# Guidance for Occupational Hygienists on the Assessment and Control of the Health Risks from Metalworking Fluid (MWF)

March 2025

Version 1.1

## Metalworking Fluid Expert Group


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### Feedback

We welcome feedback on this guide.
Comments should be sent to BOHS at membership@bohs.org.

### Version History

| Version | Release date | Comments and amendments |
|---|---|---|
| Version 1 | November 2024 | Original version |
| Version 1.1 | March 2025 | Pages 5, 37 and 42 – update of URL for COSHH Essentials Machining with metalworking fluids.<br>Page 21, Table 5.1, Examples, 2nd major bullet point – addition of information to explain the term ‘high-efficiency’ in relation to filters for LEV systems.<br>Pages 38 and 42 – replacement of URL for HSE Case studies – metalworking fluids with URL for HSE Resources – metalworking fluids. |


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## Contents

# 1. Introduction

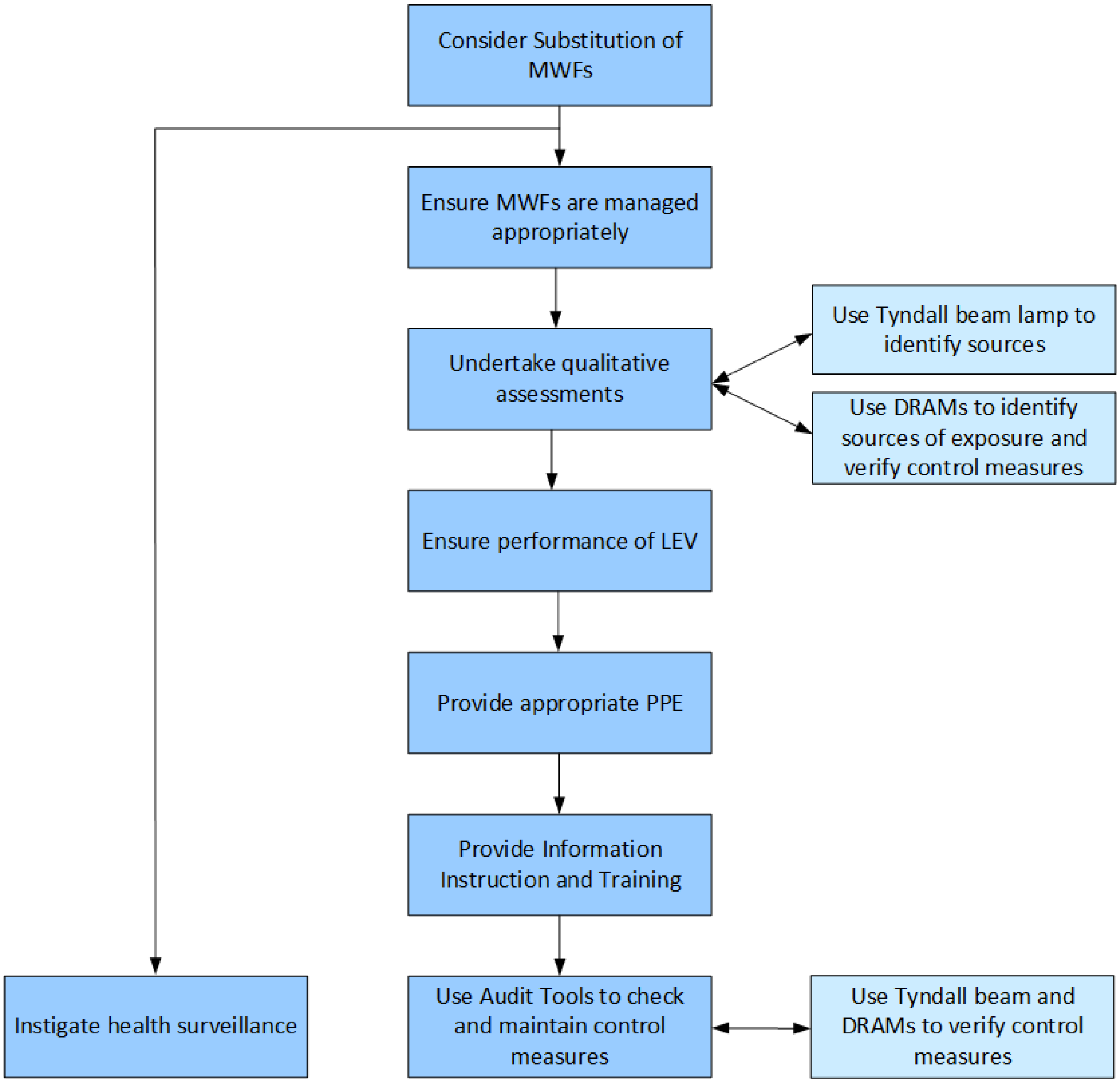
This guidance is aimed at Occupational Hygiene Professionals and provides information about how to assess, prevent or control exposure to metalworking fluid (MWF) according to the principles of good control practice, as outlined in the Control of Substances Hazardous to Health Regulations (COSHH). Research has shown that the use of traditional techniques of personal monitoring and comparison to exposure limits are no longer informative. This guidance is intended to help occupational hygienists use appropriate techniques for exposure assessment and to inform them of what is considered good control practice.

Historically, personal exposure monitoring to MWF mist was advocated and whilst no exposure limit was set in the UK, the Health and Safety Executive (HSE) published control guidance values. These guidance values have since been withdrawn. Outbreaks of ill health caused by MWF have shown that the guidance values were not adequate in terms of controlling health risks. Furthermore, the published measurement method MDHS 95/3 (HSE MDHS 95/3, 2015) for MWF emulsion is not always relevant because of changes in the composition of some products. This guide explains the qualitative and semi-quantitative techniques which should be used in place of traditional exposure monitoring.

Figure 1.1 lists the steps which occupational hygienists need to take in assessing and controlling exposures to MWF. An important step is the management of fluid quality; this is not covered in this guidance which focuses on control of exposure. Occupational hygienists should familiarise themselves with the United Kingdom Lubricants Association (UKLA) ‘Good Practice Guide for Safe Handling and Disposal of Metalworking Fluids’ (UKLA, 2023).

Occupational hygienists are also directed to the five COSHH Essentials guidance sheets for machining with metalworking fluids (https://www.hse.gov.uk/coshh/essentials/direct-advice/metalworking-fluids.htm ) which provide straightforward advice in 'factsheets'. They set out basic advice for employers and employees on what to do to control exposure to MWF in the workplace. HSE also provides guidance on occupational health surveillance (https://www.hse.gov.uk/health-surveillance/) including general guidance sheets (https://www.hse.gov.uk/pubns/guidance/gseries.htm).

**Figure 1.1 Flow chart setting out the framework for managing health risks from exposure to MWF.**



# 2. Health Hazards and MWF

## 2.1 What are MWF?

MWF provide diverse functions including cooling, lubrication, and metal chip removal. They improve machine tool life and the surface finish of parts and operate under specific manufacturing conditions. There are three main types of MWF:

1. **Neat cutting oils** (also known as mineral oil or straight oil): These contain no water and are made from petroleum, animal, marine, or vegetable oils and are used for machining at relatively low feed rates and extreme pressures at the tool-workpiece interface.
2. **Water-miscible MWF:** These are the most used MWF in the UK**.** They contain a base oil (typically naphthenic or paraffinic oils) and more than 20 different ingredients such as buffer salts, corrosion inhibitors, coupling agents, defoamers, dyes, emulsifiers, lubricity agents, biocides, perfumes, viscosity and viscosity modifiers. They are typically used at working dilutions from 3% to 10% concentration after dilution in water forming a milky solution. This type of MWF also includes:
    - **Semi-synthetic MWF:** They contain from 20% to 50% of base mineral oil in water with the balance of constituents being other additives for improved performance and some biodegradability.
    - **Synthetic MWF:** They contain no base oil and are composed of polyalphaolefins, synthetic oils (i.e. gas-to-liquid oils), or polyethylene glycols, in water and they offer improved biodegradability.
3. **Soluble oils**: These water-miscible MWF have a higher oil content (typically 5% to 20%) and offer a balance between cooling and lubrication properties but are gradually being replaced by synthetic MWF which offer improved environmental and health considerations.

Safety data sheets (SDS) for MWF products include chemical hazard information for ingredients that in the fluid concentrate may present a risk to health. Individuals may react to some chemical ingredients in the diluted MWF.

## 2.2 What causes respiratory and skin disease in machinists?

The main health risks in machinists are skin and respiratory diseases caused by exposure to MWF constituents, oxidised constituents, and contaminants such as tramp oil, metals, biocides and microorganisms. These additional hazards are not identified in SDS.

Once water-miscible MWF are diluted to their working concentration, the deterioration and contamination of the fluid support the growth of microorganisms. When aerosolised by machining, used MWF is more likely to cause irritation and inflammation in the nasal passages, throat, lungs and eyes. Some microorganisms that grow in water-miscible MWF are recognised human pathogens but most are common environmental organisms that grow in wastewater.

Modern neat oils are made from highly refined ingredients addressing some of the historical risks of exposure to impurities such as carcinogenic polyaromatic hydrocarbons which caused scrotal and skin cancer in machinists. Neat oils present a considerably lower risk of contamination by microorganisms unless contaminated by tramp oil and water.

### 2.2.1 Respiratory disease

- High-speed machining and grinding operations using water-miscible MWF generate mist/aerosols containing droplets larger than 100 µm in diameter and as small as a few nanometres. Whilst droplets from 100 - 300 µm may enter the upper airways, droplets smaller than 10 µm enter the airways and lungs.

- Respiratory tract infections by bacteria and fungi are uncommon in machinists, but the inhalation of these microorganisms causes respiratory sensitisation and allergy in some machinists. Some types of bacteria also release toxins (for example endotoxin from gram negative bacteria) which cause inflammation in the respiratory tract. High concentrations of endotoxins have been found in used MWF but airborne concentrations are typically lower than those known to cause inflammation in most people.
- Water-miscible MWF contain increased concentrations of soluble metals and fine metal particles. These particles may be aerosolised during high-speed machining and grinding. Nickel, chromium, and cobalt are sensitising metals which cause respiratory allergies such as asthma.
- Some machinists risk developing occupational asthma from exposure to the chemical ingredients in freshly prepared water-miscible MWF including ethanolamines and certain biocides.
- Machining increases the temperature of MWF causing them to release volatile organic compounds (VOCs) like acetone, ethanol, toluene, and xylene, as well as chemicals released by microorganisms. Combined VOC emissions from MWF can irritate and inflame the airways, and these symptoms occur more frequently in machinists exposed to contaminated water-miscible MWF. Long-term exposure to some VOCs causes cardiovascular, neurological and carcinogenic effects.

The main types of respiratory disease and symptoms in machinists are:

- **Occupational Asthma (OA).** This is caused by exposure to allergens and irritants and made worse by environmental conditions such as cold air**.** The development of OA may take months to years of exposure to these hazards. Employees who develop asthma from exposure to allergens develop immune sensitisation, and subsequent exposure to small quantities of the allergen may trigger more severe reactions. New cases of OA have been reported in machinists exposed to ‘used’ water-miscible MWF mist compared to employees not exposed, and at mist concentrations below the historical UK HSE guidance value of 1.0 mg/m$^3$ including other regulatory limit and control guidance levels used in Europe and the USA.
- **Occupational Hypersensitivity Pneumonitis (OHP).** This is an allergic lung disease caused by repeated inhalation of fungi and bacteria, animal proteins and some chemicals such as polyurethanes and isocyanates. It was previously referred to as Extrinsic, Allergic Alveolitis (EAA). Exposure to water-miscible MWF has become the most common cause of OHP reported to the UK Surveillance of Work-related and Occupational Respiratory Disease (SWORD) scheme (Barber et al, 2017). In machinists, OHP cases increased after the introduction of water-miscible MWF. Specific types of bacteria that grow in poorly managed water-miscible MWF may cause OHP in machinists.
- **Impaired lung function.** Reduced lung function has been observed by machinists at the end of their daily shift and the end of their working week. This has been observed in those exposed to water-miscible MWF mist and in older machinists who have worked for many years. These reductions are also larger when machinists are exposed to ‘used’ MWF.
- **Bronchitis**. There is an increased prevalence of chronic bronchitis in machinists exposed to water-miscible MWF mist, compared to non-exposed employees. This increase generally occurs in those exposed to concentrations of MWF mist below the historical UK HSE guidance value of 1.0 mg/m$^3$ including other regulatory limit and control guidance levels used in Europe and the USA.
- **Irritation to the upper airways.** VOC emissions can cause symptoms of nasal congestion, runny nose, sneezing, sinusitis and sore throat. These symptoms occur more frequently in machinists exposed to used and contaminated water-miscible MWF.

