft seals and the like should be dealt with as soon as they are discovered. Although these are areas where personnel are not intended to be present during working hours, it is still the case that machinery personnel spend many hours in these spaces, for example, cleaning and maintaining filters, fuel and lube oil separators and other equipment. Instead, the actual cleaning work should be carried out in dedicated cleaning rooms, where it is possible to transport the items to be cleaned. Large vats of diesel oil should not be used for cleaning. Where possible, other less hazardous cleaning agents and methods should be used, such as ultrasonic cleaning or clean-in-place (CIP), which do not require major dismantling.

Personal protective equipment
Based on the hierarchy of control, the use of personal protective equipment is always the last step when it is not possible to eliminate or further reduce the risks by other technical or organisational measures. All personal protective equipment should be selected and designed to suit the wearer and be appropriate to the work being carried out.

Where respiratory protective equipment must be used, it should be specifically designed to ensure that the size and model of the equipment is appropriate for the person using it. The same respirator will not fit all faces. Respirators designed to fit tightly against the face, known as tight-fitting respirators, must also be tested for tightness. This can be done by a fit

THE HIGHEST LEVELS OF CONTAMINANTS HAVE BEEN FOUND IN THE SEPARATOR ROOM

testing using an appropriate quantitative or qualitative method. Quantitative methods are based on either measuring the number of particles inside and outside the respirator or measuring the air pressure inside the respirator. The qualitative method basically involves wearing the respirator under a hood covering the head, neck and shoulders. A flavour or fragrance is then injected into the hood. If the user can taste or smell the substance, the respirator does not seal properly. The test should be performed by a person with knowledge of respirator use and fit testing methods.

More detailed descriptions of fit testing methods are given in the international standard ISO 16975-3:2022.

Proposed measures for newbuildings

At the design stage, it is important to consider the design of ships and the choice of equipment. Of particular importance for the indoor environment are:

- the choice of propulsion system and fuel
- ventilation arrangements
- the design of workplaces and engine rooms, where the highest levels of air pollution have been measured.

Propulsion and fuel

Air quality on board is strongly influenced by the fuel used for propulsion and auxiliary engines. In addition to the improvements in air quality that have been demonstrated by using cleaner fuels, there are other improvements in the working environment. For example, maintenance and cleaning intervals for filters and separators can be extended, and the work itself can often be done in less time because cleaning is much easier. Ships running on heavy fuel oil require more time and the use of more and stronger chemicals to clean tanks, sump trays and other equipment.

All operational options have characteristics and risks that require special consideration in the design of systems, operation and maintenance procedures, training and emergency procedures. Risk assessments must therefore cover the risks of serious injury and ill health as well as the satisfactory performance of tasks.

All liquid fuels are considered toxic, with the exception of natural gas. Methanol is acutely toxic by both ingestion and dermal exposure. However, it is not carcinogenic. As ships still have systems to run on petroleum-based fuels, few tasks have disappeared completely and none of the operational alternatives involve lower direct costs for personnel. However, there are differences in how often different tasks need to be performed and under what conditions. Cleaner fuels reduce the need to clean components and machine areas. This in turn means less exposure to hazardous substances and that working time can be spent on other tasks that are perceived to add value. Since many jobs on board involve simultaneous exposure to several known risk factors, a holistic approach is needed that includes preventive measures and long-term health promotion. It is not enough to target only the worst exposures.

Each operational option has its own characteristics and risks. These require special consideration in system design, operation and maintenance procedures, education and training, and emergency procedures. Whichever option is considered, it is essential that health and safety aspects are considered as early as possible in the planning and design process. These do not only have to cover risks of

serious injury, but also ensure that work tasks can be carried out in a satisfactory manner throughout the life of the ship, with the minimum risk of ill health and accidents. This requires a systematic analysis of working environments and tasks during operation, maintenance and emergency situations.

To a large extent, the work of the engine crew is affected by the choice of propulsion system and fuel. This is primarily related to tasks that affect the ship's fuel system and propulsion in various ways, but also work with other peripheral equipment such as bilge water and sludge handling, and not least general cleaning of the engine rooms.