**Figure 2.1 Spirometry lung function tests used in occupational health surveillance. Photo shows a patient using a spirometer.**

### 2.2.2 Skin disease

Freshly prepared water-miscible MWF can present a risk for dermatitis if the skin regularly comes into contact with these fluids. This can cause a ‘wet work’ irritant dermatitis which is made worse by the high alkalinity (>pH 9.0) of water-miscible MWF and ingredients such as surfactants, emulsifiers, and preservatives. Whilst the use of disposable single use gloves may be required for specific handling tasks to prevent skin contact with MWF and other hazards, these types of gloves should not be worn continuously as they will occlude the skin. This will cause moisture retention under the gloves and can irritate the skin.

Biocides are added to water-miscible MWF to prevent the growth of bacteria and fungi. The manufacturer’s recommended working concentrations of these biocides should be followed to minimise health risks. However, some employees may become sensitised even when exposed to the working concentrations of biocides. Exposure to concentrated biocide solutions presents a greater risk of skin and respiratory sensitisation to these chemicals. Formaldehyde-releasing compounds, and 5-chloro-2-methylisothiazol-3-one / 2-methylisothiazol-3-one compounds, are the most commonly reported biocides to cause skin sensitisation in machinists.

Dermatitis causes painful swelling, blistering, cracking of the skin, and severe bleeding. Irritant and allergic dermatitis are the main types of skin disease in machinists mostly caused by contact with water-miscible MWF (See Figure 2.2). Dermatitis may take months or years to develop and can be a chronically relapsing condition affecting an employee’s health and quality of life, resulting in long-term sick leave, permanent disability, and loss of employment.

The main types of skin disease in machinists are:

**Irritant dermatitis**

- Irritant dermatitis occurs more frequently in machinists and typically affects the hands but can also involve the arms, neck, and face.
- 'Wet work' irritant dermatitis is more common in machinists and the duration and frequency of contact with water-miscible MWF is critical. Surfactants in MWF, oils, abrasive materials, and handling the MWF concentrate without wearing gloves can also cause irritant dermatitis. Irritant dermatitis increases the risk of machinists developing allergic dermatitis as it disrupts the healthy skin barrier.
- Atopy is a predisposition to allergic skin reactions against common environmental allergens e.g. in soaps, detergents, and fragrances. Machinists with a prior history of atopic skin disease are several times more likely to develop irritant dermatitis.
- Reducing exposure to irritant substances can help to mitigate damage, but chronic exposure may lead to irreversible scarring of the skin.

**Allergic dermatitis**

- Allergic dermatitis in machinists is caused by exposure to chemical and biological allergens. Allergic reactions are usually confined to the area of contact but may extend to the forearms, neck, and face. In sensitised people, exposure to very small quantities of allergen can trigger severe reactions, and these employees may be forced to leave their employment.
- Certain genetic risk factors predispose some individuals to allergic dermatitis including mutations to proteins which support the barrier function of the skin.

**Figure 2.2 Examples of mild (left side) and moderate (right side) irritant dermatitis on the hands caused by wet work.**

## 3. Management of MWF Quality in the Workplace

Comprehensive guidance is available from the UKLA on the effective management of MWF (UKLA, 2023). Maintaining the quality of MWF is important for machining production and performance and to minimise health risks. Changes in the composition of water-miscible MWF can give rise to increases in bacterial growth and fluid misting. Table 3.1 summarises different MWF quality parameters which may affect health risks. Measures to minimise these health risks are summarised in Table 3.2.

**Table 3.1 MWF quality parameters which may affect health risks.**

| | |
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| **MWF concentration** | During use, evaporation can increase the concentration of the circulating MWF and cause foaming leading to increased mist formation. Over-dilution of the MWF supply may stimulate bacterial growth. |
| **MWF pH** | Many water-miscible MWF are designed to operate above pH 9.0 which also restricts the growth of most bacteria, but below pH 8.5 many types of bacteria grow more readily. Higher pHs can also cause skin irritation. |
| **Tramp oil** | Tramp oil above a 2% concentration in the MWF encourages bacterial growth, and causes smoke, and lubricant foaming. |
| **Metal waste** | Metal contamination in water-miscible MWF promotes microbial growth, and sharp metal swarf and metal fines may cause cuts and abrasions. |
| **Stagnation** | Allowing MWF to stand uncirculated for long periods (days) increases the growth of anaerobic bacteria which cause odour problems from the noxious gases (hydrogen sulphide) and volatile organic compounds. |
| **Biocides** | The incorrect use of biocides can cause biocide-resistant organisms, and may be harmful to the operator. |
| **Operating temperature** | Operating MWF at a temperature above 30°C creates optimal conditions for microbial growth and evaporation which increases the MWF concentration. |

**Table 3.2 Actions required to manage the quality of MWF.**

<table>
<tr><td rowspan="2">MWF odour and appearance</td><td><ul><li>Visually check the appearance of MWF daily for changes in appearance.</li><li>Look for signs of biofilm formation, tramp oil, fines and swarf, foaming and other foreign materials.</li><li>Check for any changes in odour.</li></ul></td></tr>
<tr><td>Stagnant MWF can smell rancid or sulphurous.</td></tr>
<tr><td rowspan="2">MWF concentration</td><td><ul><li>Measure the concentration of the MWF using a refractometer at least weekly.</li></ul></td></tr>
<tr><td>Changes in MWF concentration can stimulate microbial growth/foaming.</td></tr>
<tr><td rowspan="2">MWF pH</td><td><ul><li>Check the pH using test strips or a pH meter at least every week.</li></ul></td></tr>
<tr><td>pH measurements indicate fluid quality, a sharp drop in pH may indicate high bacteria levels and a sharp increase in pH may indicate possible chemical contamination (e.g. alkaline cleaning solutions).</td></tr>
<tr><td rowspan="2">Tramp oil</td><td><ul><li>Visually check for tramp oil at least every week.</li><li>Record the checks on tramp oil leaks and the consumption of the machine oil supply.</li><li>Use coalescers or oil skimmers to remove tramp oil accumulating on the surface of the MWF supply. The following types of devices can be used to reduce the tramp oil contamination in the MWF supply.<ul><li>Surface oil skimmers.</li><li>Coalescers: either tank-side coalescers or portable coalescers.</li><li>Portable tramp oil centrifuges.</li></ul></li></ul></td></tr>
<tr><td>Tramp oil promotes microbial growth and affects air quality and MWF performance.</td></tr>
<tr><td rowspan="2">Metal waste</td><td><ul><li>Undertake visual checks for accumulation of metal fines in the MWF supply and sumps. Fit the machine tool with the following types of devices to remove metal swarf and metal fines:<ul><li>Magnetic filters.</li><li>Paper/cellulose filters.</li><li>Mesh filters.</li><li>Centrifugation chamber.</li><li>Sedimentation tanks in the lubricant supply.</li></ul></li></ul></td></tr>
<tr><td>The amount of metal fines that accumulate in the MWF is highly dependent on the type of metal being machined, the machining processes and the cutting/grinding speed. Soluble metal, metal fines and swarf support the growth of microorganisms in water-miscible MWF.</td></tr>
<tr><td rowspan="2">Circulation and flow</td><td><ul><li>Ensure that MWF is circulating.</li></ul></td></tr>
<tr><td>Poor flow may increase MWF supply pressure causing foaming, misting and reducing the performance of the MWF, and increasing the potential for microbial growth.</td></tr>
</table>

| | |
|---|---|
| **Monitoring bacterial growth** | • Test the MWF using dip slides to determine the number of colony-forming bacteria.<br>• Undertake weekly dip slide tests unless you can demonstrate that the controls in place are keeping bacteria growth consistently below 10,000 CFU/ml ($10^4$ CFU/ml) in which case the frequency of these tests may be reduced (to at least monthly).<br>• Inspect the machine, machine enclosure, and sump surface for visible signs of fungal growth. |
| | Bacterial growth is a primary cause of respiratory illness from MWF mist inhalation. Tests will indicate bacterial growth before visual methods and allow for quicker and easier interventions. |
| **Operating temperature** | • Check weekly the temperature of the sump. Leave the probe in the fluid for several minutes and check that the temperature is not above 30$^{o}$C. |
| | It is recommended that the MWF operating temperature does not rise above 30°C unless required for the performance of the MWF as this can promote the growth of microorganisms and increase water evaporation. |
| **Cleaning** | • Carry out cleaning of sumps at a frequency indicated by the dip slide results, visual checks, and MWF manufacturer's instructions.<br>• Use techniques which minimise splashing, mist and contact e.g. wet vacuum. |
| | The removal of waste metals from sumps helps to maintain the MWF supply volume, restricts the growth of microorganisms and prevents stagnation. |
| **Storage of MWF** | • MWF concentrate should be stored indoors (between 5$^{o}$C and 40$^{o}$C) in drums or IBCs.<br>• Ensure these stocks have appropriate hazard warning labels.<br>• Rotate the stocks to ensure they are used within their shelf life. |
| | Storing the MWF concentrate outdoors is acceptable but additional precautions should be taken which are explained in the UKLA 'Good Practice Guide for Safe Handling and Disposal of Metalworking Fluids' (UKLA, 2023). |
| **MWF dilution** | • Ensure the water source used to dilute the concentrate meets manufacturer's recommendations for pH and hardness.<br>• Use water directly from the mains (avoid stored water). |
| | Stored water can increase the risk of bacterial growth. |
| **Record keeping** | The checks on MWF appearance, odours, concentration, pH, metal contamination, and dip slide tests on bacteria and fungi should be recorded on charts so that any trends in the data can be monitored.<br>It is good practice to retain these MWF records to support future management of the MWF supply and to provide evidence that actions have been taken to address any deterioration in MWF quality. |

# 4. Assessment of Worker Exposure to MWF

## 4.1 Quantitative assessment of exposure

Measurement of personal exposure to MWF for risk assessment is not advocated, for the following reasons:

- A reliable quantitative assessment of exposure to MWF is technically difficult, and
- Exposure limit or guidance values that will reliably protect exposed individuals from the risk of skin and lung disease are undetermined.

The risk of developing health outcomes such as allergic asthma is influenced by many variables, including genetic factors, and the individual's history of developing atopy in earlier life or from their previous exposure to allergens.

Appendix 1 gives an overview of some of the historical methods used to assess exposure as well as the different exposure limits which have been adopted. Referencing withdrawn limits or guidance values is not recommended as evidence indicates they are insufficient to protect worker health.

## 4.2 Qualitative assessment

Whilst traditional exposure measurements are not advocated, semi-quantitative and qualitative techniques can be used to assess the performance of controls used to reduce employee exposure over time, and to demonstrate improvements in the use of these control measures.

Qualitative assessment provides an alternative to traditional personal monitoring methods to assess the potential for workers' exposure and the efficacy of control measures (including the machine's enclosure and LEV's effectiveness). A range of methods exist, and a control-focused approach offers value to assess emissions. Depending on the situation under review, methods could include the following:

- Using a dust lamp to check for MWF mist escaping from doors or gaps in the enclosure.
- Using a smoke pencil to show air is being drawn into the enclosure demonstrating that the air pressure inside the enclosure is negative with respect to the room air.
- Smoke clearance test to establish the time to clear the enclosure.
- Direct Reading Aerosol Monitors (DRAMs) can be used to assess relative changes in MWF mist either to detect leaks from enclosures, or failures in other control measures (e.g. recirculation filters).

### 4.2.1 Use of a dust lamp (Tyndall beam)

A dust lamp can be used to visualise mist to determine the need for the installation of control measures such as LEV. The correct use of this method is described in the HSE publication MDHS 82/2 (HSE MDHS 82/2, 2015).

The dust lamp provides a beam of focused light which is scattered as it interacts with airborne particles/droplets allowing visualisation of respirable particles below ~10µm (aerodynamic diameter).

For fine particles, the intensity of the scattered light is greatest at a small angle to the incident light beam (5-15º).

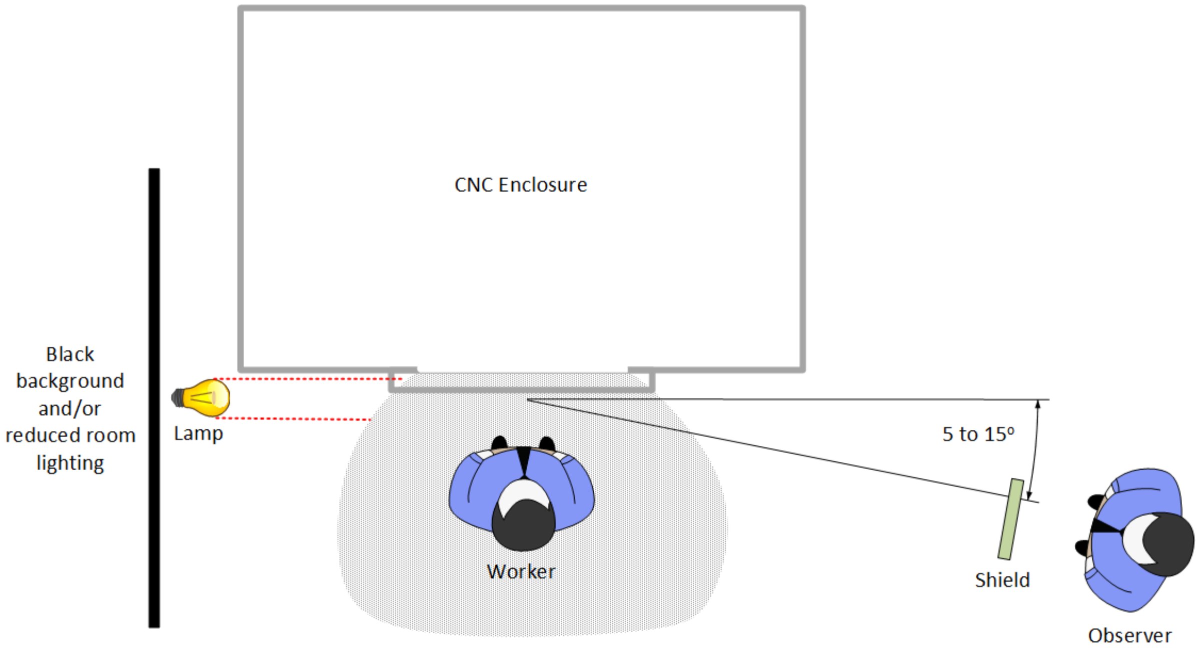
As the angle of viewing is increased, the intensity of the scattered light falls rapidly. For particles <0.1 µm, scattering by mechanisms other than diffraction occurs and the intensity of the light scattered is relatively low.

Figure 4.1 illustrates the use of a dust lamp to illuminate mist from a CNC machine. Figure 4.2 shows a photograph of MWF mist illuminated by a dust lamp. The lamp can be used to show the behaviour of airborne contaminants and identify loss of containment within an enclosure.

**Tips:**

- Keep background lighting levels low, if possible the particle cloud should be observed against a darker background, for example a black 'pop-up' screen.
- Ensure you have an adequate shield and viewing angle to the light source.
- Film the activity and use freeze-frame images in reports and training materials.
- If taking still images, disable the flash and use a stand to achieve a sharp, steady image.
- If shooting a video, select a manual setting (if possible) to prevent the camera constantly adjusting the exposure settings.
- Check the range of machining programmes used, as the mist generated may be different.

**Figure 4.1 Use of the dust lamp.**




**A dust lamp can be used:**

- To assess the control of MWF mist during CNC machining to help prioritise which machines require LEV.
- As part of the commissioning of LEV systems.
- As part of routine LEV system performance checks.

**Figure 4.2 Photo showing visualisation of mist using a dust lamp.**

*Source: www.hse.gov.uk*

### 4.2.2 Smoke testing

Operators should not open the CNC enclosure doors before the MWF mist has cleared from inside the machine. Smoke generators are available in various sizes (depending on enclosure volume), they produce smoke and may be used for specifying the clearance time of a CNC enclosure by LEV. This informs the operative when it is safe to open the enclosure doors after a machining cycle. An example of a clearance time test using smoke on a large CNC enclosure is shown in Figure 4.3.

The clearance time should not be simply calculated from measurements of the LEV's fan volume flow as there may be incomplete air mixing within the enclosures.

CNC enclosures vary considerably, and a specific method which suits them all cannot be easily specified. Occupational hygienists may find the HSE guidance on measuring paint spray booth clearance time useful (https://www.hse.gov.uk/mvr/bodyshop/cleartime.htm). However, the exact methodology used depends on the specific circumstances.

Elements which need to be considered when undertaking a clearance test include:

*Pre-assessment*

- Confirm that smoke can be used in the building and arrange for fire monitoring alarms to be temporarily disabled. It may also be necessary to inform personnel in the area to prevent fire alarms being manually activated at the sight of smoke.
- Ensure the enclosure door viewing panels are clean.
- Ensure that the level of lighting inside the enclosure provides sufficient contrast to view the smoke when using the dust lamp.

*Assessment*

- The LEV needs to be switched off during the smoke-filling period and enough smoke generated to ensure the opposite walls of the enclosure are not visible.
- Close the doors.
- Turn on the LEV and start a stopwatch.
- Record the time from switch-on of the LEV to the full clearance of smoke. In some cases, particularly larger enclosures (but not those where the operator must walk in), the operator's breathing zone may be clear before the enclosure has cleared entirely and this time can be used instead. In these cases, it is important to check there is no displacement of smoke towards the operator when the doors are opened.
- Repeat tests are advisable and the clearance time should be rounded up to the nearest quarter minute.
- You can also check for any leaks, confirming that the enclosure is under negative pressure.

*Post-assessment*

- Inform personnel activity complete and that fire alarm systems can be reactivated.
- The clearance time can be used to establish the time delay before the enclosure doors are opened.
- The best way to implement the delay is to include it in the machine programme, so the interlocks will not allow the doors to be opened until the time has passed. This will not be possible on all machines, for example, older machines which do not have guard locking on the enclosure door, in this case, a manual timer can be used.
- This time delay before doors are opened should also be displayed on the machine (an example is shown in Figure 4.4).

**Figure 4.3 Timing the clearance of smoke inside a CNC enclosure.**


*Source: www.hse.gov.uk*

**Figure 4.4 Safety labelling for the door of a CNC enclosure.**


*Source: C Stearne*

**Smoke pens/tubes**

Smoke tubes or pens deliver very small quantities of smoke and are best used to visualise inward airflow around seals and openings on a CNC enclosure to check that adequate negative pressure is being maintained when the LEV is operating.

1. Activate the smoke generation according to the manufacturer's instructions.
2. Ensure that the LEV is switched on.
3. Puff smoke near any openings of the enclosure, for example the door seal or parts chutes.
4. If the smoke is clearly being drawn inside the enclosure, this indicates that the enclosure is under negative pressure. If it is not, investigate any potential causes e.g. insufficient volume flow rate due to a blocked filter.

Smoke testing (using smoke generators/smoke pens) should be completed:

- As part of LEV commissioning by checking for leaks, to establish clearance time and check enclosure under negative pressure.
- As part of the 14-month thorough examination and test (TExT) to verify that design performance is maintained.
- As part of regular checks to ensure the performance of LEV to maintain negative pressure.

### 4.2.3 Direct Reading Aerosol Monitors (DRAMs)

DRAMs are used to obtain semi-quantitative estimates of changes to the number of airborne particles. They are sensitive instruments that need to be maintained according to the manufacturer's instructions.

The most common type of DRAMs used are photometers which use either a laser or a light-emitting diode source. Based on light scattering they provide a semi-quantitative estimate of the mass concentration of particles from 0.1 to 10 µm in size range, but they may be less sensitive in detecting particles <0.3 µm.

Some DRAMs are also fitted with size-selective inlets (e.g. respirable cyclone, PM2.5 and PM10) to monitor specific particle size classes. The principle of operation of a photometer is illustrated in Figure 4.5.

It is important to understand the limitations of DRAMs. For example, their accuracy may be reduced in environments with high humidity and high background particle levels. These monitors are usually calibrated by the manufacturer using standardised solid particle sources, not fluid droplets. Different types of commercially available DRAM have been evaluated under laboratory conditions by HSE and a summary of the results is provided in a technical workshop report (HSE RR1149, 2019). This study found that whilst most of the tested DRAM responded linearly to an increasing concentration of MWF, they all differed in the gradient of this response. DRAMs can be used to determine relative changes in MWF mist but are not suitable for quantitative measurements. Practical advice on using DRAM for monitoring respirable aerosols has been summarised in a 'Manual of Analytical Methods' by the US National Institute for Occupational Safety and Health (NIOSH, 2021)

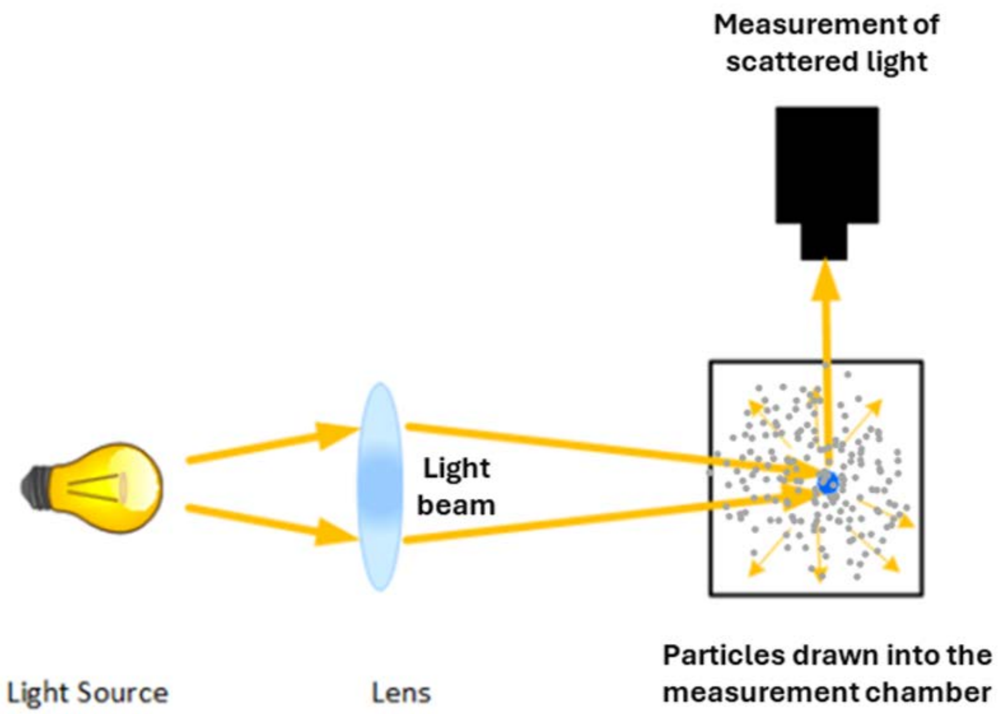
DRAMs may be used practically to:

- Conduct checks on the performance of the filters in oil mist extraction units.
- Check that MWF mist concentrations have been lowered after suitable clearance times.
- Assess the effectiveness of MWF mist containment measures e.g. enclosure.
- Monitor other actions taken to reduce MWF emissions into the workshop air.

The use of a DRAM alongside a dust lamp is recommended, as this will help verify that the particulate being measured by the DRAM is MWF mist or smoke from the machining process.

**Note:** Whilst DRAMs can be used to assess changes in airborne particulate mass, the results should not be directly compared with any regulatory exposure limits (or guidance values).

**Figure 4.5 Principle of operation of a Direct Reading Aerosol Monitor (example shown is a photometer).**




HSE research reports RR1044 (HSE RR1044, 2015) and RR1149 (HSE RR1149, 2019) give further information on the use of DRAMs in machine workshops.

# 5. Control of Worker Exposure to MWF

## 5.1 Hierarchy of control

There is a broad hierarchy of control measures in order of their overall effectiveness and sustainability. More than one measure will be needed to achieve adequate control. Where Personal Protective Equipment (PPE) is selected, this must be in addition to other measures. Table 5.1 below sets out the hierarchy of control as applied to health risks from the use of MWF with examples.

**Table 5.1 Hierarchy of control as applied to health risks from the use of MWF.**

| Control | Examples |
|---|---|
| **Elimination of MWF use**<br>**(Section 5.2)** | Not usually practical but alternatives include:<br>• Dry machining with air cooling.<br>• Cryogenic cooling. |
| **Substitution to a less hazardous MWF**<br>**(Section 5.3)** | There are other coolants which are reported to be less harmful to the skin or produce less mist:<br>• Vegetable oils.<br>• Coolants containing no mineral oil or emulsifiers.<br>• Bio-concept fluids.<br>Whether these reduce respiratory health risks is unclear, and aqueous alternatives still present wet work dermatitis risk. |
| **Change or modify the work process to minimise emission of MWF mist/droplets**<br>**(Section 5.4)** | • Reducing cutting speed (not always possible).<br>• Optimising fluid delivery in terms of rate and type (e.g. flood, through-tool) to ensure cooling, prevent ‘smoking’ and minimise the formation of fine mist e.g. delivery nozzle position. |
| **Apply controls to contain and/or remove MWF mist/droplets**<br>**(Section 5.5)** | • Enclosing CNC machines as much as possible, e.g. retrofit concertina roof panels for vertical milling machines partially open at top.<br>• LEV (including suitable filtration) to remove mist from the CNC enclosure.<br>• Enclosing conveyors, chutes and bins.<br>• Fit splash guards to manual machines. |
| **Procedures and work equipment which minimise inhalation exposure to mist and/or skin contact with MWF/wet swarf etc.**<br>**(Section 5.6)** | • Programme fluid delivery to stop on cessation of machining.<br>• Programme a time delay after machining has stopped to ensure that the interlocked door does not open until the MWF mist is extracted from the enclosure via LEV.<br>• Automated tool changing via machine programme.<br>• Automated component feed and delivery.<br>• Automated compressed air nozzles built inside the machine and incorporated into machine programme so used while CNC doors are still closed.<br>• Whenever possible, select suitable alternatives to compressed air for the removal of excess fluid and/or swarf/chips from components and machine surfaces:<br>o Absorbent materials<br>o Spindle-mounted fans<br>o Vacuum systems |

| Control | Examples |
| --- | --- |
| | o Low pressure coolant guns to wash away the swarf (without generating mist)<br>o Use of hand tools to remove swarf from machines<br>• Limit the use of compressed air guns and when using:<br>o Reduce the air pressure to as low as practicable and use LEV (this may be inside the machine enclosure).<br>o Use longer lance models.<br>o Use nozzle designs that minimise blowback/mist formation.<br>• Regular planned preventative maintenance schedules for LEV including high-efficiency filters and prefilters. The term 'high-efficiency' applies to systems that have a good level of filtration, as a minimum this should consist of two but ideally three different stages.<br>• LEV TExT every 14 months.<br>• Regular cleaning of equipment surfaces and floors.<br>• Maintenance of fluid quality to reduce the growth of microorganisms and correct the concentration of coolant.<br>• Top up fluid sumps using in-line dosing systems or automated mixing equipment.<br>• Provide equipment to remove and replace sump fluids with minimum spillage e.g. wet vacuum.<br>• Avoid the use of high-pressure water hoses for sump cleaning where practicable.<br>• Provision and use of sufficient welfare and washing facilities.<br>• Ensure good personal hygiene practices are maintained. |
| **Personal Protective Equipment (PPE)<br>(Section 5.7)** | • Provision of suitable PPE including gloves.<br>• Provision of suitable Respiratory Protective Equipment (RPE) e.g. powered respirator with a P3 filter. The selection of suitable RPE will also need to consider wear time (further guidance in HSG53 (HSE HSG53, 2013)).<br>**Note:** Where tight-fitting RPE is worn, workers will need to be clean shaven and pass a face fit test (further guidance in INDG479 (HSE INDG479, 2019)). |