Ventilation arrangements

There are special requirements for ventilation arrangements, such as the location of vents on certain tanks in relation to fresh air intakes. On Swedish ships, there are also requirements for special process ventilation in workshops, galleys and paint stores where paint is mixed. Even for those tanks where there are no special requirements, the location of vents and their relationship to air intakes should be carefully considered. It is also important to ensure that engine exhaust is directed away from the ship in such a way that there is no risk of it being drawn into the fresh air intakes, regardless of wind conditions or direction.

Design of workplaces and living environments

From the design stage, it is important to ensure that all common tasks can be carried out safely and efficiently.

Premises and living areas need to be designed and dimensioned for normal cleaning. For example, there must be sufficient space to manoeuvre a cleaning trolley, vacuum cleaner and other necessary equipment. Access to and location of scuppers and other drains must also be planned. Clear floor surfaces make cleaning easier. In toilet and shower areas, cleaning is facilitated if the toilet seat and washbasin are wall-mounted.

Engine rooms must have a dedicated cleaning area where filters, separators and other machine parts can be lifted for cleaning. This can be achieved either by means of lifting beams running through the engine room and directly into the cleaning room, or by allowing the parts to be moved there by trolleys or pallet jacks.

Cleaning rooms should be well ventilated. Excess air should be exhausted and should not enter adjacent machinery and personnel areas. The cleaning room should also have access to hot and cold water, compressed air and high-pressure washing facilities.

In addition, work should be organised in time and space to avoid unnecessary strain on the respiratory system. Increased physical exertion increases breathing and the absorption of contaminants. Engine rooms in general and separator rooms in particular are often hot. Even the ship's galley can sometimes have high temperatures, depending on the climate zone. Working in intense heat increases stress on the body, so it may be necessary to plan regular breaks in cooler and better ventilated areas. This guide focuses on uptake through the respiratory tract, but absorption of harmful substances also occurs through the skin. It is therefore important to ensure that procedures are in place for changing and cleaning work clothing and gloves, and that appropriate protective gloves of the right type and size are available.

Although the concentrations of airborne contaminants measured are well below the OEL values for catering staff, it is still important to design ship galleys to provide good general ventilation throughout the space, supplemented by special extractors at frying tables and the like to capture airborne contaminants close to the source. As with other spaces, it is important to have good procedures for cleaning and maintaining work equipment and ventilation systems.

Work also needs to be organised to reduce individual exposure through job rotation, job changes and the opportunity to take breaks in a lower-exposure area.

On cargo ships, the cooks have little opportunity to rotate with another person on board, but instead they have a natural rotation of work as they do all the kitchen tasks themselves. Fewer portions are prepared than on a passenger ship. On cargo ships, cooks are more exposed to fuels and their exposure is characterised by personal habits such as the use of perfume, shaving cream or chewing gum.

Measures to reduce exposure can be both technical and organisational. It is important to provide good general ventilation for both workstations and cabins. In some areas, such as welding and machining workstations, cleaning of engine parts, mixing of paints, over frying tables in the kitchen, etc., it may be necessary to supplement the general ventilation with special or improved exhaust systems to capture air pollutants close to the source. Good cleaning and maintenance procedures for work equipment and ventilation systems are also important. Organisational measures can include planning and distributing work to reduce individual exposure through job rotation, job changes and opportunities for breaks in lower-exposure areas.

Thinking ahead about changes that affect the work environment

The Work Environment Act places great emphasis on the importance of planning for a good work environment. In Swedish workplaces, it is a legal requirement that changes to operations that may affect the work environment must be risk assessed. The risk assessment must be carried out together with the work environment representative and the personnel affected by the change. This also applies to Swedish-flagged vessels. For ships that are not covered by Swedish work environment legislation, this type of risk assessment can be carried out because it is a good idea, even though it is not an explicit legal requirement. The idea is to identify risks so that they can be addressed while it is still possible.

Deficiencies in the design of workplaces and systems can lead to failure of the person performing the task:

- Spend too much time doing the job, resulting in less time for other tasks.
- Do the job incorrectly, which can lead to harm to people, equipment and the environment.
- Become stressed and insecure, reducing their ability to complete tasks.
- Do not know how to use the different functions of the systems, which means that the benefits are not realised.

Well-designed workplaces and systems, on the other hand, enable the tasks to be performed safely and efficiently, reduce the learning time required to perform the task, and increase the commitment and satisfaction of those performing the task. Ultimately, it also leads to lower development costs.