## 5.2 Elimination of MWF from the machining process by using alternative means of lubrication and cooling

Pressure to address environmental risks and the advent of advanced material technology is driving the development of alternative cooling and lubrication methods using novel ingredients and materials. Prevention or minimisation of occupational ill health in machine operatives is not the main driver and elimination of MWF or substitution to a less toxic alternative is often incidental. The health and safety implications for these alternative lubricant technologies need to be considered before their use becomes more widespread. Examples of alternative lubricant technology are summarised in Table 5.2.

**Table 5.2 Alternative means of lubrication and cooling.**

| Alternative means of cooling/lubrication | Potential applications | Possible H&S risks |
|---|---|---|
| Dry machining with ambient air cooling | Cast iron is easily machined dry as it contains graphite which acts as a lubricant. However, the use of MWF generally improves surface finish, suppresses dust, and clears swarf.<br>Aluminium, magnesium and copper alloys machined under dry conditions quite well.<br>Dry machining is unsuitable for pure aluminium, copper, magnesium, and low-carbon steels and for tapping and drilling. | Generation of metal fume/dust which itself may require control through LEV.<br>No corrosion protection of the freshly machined surface unless a system is employed to spray the surfaces directly after machining. |
| Dry machining with compressed air cooling or cooled air | In theory, any application where air can be blown through the tool to remove debris and cool the surfaces. | Pressurised air may generate aerosols of fluid and small metal particles and require management of the inhalation risks. Large compressors may also raise noise levels. |
| Cryogenic cooling (nitrogen or carbon dioxide) | Pre-cooling the workpiece, cooling the cutting tool and cutting zone. | Risks from storage and release of asphyxiant gases. |
| Ionised air | This method is said to extend tool life and reduce the lead time of machining and is more suited to high-speed machining. It eliminates lubricant waste, toxic emissions and fumes, and since no oil is used it minimises $CO_2$ emissions. It also supports cost-efficient recycling of clean metal swarf. | The health risks are uncertain until this method becomes more widely used. |
| Nanofluids/nanoparticles | Nano-enhanced bio-lubricants have been investigated for turning, milling, grinding and for difficult-to-machine materials. When mixed with vegetable oils they are said to improve surface quality, antifriction and anti-wear properties. | There is concern that certain lubricant metal nanoparticles may present a toxicity risk when inhaled. They may also pass across the lining of the nose and enter the brain. Nanographite is also being considered as a lubricant but there is less information about its potential toxicity. |

## 5.3 Substitution by using alternatives to conventional MWF

The substitution of a conventional MWF is not straightforward. The cooling performance, anti-corrosion and anti-foaming properties of some MWF are important properties that have to be matched to the type of metal and machining work undertaken. To address potential health and environmental risks alternative lubricant technology is being developed with examples summarised in Table 5.3. Some of these are being used in UK machine workshops. These alternative lubricants will also degrade in use but there is yet little published evidence whether in doing so they cause a health risk. On a precautionary basis, the same control measures (e.g. containment and use of LEV) that are used for conventional MWF should be applied to these lubricants.

**Table 5.3 Alternatives to conventional MWF.**

| Type of alternative to MWF | Potential applications | Comments |
|---|---|---|
| Vegetable oils e.g. sunflower, castor, coconut, canola, palm, soybean | Minimum Quantity Lubrication (MQL) machining applications. | Unless chemically modified they readily undergo oxidation and hydrolysis reactions. Microbial growth and degradation may still be an issue if a long sump life is required. |
| Coolants containing no mineral oil or emulsifiers | Wide range of machining processes. | These have been developed to reduce fume/mist emissions, often marketed as 'low misting fluids'. |
| Bio-concept fluids | Wide range of machining processes. | Some MWF have been formulated to support the growth of a dominant non-pathogenic bacteria that commonly grows in water. These bacteria are allowed to proliferate to out-compete potentially harmful bacteria. Consequently, biocides are not added to this MWF, reducing the risk of skin sensitisation. However, the quality of bio-concept fluid has to be maintained otherwise complex mixtures of bacteria will grow in it. See HSE guidance Bioconcept fluids (https://www.hse.gov.uk/metalworking/bioconcept.htm). |

### 5.3.1 Minimum Quantity Lubrication

Minimum Quantity Lubrication (MQL) is sometimes referred to as near-dry machining and involves applying a very small volume of coolant into a fast-moving air stream, generally the workshop compressed air supply (5-15 bar). There is no excess coolant to recirculate, so contamination of coolant is not an issue, although the fluid must not be allowed to exceed any 'use-by' date (particularly where the MWF is vegetable-based as these are liable to deteriorate).

During machining, there is no visible fog or mist, but fine particles not visible to the naked eye are generated and will need to be controlled using LEV fitted with suitable filtration. High-efficiency filters are likely to be needed due to the size of the mist particles.

Some new high-speed machining centres are designed specifically for MQL and compressed air/fluid application. MQL is regarded as an acceptable method for milling machines and has been shown to improve tool life significantly. However, it is not suited to drilling and tapping.

## 5.4 Change or modify the process to reduce the emission of MWF mist

It may be possible to reduce mist generation by changing the machine operating parameters and how the fluids are delivered within production and quality control requirements. These should be reviewed with the client company. Figure 5.1 illustrates the main factors which influence mist formation. Spindle speed has the largest influence on the volume of mist formed and droplet size, and this is illustrated in Figure 5.2.

**Figure 5.1 Factors influencing MWF mist, vapour and fume formation.**

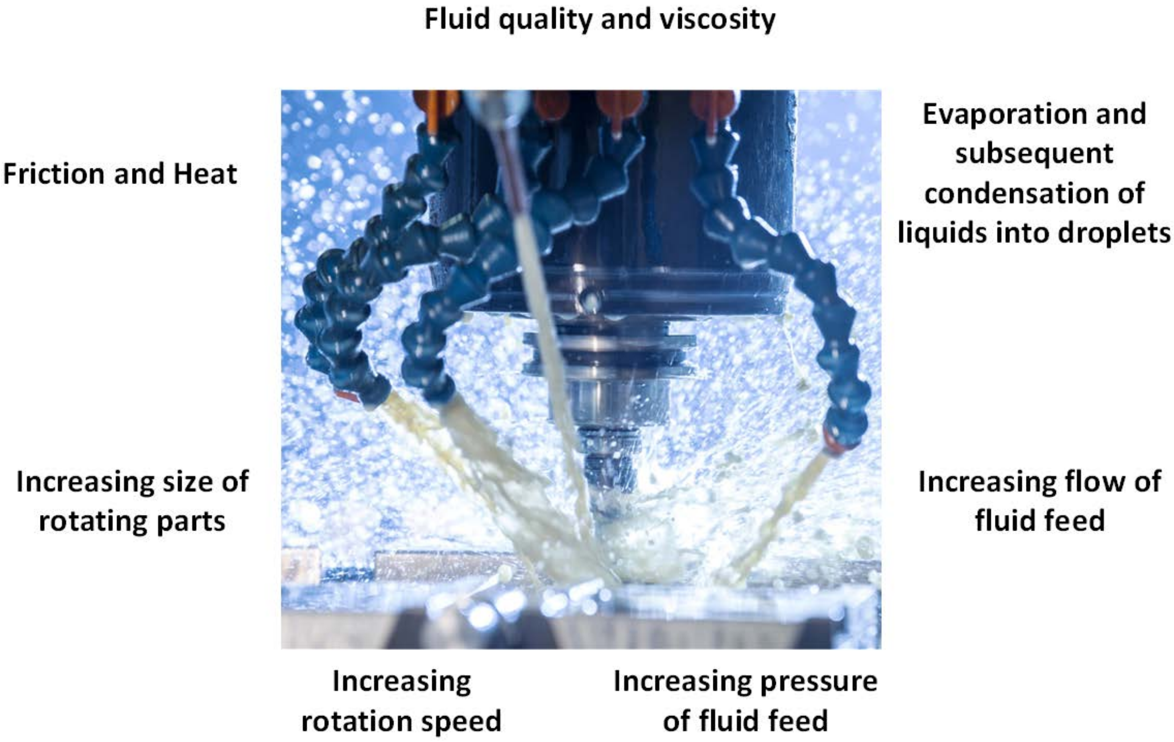
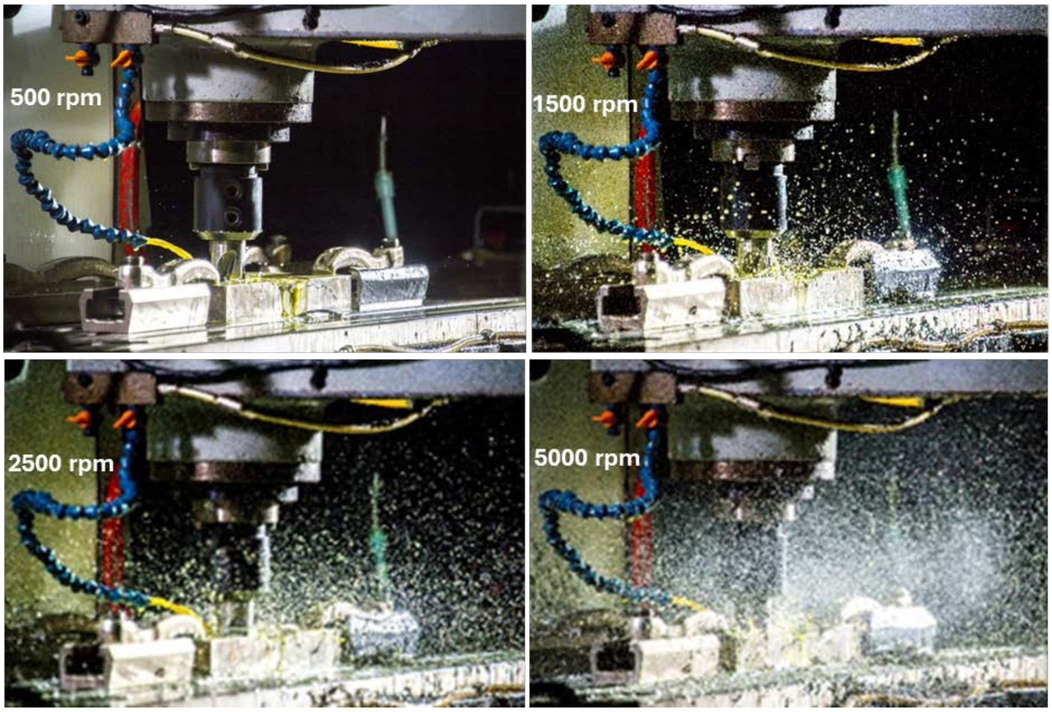



**Figure 5.2 Effect of spindle speed on size and volume of MWF mist.**




*Source: www.hse.gov.uk*

## 5.5 Engineering controls

### 5.5.1 Enclosure and Local Exhaust Ventilation (LEV)

The nature of metal-cutting operations generally results in an energetic multi-directional release of a contaminant cloud of mixed particle sizes. Effective control of this will generally require enclosure and extraction of the contaminant cloud by LEV.

This section summarises guidance on how enclosure and LEV systems are used to control exposure to MWF mist. It is not intended to cover all aspects of LEV design and the reader is referred to HSE guidance HSG258 'Controlling airborne contaminants at work: A guide to local exhaust ventilation (LEV)' (HSE HSG258, 2017) and to the ACGIH guidance 'Industrial Ventilation: A Manual of Recommended Practice for Design' (ACGIH, 2023).

Metal cutting machines come in a range of sizes from tabletop units to large gantry or bridge machines which can occupy a 'workshop footprint' of over 100 square metres. The degree to which they are enclosed will depend on machine guarding requirements which will be determined by the type and speed of cutting operation.

During machining the enclosure will fill up with mist which may:

- Leak out of the enclosure through any gaps; CNC enclosures are not intended to be airtight and some enclosures by design have openings at the top.
- Deposit through impaction on the internal surfaces of the enclosure.
- Remain suspended inside the enclosure.

The particle size profile or range of machine-generated particles will vary, depending on the factors shown in Figure 5.1. Processes such as evaporation, condensation and coalescence may result in changes in the particle size profile over time. The time it takes for particles to naturally settle out will be dependent on their size, with smaller particles taking longer. Sub-micron particles will behave as a particle cloud and move with the air mass, and so they are likely to escape the enclosure when opening the enclosure doors, directly into the operator's breathing zone.

**Enclosure with no LEV**

Time and production constraints do not usually accommodate keeping machine enclosure doors closed sufficiently long enough for the fine mist to settle. In some cases, even waiting 60 seconds has been reported as impacting production rates. Consequently, the only way of minimising exposure whilst minimising impacts on production rates is to forcibly extract the mist from the enclosure using LEV.

Reliance on settlement or dwell time as a permanent control measure should only be considered where the following criteria are met for **all** machining operations undertaken:

- The machine is fully enclosed (not open at the top for example) either by its own enclosure or it is located in a dedicated room and there are no leaks of mist observed during machining.
- Machining programmes are such that they run for long periods and/or can be left without the need to open the enclosure for component inspection or removal. These will often have automatic feed and parts collection systems, or the part itself is complex and various cutting operations take place over an extended period.

Any change in the above will require a review of the risk assessment and controls required.

**Conventional CNC machines**

A conventional CNC machine is depicted in Figure 5.4. A combination of enclosure and LEV will usually be required when CNC machining with MWF. Conventional CNC machines are enclosed by design; the enclosure acts as machinery guarding which also facilitates the containment and removal of mist by LEV. Therefore, it is generally practical and affordable to fit LEV on most CNC machines. Some machines by design are partially open at the top to allow the movement of the tooling head; in such cases, to enclose further, the installation of panels and/or concertina sections may be possible.

Recirculating LEV systems (i.e. systems that are specifically designed to return air to the workplace) are common due to low capital cost and the need to move machines. These are either directly mounted onto the machine casing or otherwise connected by a short piece of ducting. Other designs comprise a free-standing air cleaner or extraction unit positioned adjacent to the machine (as shown in Figure 5.4). Branched systems which serve multiple machines or even two standalone units on the same machine (larger enclosures) are also common.

The LEV design principles for an enclosure should be employed when commissioning or reviewing the adequacy of existing LEV:

- Mist should be contained inside the enclosure during machining. Minimise gaps in the fabric of the enclosure e.g. fit sump covers and additional roof panels and maintain door seals. Some gaps will be required to allow in 'make-up' air to replace that extracted.
- Current British Standards for the safety of specific CNC machines (turning machines/lathes and milling machines/machine centres) state that enclosures must be designed with an interface to allow LEV to be attached to the enclosure (see Figure 5.3).
  **Note:** The 'interface' is often not in an efficient or effective location, resulting in very long mist clearance times, so may need to be re-positioned.

**Figure 5.3 Interface for LEV as seen from inside a CNC enclosure.**

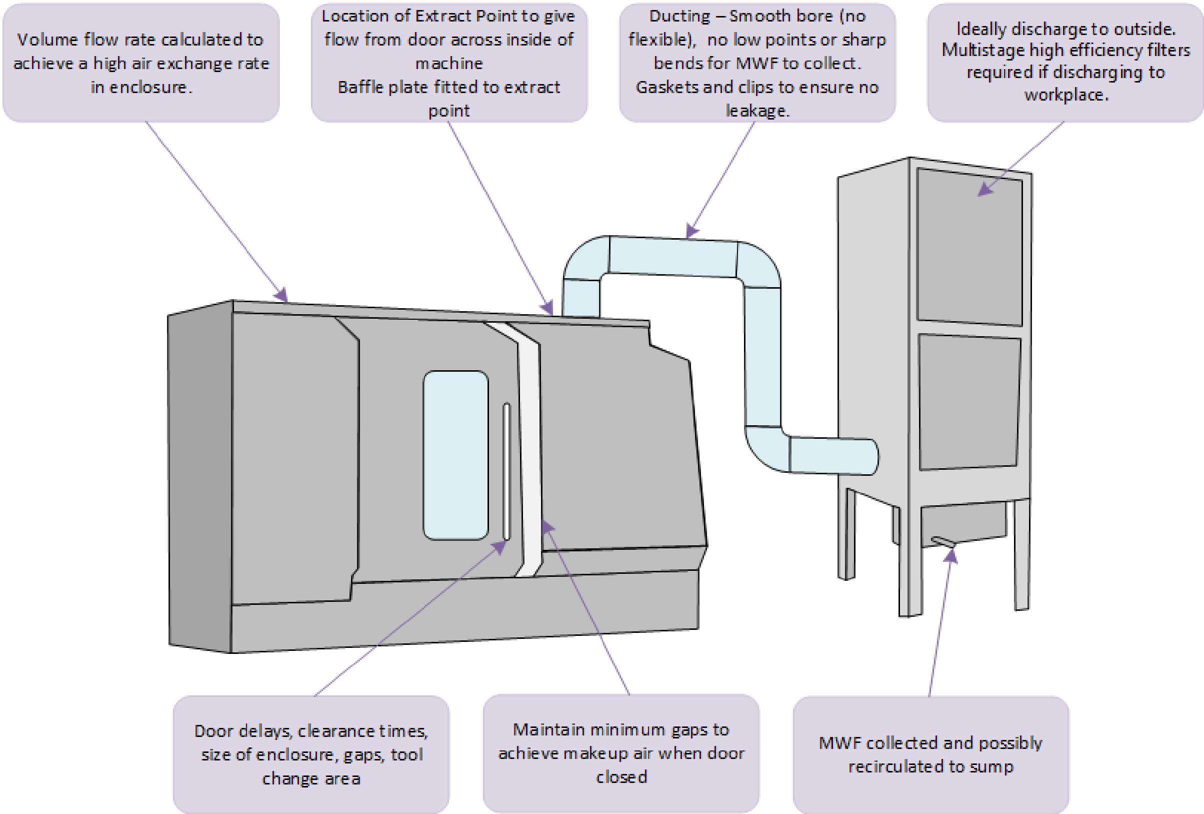
*Source: www.hse.gov.uk*

- Locate extract ports where they do not get blocked with swarf/fines and draw mist away from the doors protecting the operator's breathing zone. This will generally mean that they are located towards the top of the enclosure.
- Baffle plates located inside the enclosure are also used to prevent liquid coolant and swarf/chips from being drawn into the LEV system.

- The volume flow rate will need to consider:
    - the internal volume of the enclosure excluding the volume taken up by internal fittings (e.g. chuck, bed, turret).
    - any open areas e.g. open tops, and openings around the tool changer.
    - the required 'air change rate' based on the duty holder's preference for time delay on completion of a machine cycle. This will often be determined by production demands e.g. are they prepared to delay opening by 20 seconds or 2 minutes? **Note:** the calculated air change rate does not necessarily equate to removal of mist from the entire enclosure, which is why the air movement should be verified by undertaking a smoke test.

Figure 5.4 shows the elements which should be considered when assessing the effectiveness of LEV in controlling MWF emissions.

**Figure 5.4 Design elements which should be considered when assessing the effectiveness of LEV in controlling MWF emissions.**




### 5.5.2 Air cleaners (extraction units)

Air cleaners or extraction units are devices designed to remove airborne contaminants generated during machining processes such as oil mist, MWF mist and fine metallic particles. Consequently, these extraction units are multistage.

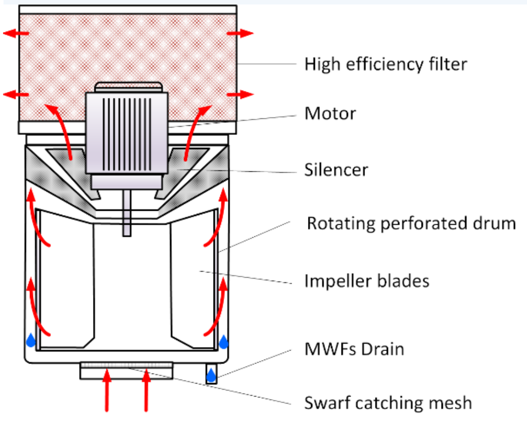
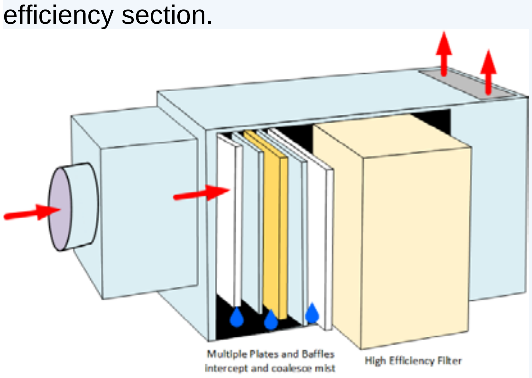
Considerations for selection and use include:

- The need for multistage high-efficiency filters where venting back into the workplace.
- Drained coolant to be returned to the sump.
- Monitoring pressure differential across the filter with gauges.

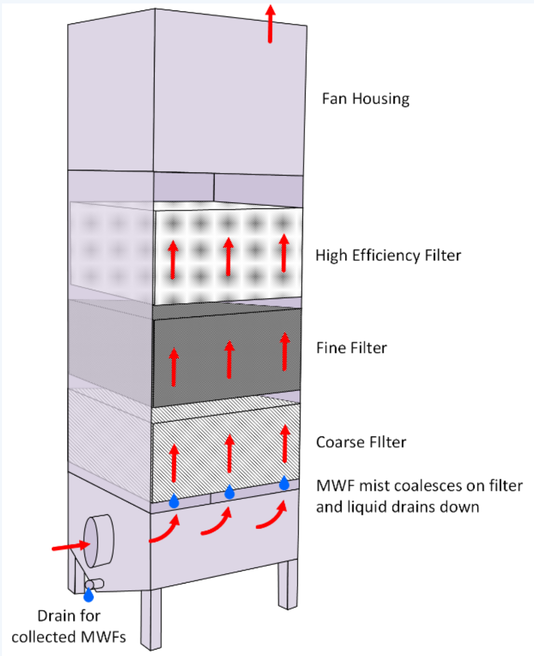
- Air flow monitoring.
- Filter changes and maintenance to be specified.
- Alarm or pressure gauge on the filter if it is returning air to the workplace.

The advantages and disadvantages of different mist extraction systems are summarised in Table 5.4.

**Table 5.4 Advantages and disadvantages of different types of air cleaners for MWF.**

| Centrifugal air cleaners | Advantages | Disadvantages |
|---|---|---|
| Mist enters directly into a rotating drum with filter media in the centre. The centrifugal force pushes large particles out into the drain. The air then enters the after filter.<br>  | • Inexpensive and small size. | • The balance of the fan can be a problem.<br>• High maintenance cost and the filters may need to be changed frequently.<br>• Problems if the swarf enters.<br>• Poor drainage.<br>• Check the filter grade – should be high-efficiency.<br>• Check for leakage from the filter if modifications are undertaken such as retrofitting cables. |
| **Panel filters** | **Advantages** | **Disadvantages** |
| Mechanical air purification using a series of horizontal static filters arranged in a high-efficiency section.<br>  | • High-efficiency long-life filters. | • Expensive to purchase or replace filters.<br>• High maintenance.<br>• The prefilter may need frequent changes, e.g. monthly.<br>• Pressure gauges for monitoring the filter performance may not be fitted as standard.<br>• Poor drainage arrangement. |

<table>
<tr><th>Cartridge filters</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>
Air enters at the bottom section and passes through prefilters including a mesh, a secondary stage, then a high-efficiency filter unit. A drain on the system returns MWF to the sump.



</td><td>

- High-efficiency.
- Long filter life.
- Simple to maintain.
- Filter monitoring.
- Low maintenance.

</td><td>

- Expensive.

</td></tr>
<tr><th>Electrostatic (not recommended)</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>
A high potential electric field is established using a discharge electrode of a small cross-sectional area and a large surface area collection electrode plate. Mist enters a chamber through an ionizer that charges the particles which are captured on the plates. Consideration should be made for the addition of the required high-efficiency filter section.
</td><td>

- No filters.
- Energy low.
- Low pressure drops.

</td><td>

- Not recommended for water soluble MWF or high contamination.
- High maintenance - regular cleaning.
- No gauges.
- Filtration is less efficient.
- Plates can be damaged.
- Higher initial cost.
- High-efficiency section required.
- Poor drainage arrangements.