The earlier you start developing new workstations, the greater the opportunity to make changes. At the same time, the cost of these changes is low. The ability to influence and change flaws in the design of a system decreases over time, while the cost of change increases.

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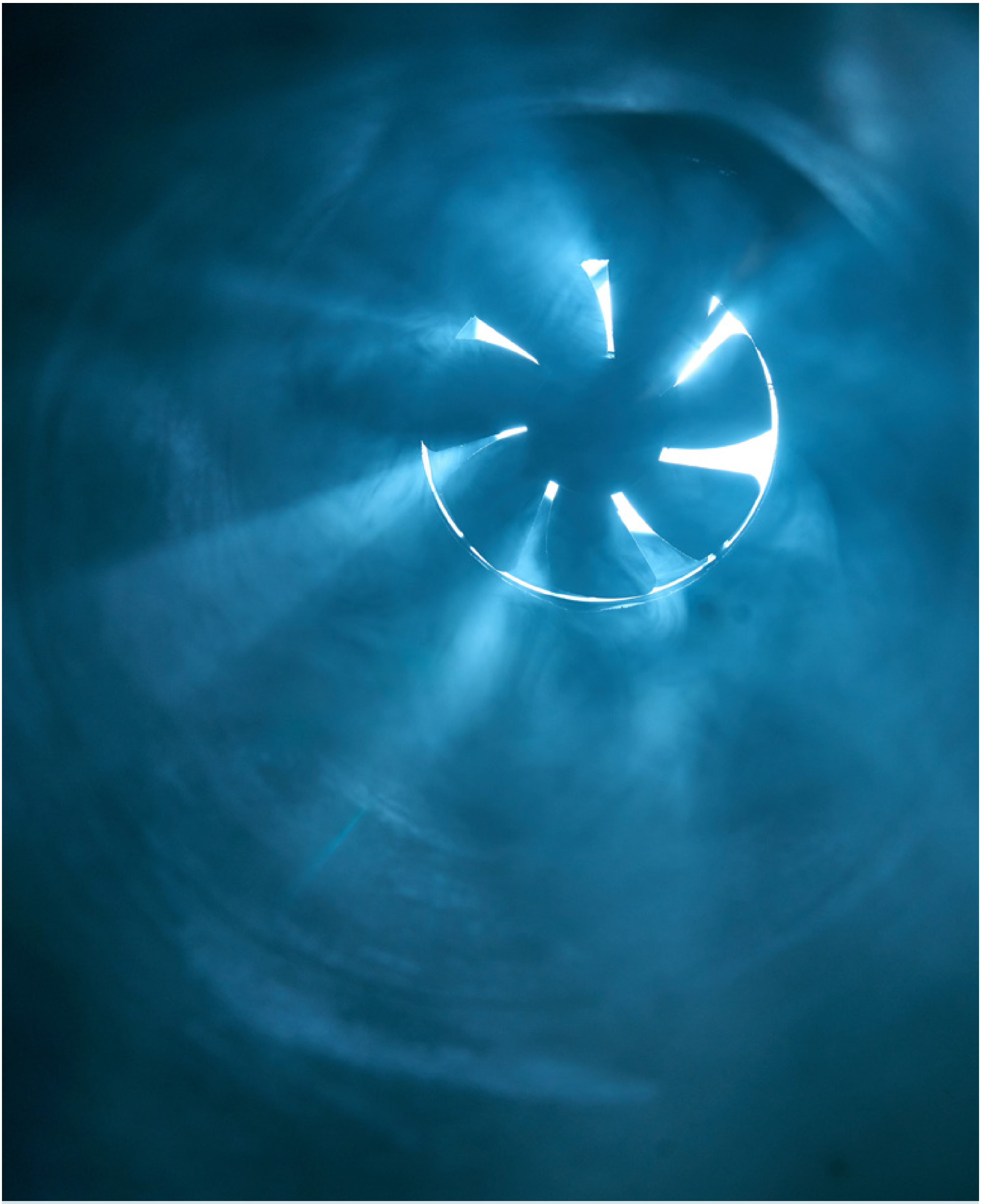
THE AIR QUALITY OF SHIPS HAS AN IMPACT BOTH ON THE PERCEPTION OF THE INDOOR ENVIRONMENT AND ON THE HEALTH AND PERFORMANCE OF THE CREW



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