</td></tr>
</table>

**Manual machines**

It is generally not practicable to install LEV on manually operated machines as these are not fully enclosed. Due to the design of manual machines, it has also proved difficult to retrofit LEV around the chuck and cutting head/tooling. However, as they typically operate at lower speeds, they produce less respirable MWF mist. Enclosing splash guards will provide an effective barrier to larger droplets, reducing skin and eye contact.

There will be some manual machining processes where a fine mist is produced, for example, grinding machines. In these cases the degree of mist generation during normal production should be assessed and the implementation of control measures explored. The use of capture or receiving hoods will generally be of limited effectiveness, but the addition of an enclosing lid will improve this.

**Large gantry machines**

These machines have been observed to generate significant mist and splashes due to the relatively large quantities of coolant used. However, because they are generally open, operator exposure is likely to result from increased background concentration in the localised area, rather than placing their head in an enclosure full of mist.

The moving table-type CNC machines work on large blocks of metal such as engine blocks and should have enclosure-type guarding, but this is likely to be more open and may use plastic curtains. Older models (due to guarding requirements) are open at the top and sides and so not conducive to retrofitting with LEV unless an enclosure can also be retrofitted. Further enclosure can be achieved by installing additional panels, plastic curtains and tunnel enclosures. Some bench-type machines can be fitted with a concertina roof but retrofits may not be possible.

Specialist advice is required before commissioning any form of extraction system as designs are likely to be complex and costly. The use of air curtains and localised air cleaning units may be possible.

## 5.6 Work procedure controls

Work practices and procedures to reduce both inhalation and skin exposure to MWF can be effectively applied alongside engineering and other controls to form a comprehensive control strategy.

**Note:** This section focuses on the control of exposure to MWF mist. It does not cover the management of MWF quality itself, which was briefly summarised in Section 3. For more information on the management of MWF, the reader is directed to the UKLA Guidance (UKLA, 2023) and advice within relevant HSE COSHH Essential MW5 (HSE COSHH MW5, 2021).

### 5.6.1 Alternatives to compressed air guns

Compressed air is used to clean components and tooling heads and is critical to ensure a quality finish. The aerospace industry requires a high degree of cleanliness to ensure tolerances are met. Depending on the process, operators may open CNC machine doors several times when machining a single component to check tolerances and clean the cutting tool to remove swarf/chips such that the component surface is not abraded during the next cutting cycle.

The use of compressed air for blowing down components generates large amounts of MWF mist. In addition to the inhalation risk, this can contaminate the clothing and skin. Figure 5.5 shows a demonstration of MWF droplet deposition onto the body of a manikin when a compressed airline is used for cleaning workpieces. The MWF droplets were visualised by the addition of UV-sensitive tracer dye. This type of deposition occurs when standing too close to the compressed air gun, when operating the gun outside of the enclosure without an additional source of extraction, or when the air gun has not been fitted with a protective shield.

**Figure 5.5 MWF droplet deposition from the use of compressed air.**

*Source: www.hse.gov.uk*

The use of compressed air to clean workpieces poses several safety and health risks. For example, inhalation exposure risks when compressed air generates MWF mist containing chemical and biological hazards. Other risks include:

**High air pressures:** Compressed air is extremely powerful causing injuries from high velocity projectiles directed towards the body, or blockage of blood vessels (an embolism).

**Noise exposure**: The noise generated by compressed air systems at high pressure can harm hearing.

**Skin irritation and dermatitis**: Direct contact with compressed air can cause skin dryness, irritation, or frostbite if the air is sufficiently cold. The force of the compressed air can also drive contaminants into the skin.

There are several alternatives to compressed air. Examples of commercially available alternatives are given in Table 5.5.

These other methods of cleaning offer advantages but also have limitations, which may limit options to replace the use of compressed air completely.

Compressed air guns should not be used for cleaning:

- the  surfaces of the machine.
- clothing e.g. coveralls.
- air extraction grills inside the machine to LEV systems that may be covered in swarf.

**Table 5.5 Alternatives to compressed air guns.**

| | |
|---|---|
| **Integral air jets** | Integral air jets are incorporated in modern CNC systems and remove lubricant as part of the operating cycle whilst the enclosure door is sealed. The operator can then remove a dry component. |
| **Spindle mounted fans** | Tooling mounted fans rotating at high speed to remove swarf, chips and lubricant from the workpiece while inside the enclosure with doors sealed. |
| **Vacuum systems** | Vacuum systems utilise suction power to collect and contain the fluid and contaminants, preventing misting. Vacuum systems can be portable or integrated into a CNC machine set-up. |
| **Low-pressure coolant gun** | Coolant from the main sump is fed as a low-pressure stream to wash down machine internals and remove metal chips. |
| **Ultrasonic cleaning** | Ultrasonic cleaning involves immersing parts in a tank filled with a cleaning solution and subjecting them to high-frequency ultrasonic waves to remove contamination. |
| **Solvent or chemical cleaning** | This involves using a cleaning solvent or solution to dissolve and remove contaminants from the parts. Automated systems are preferable, as manual cleaning introduces additional risks of skin and inhalation exposure to solvents and vapours. |
| **Compressed air cleaning booths** | Compressed air cleaning booths allow for air to be applied within an enclosed chamber reducing exposure risk to the operative. |

When it is necessary to use compressed air guns, the exposure risks can be mitigated as follows:

- Reduce the operating exit pressure below 2.0 bar which is suitable for removing MWF whilst reducing the emission of small droplets, particles and noise. It also reduces energy costs. Lower pressure also improves the control and precision of the cleaning process.
- Use compressed air guns inside machine enclosures with LEV running to reduce the likelihood of operator exposure. In large CNCs, the effect of LEV may be minimal in controlling mist generated from compressed air cleaning and additional controls could be required.
- Use compressed air guns with long-handled lances to increase the separation distance from the operator.
- Fit compressed air gun lances with shields to minimise splash back on the operator.
- Use improved air gun nozzle designs which reduce misting and noise levels.

### 5.6.2 Use of tools

Tools can reduce the risk of skin exposure to MWF, both during parts handling and fluid preparations:

- **Tongs or clamps** offer an alternative to handling parts during loading and unloading but may not be a feasible option for operations requiring precise positioning.
- **Conveyor systems** include automated unloading and conveyor systems which are being built into modern CNC machines at added cost and may be limited to parts of specific size, weight and complexity. These systems may be difficult to retrofit to older CNC machines.

- **Swarf hooks or magnetic wands** can be adopted to avoid skin contact with fluids when removing swarf and chips from parts.
- **Automated mixing devices** remove the need for manual mixing and handling of fluids during preparation.

### 5.6.3 Decontamination and skin care

A personal hygiene regime for machine operatives is a fundamental element of an overall control programme to reduce risks of skin disease.

**Contamination prevention:** Spills, surface contamination and cloths used for clean-down can lead to inadvertent skin exposure. Spills and surface contamination should be cleaned up promptly to prevent the spread of contaminants and cloths, paper, or other materials used for cleaning should be disposed of carefully and immediately after use. This may involve designating specific containers or disposal areas for contaminated materials.

**Hand hygiene:** Hand washing facilities must be provided to employees so they can wash their hands and skin at the end of work periods. They should also be provided with appropriate non-irritating soaps and disposable paper cloths or hand dryers for drying their skin properly. Information and resources on maintaining good personal hygiene, and handwashing and drying techniques, should be displayed in these wash areas. Employees should promptly report any skin or respiratory symptoms out of the normal to their supervisors for referral to an occupational health provider.

**Pre-work and after-work creams:** The use of these creams before and after work helps to moisturise the skin, remove contaminants, and support the skin's natural resistance to water. Studies have indicated that consistent use of pre-work and after-work creams reduces the occurrence of dermatitis. This is an important consideration where prolonged glove use is required. However, these are not a substitute for wearing appropriate protective gloves but may help to reduce the amount of chemical contamination directly on the skin surface.

**Eating, drinking and smoking/vaping:** Hand washing should be undertaken before eating, drinking, or smoking. Designated break areas away from the work area should be established so that employees can eat and drink away from the workshop area and these should be kept clean and tidy.

### 5.6.4 Prioritisation of controls

Reviews and assessments of exposure to hazards and control measures should be undertaken regularly and recorded. Risk identification forms a fundamental step in risk assessment, and identifying areas to target further mitigations is essential. Section 8 Audit and Review and Appendix 2 Assessment/Audit Tools give further guidance on this.

### 5.6.5 Record keeping

There is a legal requirement under COSHH Regulations to maintain records relating to statutory testing for a minimum of five years i.e. LEV TExT reports. Where implemented procedures relate to exposure to MWF, it is recommended that these records are also kept, including fluid maintenance and management records and LEV weekly checks.

## 5.7 Selection and use of Personal Protective Equipment (PPE) and Respiratory Protective Equipment (RPE) for machining work

### 5.7.1 Background

PPE (such as overalls, gloves, protective glasses, face shields and safety shoes) should be used to prevent contact exposure to chemicals and MWF and to prevent physical injury. RPE may under some circumstances need to be worn by machinists. This should only be considered after other control measures (e.g. containment and LEV) have been implemented but a residual risk of inhalation exposure to hazards remains. The decision should be based on a suitable and sufficient risk assessment by the employer which needs to consider the exposure circumstances and the risks to health or physical injury.

PPE requirements will vary for different tasks such as handling neat MWF and chemical additives, draining and cleaning of machine sumps.

### 5.7.2 Protective gloves

- **Disposable single-use gloves**:
    - If handling of wet workpieces is required, single-use disposable gloves (such as nitrile) may be used but only where these do not add to other risks from machinery, such as entanglement.
    - These gloves need to meet the standard BS EN ISO 374-2. Disposable gloves provide limited protection and some chemicals will permeate the glove material and contact the skin. Glove manufacturers provide information on the suitability of glove materials for preventing the permeation of specific chemicals. As a general rule, disposable gloves should not be worn for longer than 20-30 minutes because of the risk of chemical breakthrough of the glove material and because of occlusive effects on the skin.
- **Chemically resistant gloves:** should be worn when handling concentrated stock solutions of MWF and additives such as biocides. They are also appropriate for certain tasks such as cleaning out sumps when contact with MWF is likely. These gloves should be thicker and more chemically resistant and made from nitrile, butyl or neoprene. They should also be worn when handling neat oils and strong acid or alkaline solutions as well as solvents. For advice on glove selection refer to HSE INDG330 (HSE INDG330, 2000).
- **Sharp metal waste and metal fines:** Machining produces sharp metal swarf and abrasive fine metal particles which need to be removed from machines and the MWF supply system. These should not be removed by hand but using suitable tools and wearing cut-resistant gloves that comply with the standard BS EN 388. The glove material should be non-absorbent and made from materials like nitrile-coated High-Performance Polyethylene (HPPE).

Thicker protective gloves may have an inner lining material and if this lining extends through the glove material it can allow wicking of MWF to the skin. This risk should be considered when purchasing such gloves.

### 5.7.3 Protective clothing

Exposure to MWF and other chemicals can occur when fluid is absorbed by clothing, or when droplets fall onto unprotected skin on the face, arms, legs and feet. Machine operators should wear safety coats, trousers, or coveralls to protect the upper torso and legs. This clothing needs to meet the standard BS EN ISO 13688 and be made from durable material that withstands cuts and abrasions with minimal absorption of liquid (e.g. MWF). For handling low-risk chemicals, waterproof aprons may be sufficient to shield from accidental splashes.

### 5.7.4 Eye protection

Machining is a risk for eye injury and absorption of MWF droplets that fall onto the eye surface. Injuries can also occur if compressed air guns are used for cleaning work without wearing eye protection. Eye protection equipment needs to comply with the standard BS EN ISO 16321-1. Relevant types of eye protection for machinists include:

- **Safety spectacles**: Made from break-resistant plastic/polymer with wrap-around side shields to reduce stray particles reaching the eyes. They should be designed to accommodate users who need to wear prescription glasses or accommodate prescription lenses. However, they do not protect from exposure of the eyes to mists and aerosols.
- **Goggles:** Made from a plastic/polymer frame which holds the lenses with a flexible elastic headband. They provide eye protection from all angles as the rim is in contact with the face. They may be vented but are unsuitable for protection against gases and fine dust. Unvented goggles may be available but the visor fogs rapidly and their use is limited to a few minutes.
- **Face shields**: These consist of a large face-covering transparent shield with an adjustable head harness to hold it in place. They protect the face from exposure to fluid droplets and metal shards but provide no protection against the inhalation of airborne dust and fine droplets, nor do they protect against sprays and splashes of liquids that can run down the face behind the shield.

### 5.7.5 Foot protection

Safety shoes ensure that feet are not injured and the skin of the foot is not exposed to liquid MWF during activities where there is a risk of immersion, spills and splashes. For workshops, safety boots/shoes should be reinforced with protective toecaps and made from durable non-absorbent waterproof materials that meet the requirements of the standard BS EN ISO 20345+A1.

### 5.7.6 Selecting suitable PPE and RPE

*a. Selecting PPE*

The following should be considered when selecting suitable PPE:

- Check that PPE is marked with the appropriate CE or UK Conformity Assessed (UKCA) marking to meet the requirements of the amended PPE at Work Regulations (HSE L25, 2022) and EU Regulation 2016/425 (incorporated into UK law).
- Consider the hazards that machinists are exposed to, and for how long, e.g. contact with MWF on surfaces, formation of sprays and handling of concentrated chemicals as well as metal waste.
- When several types of PPE need to be worn at the same time, consider whether this could interfere with the safe use of critical equipment such as tight-fitting RPE.

*b. Selecting RPE*

The use of RPE as a protective measure is lower down on the COSHH control hierarchy. If exposure cannot be adequately controlled in machine workshops by other means it may be necessary to consider the use of RPE under the following circumstances:

- Tasks that generate mists/fumes/gases e.g. sump cleaning but these emissions cannot be fully contained using other control measures.
- When maintenance work e.g. sump cleaning is carried out in restricted spaces where the risk of inhalation exposure to hazards may increase. **Note:** Cleaning a large, enclosed sump or underfloor tank may create a confined space risk which must be assessed and appropriate measures such as a permit to work system put in place.

Other things to consider when selecting RPE:

- If a risk assessment demonstrates the need for a machinist to use RPE to manage residual exposure risk, powered respirators are the better option. Non-powered respirators are limited to a continuous wear time of less than an hour, after which the user should take a break.
- The COVID pandemic led to 'ear loop' respirators entering the UK marketplace and there may also be the perception by some that surgical masks or face coverings are RPE. None of these are considered suitable or sufficient RPE.
- The protection face-fitting RPE provides to the user is defined in terms of an Assigned Protection Factor (APF). When calculating the correct protection, the APF value chosen should always provide a margin of safety. An APF of at least 20 is recommended for MWF mist.
- For reusable respirators, details of the appropriate filters for solid particles, liquid droplets, vapours and gases are summarised in Table 1 in HSE publication HSG53 (HSE HSG53, 2013). Particulate filters will be required for RPE should machinists remain at risk of exposure to MWF mist, particles and fume.
- Where tight-fitting RPE is selected, workers must pass a face fit test before using the respirator to ensure that no ingress of airborne particles occurs around the mask seal. A clean-shaven face is required to undertake the face fit test and when using respirators. Follow the advice provided by HSE in INDG479 (HSE INDG479, 2019).
- Pre-existing medical conditions such as asthma, skin allergies or heart problems may restrict or prevent some workers wearing any RPE, or certain types of RPE. If unsure, the employer should arrange for appropriate medical assessment.
- Safety spectacles worn under full-face respirators should be compatible and certified for protection against the impact of flying objects otherwise the respirator visor itself must be impact resistant.

An occupational health provider may conclude that an employee who has developed a work-related respiratory illness may return to their work once additional control measures are in place including the use of RPE. This decision should be based on medical advice about their fitness to wear RPE as set out in HSE HSG53 (HSE HSG53, 2013). Wearing RPE is a last resort decision that may apply if the employee cannot be relocated to work where they will not be exposed to the relevant hazard. They may need to use a powered respirator which has a fan unit (often fitted to the back of the user) which pulls external air through filters (particulate and VOC). This supplies a stream of clean air under positive pressure to a loose-fitting hood placed over the head. However, if worn for long periods they can cause discomfort which needs to be monitored.

#### 5.7.7 Checking and maintaining PPE and RPE

Users should regularly check and maintain their PPE and RPE before they use it, and should follow the manufacturers' instructions:

To maintain their PPE, employees need to be provided with a suitable locker storage for their work clothing. This should include a room where staff can remove their PPE and where any contaminated clothing can be stored separately from clean clothing. Work PPE should be cleaned according to the manufacturer's instructions and by an approved cleaning process. Contaminated clothing should not be taken home for cleaning by employees.

For RPE:

- Check the integrity and conditions of the straps, face seals, hoses, valves, O-rings and speech diaphragm.
- Check the correct prefilters (if required) and filters are fitted.
- For powered respirators check that the battery pack is fully charged, and the airflow rate is correct.
- Ensure after use the RPE is cleaned and stored in a clean cupboard.
- Check the expiry date of the RPE and filters.

#### 5.7.8 HSE and industry guidance

Some general guidance for machinists on appropriate protective clothing is set out in the UKLA 'Good Practice Guide for Safe Handling and Disposal of Metalworking Fluids' (UKLA, 2023).

HSE guidance can be found on HSE's metalworking fluids landing web page which includes reference to COSHH essentials sheets (https://www.hse.gov.uk/coshh/essentials/direct-advice/metalworking-fluids.htm).

- 'Advice for Managers' (HSE COSHH MW0, 2021)
- 'CNC machining' (HSE COSHH MW1, 2021)
- 'Control of skin risks during machining' (HSE COSHH MW2, 2021)
- 'Sump cleaning: water-miscible fluids' (HSE COSHH MW3, 2021)
- 'Sump cleaning: neat oils' (HSE COSHH MW4, 2021)
- 'Managing fluid quality' (HSE COSHH MW5, 2021)

Information can also be obtained from lubricant manufacturers and on the product information and safety data sheets (SDS). It should be noted that water-miscible MWF typically become contaminated during use and so the type of hazards machinists are exposed to can change.

## 6. Information, Instruction and Training

The provision of information, instruction and training for workers and managers is essential for control measures to be used and maintained effectively. The key elements to consider in providing information, instruction and training are presented in Table 6.1. However, the training needs to address the specific requirements of managers, supervisors and employees and relate to their responsibilities and roles, which may require separate and specific training packages.

**Table 6.1 Elements to consider when providing information, instruction and training.**

| Considerations | Examples |
|---|---|
| The hazards in MWF | Tramp oil, bacteria, endotoxins, fungi, metal fines, biocides. |
| Ill health caused by MWF | Occupational dermatitis, occupational hypersensitivity pneumonitis, occupational asthma. |
| Reasons for concern | Outbreaks of respiratory and skin disease in machine workshops in the UK, Europe and the USA.<br>For examples see case studies on HSE's metalworking fluids resources web page https://www.hse.gov.uk/metalworking/information.htm. |
| How to spot signs of ill health | Self-checking for symptoms and provision of occupational health surveillance. |
| Tasks associated with exposure to MWF | Mist emissions from open machinery using MWF, failure to clear MWF mist from inside machine enclosure before the doors are opened.<br>Touching contaminated surfaces or handling wet machined parts.<br>Diluting and mixing MWF concentrates as well as additives and biocides.<br>Skin and inhalation exposure to MWF from the unsafe use of compressed air guns. |
| Controlling exposure to MWF | Appropriate MWF selection, checking the fluid quality and intervening early to prevent its deterioration.<br>Fitting LEV/mist extraction units to machines and maintaining daily checks on the airflow indicators and the filters.<br>Ensure that enclosure systems are not compromised by checking machine door seals and selecting an appropriate delay to allow clearance of MWF mist before the door is opened.<br>Apply good working practices which reduce emissions such as minimising the use of compressed air guns or using them below 2.0 bar pressure.<br>Fluid management:<br>• Dip slide monitoring for bacteria.<br>• Fluid pH checks.<br>• Fluid concentration checks.<br>• Minimise the use of biocide through good fluid management.<br>• Check the quality of the MWF to establish whether a system cleanout is required. If it is required, clean and flush out the supply system and sump before adding a new MWF.<br>Instructional videos about practical tests that can be undertaken to monitor the quality of MWF have been produced by the UKLA and HSE and can be viewed at https://www.youtube.com/@UKLAMetalworkingFluidGroup/videos.<br>Assess the effectiveness of controls:<br>• Use the dust lamp to identify sources of emissions.<br>• Smoke containment tests.<br>• Use DRAMS for monitoring relative changes in particle levels. |
| RPE | Selection, correct use, appropriate storage and cleaning. |
| PPE | Selection, correct procedure to put on and take off gloves, appropriate storage and laundering provisions. |

## 7. Health Surveillance

Due to the risk of respiratory disease and dermatitis in machinists exposed to MWF, the employer must put in place arrangements for occupational health surveillance. The type of occupational health surveillance required depends on the level of individual exposure and risk. The early detection of symptoms and suitable interventions (physical and educational) to minimise exposure can reduce the progression and severity of these conditions. The reader is directed to COSHH Essentials General Guidance G402 'Health Surveillance for Occupational Asthma' (HSE COSHHe G402, 2022) and G403 'Health Surveillance for Occupational Dermatitis' (HSE COSHHe G403, 2022).

Employers need to ensure that they work with a competent occupational health provider. Occupational health services may involve either a nurse or a suitably trained individual administering a questionnaire to assess the employee's history of work and exposure to hazards and their symptoms. Lung function tests may be required and for dermatitis visual checks on the appearance of the skin.

Employees who experience skin or respiratory symptoms at work should promptly report these to their supervisor for referral to an occupational health provider. Based on the occupational health provider's findings, the employee may need to be referred to an occupational respiratory or skin disease specialist for diagnosis of their condition. On return to work the employee may need to be reassigned to new work to ensure they are either no longer exposed, or their exposure to MWF is minimised.

## 8. Audit and Review

Control of exposure to MWF requires the management of a wide range of controls. It is not possible to verify the effective management of these controls only using exposure monitoring. It is therefore recommended that regular audits and reviews are carried out to ensure that exposures are adequately controlled. Suggestions for auditing an MWF risk assessment and the management of MWF are given in Appendix 2.

# 9. Glossary

| | |
|---|---|
| **ALARP** | As Low as Reasonably Practicable |
| **APF** | Assigned Protection Factor |
| **Asthma** | An inflammatory lung disease characterised by shortness of breath, wheezing, chest tightness and cough and variable expiratory airflow limitation, can vary over time and in intensity. |
| **Biocide** | A substance or mixture of substances used to kill microorganisms. |
| **Biofilm** | Bacteria and other microorganisms, embedded in a visible protective slimy layer attached to the inner surface of a sump or pipe. |
| **CFU** | Colony Forming Unit, the number of individual bacteria capable of dividing to form a visible colony. |
| **CNC** | Computer Numerical Control (term used to describe computer operated tools) |
| **COSHH** | Control of Substances Hazardous to Health Regulations |
| **Dermatitis** | Inflammation of the skin caused by allergens or irritants. |
| **Dip slide** | A sterile layer of agar coating on both sides of a plastic slide. This is used to determine the number of growing bacteria, fungi and yeast in the MWF. |
| **DRAM** | Direct Reading Aerosol Monitor |
| **Fines** | Metal particles almost invisible to the naked eye, which may be inhaled and enter the lungs. |
| **Fumes** | Particles generated by the vapourisation and subsequent condensation of MWF. |
| **IBC** | Intermediate Bulk Container (for storing MWF and waste MWF). |
| **IIT** | Information, Instruction and Training |
| **LEV** | Local Exhaust Ventilation is extraction at the emission source removing air contaminated with hazardous substances. |
| **Microorganisms** | Organisms too small to be seen with the naked eye such as bacteria, fungi, and yeast (single-celled fungi). |
| **MWF** | Metalworking Fluid: either water-miscible (an emulsion, semi-synthetic or synthetic fluid) or neat ‘straight’ oil. MWF refers to Metal Working Fluids in both singular and plural. |
| **MWF mist** | An airborne cloud of very small MWF droplets may be inhaled and enter the lungs. Mist is produced from high-speed machining with lubricants but also from the use of compressed air guns at high pressure. |
| **MQL** | Minimum Quantity Lubrication (MQL) |
| **OA** | Occupational Asthma is caused by exposure to allergens (which cause immune sensitisation) and irritant substances and processes in workplaces and is largely preventable. |
| **PPE** | Personal Protective Equipment |

| | |
|---|---|
| **pH** | Expressed as a number between 1 and 14 to indicate how acidic or alkaline the MWF is. Values below 7 are increasingly acidic, 7 is neutral, and values higher than 7 are progressively alkaline. |
| **Photometer** | An instrument for measuring the concentration of suspended particulates based on light scattering. |
| **Refractometer** | A refractometer is either a handheld manual or electronic, optical device, used to measure the refractive index of water-miscible MWF to determine their concentration. The refractive index is the extent to which the solution bends light passing through it. |
| **RPE** | Respiratory Protective Equipment |
| **SDS** | Safety Data Sheet |
| **Smoke pens/tubes** | A device for releasing non-hazardous particles as visible smoke to demonstrate that an enclosure is under negative pressure. |
| **Swarf** | The metal shavings removed by tooling during machining. |
| **System Clean** | The process of thoroughly removing old and potentially contaminated MWF from the entire circulation system of a machine tool including any tramp oil, metal waste and microbial contaminants. |
| **Tribological** | The properties of friction, lubrication, and wear of interacting surfaces of materials in relative motion. |
| **Tramp oil** | Any unwanted oil from external sources (e.g. leaking hydraulic fluid) contaminating the MWF. |
| **TExT** | Thorough Examination and Testing |
| **TWA** | Time-weighted Average |
| **UKLA** | United Kingdom Lubricants Association |
| **Vapours** | The generation of heat at the cutting zone can cause water and volatile organic compounds in the MWF to vaporise. |
| **VI** | Viscosity Index: a measure of how much the oil viscosity changes with temperature. |
| **VOCs** | Volatile Organic Compounds |

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# 11. Appendices

## Appendix 1 – Exposure Measurement – Personal Sampling Methods

### A1.1 Exposure Measurement – Limitations of sampling methodology

Used MWF has a complex composition (chemical and biological) which affects the emissions during machining. This raises challenges for adequate sampling and quantification of MWF mist. Additionally, changes in the formulation of some water-miscible MWF has meant that the HSE MDHS 95/3 (HSE MDHS 95/3, 2015) method is no longer applicable to these fluids.

Examples of MWF mist sampling methods developed by different countries are summarised in Table A1.1. Some of these methods quantify both the volatile and insoluble fractions of the MWF emissions, whilst others ignore the volatile fraction. Some of these methods may underestimate personal exposure whilst others may overestimate it.

The air sampling methodology and the duration of sampling also introduce variability. Some methods require full shift sampling while others are used for task-based sampling which may be of shorter duration. For example, MDHS 95/3 (HSE MDHS 95/3, 2015) recommends a minimum sampling time of 2 hours for boron quantification, but a minimum sampling time of 8 hours if the sodium elemental marker is used.

The fixed-duration sampling methods provide an aggregate exposure over the sampling time which, if necessary, can be adjusted to provide full shift values. Personal monitoring for a duration representative of a working shift is only applicable when comparing to a limit value that is similarly based on shift exposure i.e. 8 hr TWA. However, this provides no information about the dynamic nature of emissions during machining involving, for example, far higher peak exposures. A qualitative assessment as described in this guidance, therefore, offers wider insight into exposure risk.

Further limitations of sampling methods in common use within the UK are detailed in Table A1.1.

**Table A1.1 Examples of methods used in the UK and other countries for quantifying personal exposure to MWF emissions from machining activity.**

| Method | Application | Limitations |
|---|---|---|
| **MDHS 95/3**: Measurement of exposure to water-miscible MWF mist | Analytical method for a time-weighted measurement of the average concentration of water-miscible MWF mist. | This method is based on the measurement of the elemental markers boron, sodium or potassium. Typically, boron is the preferred marker element because it is unlikely to come from other environmental sources. Boric acid and some boric salts have been classified as Substances of Very High Concern under EU REACH regulations, (for potential for human reproductive toxicity) and most lubricant manufacturers are either formulating boron-free or reducing the boron content of their MWF, limiting the application of boron as a marker. |
| **MDHS 84/2:** Measurement of exposure to MWF neat oil mist | Gravimetric procedure for time-weighted average concentration of MWF neat oil mist after cyclohexane extraction. | The method is only suitable for neat oils (mineral oils) of high viscosity (>18 $mm^2/s^1$ at 40ºC). Lower viscosity oils contain a larger volatile component that is likely to be lost during sampling and processing leading to an underestimation of airborne concentrations. |
| **NIOSH 5524**: Metalworking fluids (all categories) | Gravimetric procedure for measuring airborne MWF mist after solvent extraction in dichloromethane/methanol/ toluene (1:1:1) and methanol/water (1:1). | As a gravimetric method, and similar to MDHS 84/2 in that regard, under/ (variable) estimations of exposure may occur due to evaporative losses (depending on the fluid) and challenges in weighing of filters (following a solvent extraction step). Quantification of the oil component only may underestimate the risk presented by other factors associated with the fluid. |
| **NIOSH 5026:** Oil mist, mineral | Analytical method for measurement of trichlorofluoroethane-soluble mineral oil mist by infrared spectrophotometry. | The method is only suitable for mineral oils and not applicable to synthetic or semi-synthetic fluids. |
| **MDHS 14/4**: General method for measurement of respirable, thoracic and inhalable aerosols. | General methods for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols. | The method is non-selective and may capture other workplace contaminants. Evaporative losses from the filter may result in underestimation of the aerosol mass. |

### A1.2 Exposure Measurement – Guidance and limit values

The complex mixture of chemical and biological hazards in used MWF makes it difficult to establish a health-based exposure limit. Epidemiological studies have found that machinists can develop respiratory and skin diseases when exposed to MWF below the applicable national exposure limits/guidance values for MWF mist.

These factors preclude setting safe levels of exposure to MWF mist. In the UK reducing exposure to levels "as low as reasonably practicable" (ALARP) applies to controlling exposure to substances that cause occupational asthma.

**Table A1.2 Summary of UK and US guidance and limit values.**

| Exposure Value | Status | Limitations |
|---|---|---|
| **UK HSE Guidance Values**:<br>3.0 mg/m$^3$ 8-hour TWA for neat oil mist.<br>1.0 mg/m$^3$ 8-hour TWA for water-miscible MWF. | Withdrawn | 2004-2005 outbreak of occupational asthma and hypersensitivity pneumonitis at Powertrain Ltd, Longbridge plant demonstrated that compliance with the HSE guidance values was not sufficient to protect worker health. Consequently, these guidance values were withdrawn by HSE, and no benchmark guidance values have subsequently been published in the UK. |
| **NIOSH Recommended Exposure Limit (REL):** 0.4 mg/m$^3$ for the thoracic fraction, or 0.5 mg/m$^3$ for total particulate mass, based on a TWA concentration for up to 10 hours per day for a 40-hour working week. | Current | Adverse respiratory effects and hypersensitivity have been reported for machinists exposed to MWF below the NIOSH REL. |
| **ACGIH Threshold Limit Value (TLV):** 0.2 mg/m$^3$ for inhalable mineral oil in MWF. | Proposed | Several health studies indicate respiratory symptoms and disease in machinists exposed to concentrations below 0.2 mg/m$^3$. |

## Appendix 2 – Assessment/Audit Tools

### A2.1 Audit tool for assessment and control of MWF exposure.

This tool aims to provide a framework for assessing the risk of exposure by inhalation, or skin contact, with MWF to inform a suitable and sufficient risk assessment. The list considers process risk factors, routes of exposure and existing control systems. It does not address the maintenance of fluid quality, which is covered by a checklist presented in A2.2.

| | |
|---|---|
| **Section A1: Risk Factors – Inhalation** | |
| **Type of Operations** | **High Risk:** High-speed CNC machining and grinding processes. |
| **Fluid quantity** | **High Risk:** Continuous high-pressure delivery of the MWF at the cutting head. |
| **Machining temperature** | **High Risk:** Elevated MWF temperature (>30ºC) which increases the evaporation of volatile constituents in MWF and promotes microbial growth. |
| **Cleaning methods** | **High Risk:** Using compressed air at pressures >2.1 bar (30 psi) and/or compressed air outside of the enclosure without an additional source of air extraction to control mist.<br>These risks can be reduced by using alternatives to compressed air or by reducing the pressure of compressed air (<2.1 bar (30psi)) and using LEV. |
| **Section A2: Controls Review – Inhalation** | |
| **Level of enclosure** | **High Risk**: Partial, or no, enclosure of the machine tool, particularly for high-speed machining and grinding operations. |
| **LEV provision** | **High Risk:** LEV is not fitted to CNC machines where it is practical to do so. Note there are machines (e.g. large gantry systems) to which LEV may not be practical to install.<br>Poor placement of the LEV extraction point within enclosures (i.e. too far from the enclosure door and operator, poor mixing of air within enclosure) can increase the inhalation risks. |
| **LEV TExT completed** | **High Risk:** Not addressing significant issues identified at previous TExT. |
| **Clearance times/door interlocks** | **High Risk:** Opening the enclosure door before the emissions have been sufficiently cleared by the LEV system. Manually overriding the door interlocks too quickly may result in inhalation of MWF mist and cause accidents. |
| **Filtration/discharge arrangement** | **High Risk:** Using recirculating mist extraction units without three-stage filtration (i.e. not fitted with a high-efficiency filter before returning the air into the workshop). |
| **Filter monitoring** | **High Risk:** Failing to monitor the efficiency of the filters in mist extraction units.<br>To avoid this risk, pressure gauges should be fitted to monitor the pressure changes across the filter units. Sensors can also be fitted to monitor vibration and the motor temperature in mist extraction units. |
| **Maintenance regime** | **High Risk:** Failing to check the performance of engineering controls such as LEV and having inconsistent maintenance regimes in place. |
| **Training** | **High Risk:** Having no formal training in place for machinists and managers regarding exposure and health risks from MWF, and the use of control processes to manage and reduce the emission and exposure to MWF hazards. |

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|---|---|
| **Fluid management** | **High Risk:** Having no programme of regular fluid quality checks for the MWF and not providing machinists and managers with training to understand the importance of these fluid quality checks to minimise the accumulation of hazards in MWF.<br>This risk can be addressed by following the UKLA and HSE guidance (UKLA, 2023 and HSE COSHH MW5, 2021). |
| **Health surveillance** | **High Risk:** Failing to put in place respiratory health surveillance for employees exposed to MWF.<br>This health surveillance needs to be undertaken by a competent occupational health provider and will involve regular lung function tests (HSE COSHHe G402, 2022). |
| **Section A3: Exposure Assessment - Inhalation** | |
| **Number of operating machines in the area** | **High Risk:** Crowded workspaces with machines placed closely together, and in workshop buildings with low ceiling height and poor general ventilation. |
| **Machine run time duration** | **High Risk:** When machines have to be run at high speed for long periods this will increase emissions, particularly when machines are not fully enclosed or enclosed but LEV not fitted. |
| **Interaction frequency** | **High Risk:** Intermittent stop/starting of the machine tools requiring the enclosure door to be opened is more likely to expose machinists to MWF mist and fume.<br>These risks are reduced by automating the changing cutting tools and parts unloading. |
| **Qualitative assessment** | **High Risk:** Not undertaking visual inspections to check for emissions from machine tools could result in employees becoming exposed.<br>The use of backlighting with dust lamp (see Section 4.2.1) or DRAM (see Section 4.2.3) to regularly monitor for emissions can help mitigate these risks. |
| **Section B1: Risk Factors – Skin Contact** | |
| **Cleaning methods** | **High Risk:** Holding closely a compressed air gun for cleaning components and machine tools resulting in splash back.<br>This risk can be reduced by replacing compressed air guns with automated component cleaning systems, only using compressed air guns under an LEV extraction source, lowering the operating pressure of the compressed air gun to <2.1 bar (30 psi), and using a compressed air gun fitted on a longer lance and splash guards. Vacuum suction devices can be used for removing waste MWF and swarf and reduce the risk of generating MWF mist and metal particulates. |
| **Handling of machined parts and metal waste** | **High Risk:** Holding and touching components and tools covered in MWF or when removing metal swarf, without wearing protective gloves.<br>The risk of skin contact and injury can be reduced by automating tool changes, introducing tongs or clamps for loading and unloading, and providing swarf hooks or alternative magnetic removal methods. If handling of wet workpieces is required, single-use disposable gloves meeting EN374-2 may be used but only where these do not add to other risks from machinery, such as entanglement. |

| Section B2: Controls Review – Skin | |
|---|---|
| **Skin disease and wearing PPE** | **High Risk:** When employees are unaware of the skin disease risks from regular contact with MWF or how to prevent this.<br>These risks can be reduced by training and raising awareness about these health risks and recognising early signs of skin disease, correct use of PPE, storage and laundering provisions. |
| **Fluid management** | **High Risk:** Allowing the quality of the MWF to deteriorate with use including contamination with tramp oil, metal waste and bacteria and fungi.<br>This risk can be reduced by following the advice in Section 3 and by referring to the following UKLA and HSE guidance (UKLA, 2023 and HSE COSHH MW5, 2021). |
| **Skin hygiene provision** | **High Risk:** Employees have their skin constantly soaked in MWF and are not taking care of their skin.<br>This risk can be reduced by employers providing suitable hygiene facilities and by employees following the advice in Section 5.6.3. |
| **Health surveillance** | **High Risk:** Employees develop skin conditions such as dermatitis because they are unaware of the risks and no health checks are in place.<br>This can be avoided by using a competent occupational health provider to undertake regular checks for dermatitis (HSE COSHHe G403, 2022). |
| **Section B3: Exposure Assessment – Skin** | |
| **Tasks that expose skin to MWF** | **High Risk:** Undertaking tasks which result in MWF droplets falling onto the machinists, or which require direct handling of MWF, without wearing protective PPE. |
| **Interaction frequency** | **High Risk:** The risk for dermatitis is increased when the skin is constantly wet with MWF, when the skin is not washed to remove the MWF residue, and when the skin is not dried after washing the hands. |

### A2.2 Worked example for a CNC shop

| Section A1: Risk Factors – Inhalation | |
|---|---|
| **Type of operation** | High-speed machining – CNC machining consistently high speed, high pressure fluid delivery |
| **Machining temperature** | Temperatures that cause mist by evaporation and condensation – mist noted during machining |
| **Cleaning methods** | Cleaning parts and machine with compressed air at high pressure >2.1 bar (30 psi) |
| **Overall Rating** | High Risk |
| **Section A2: Controls Review – Inhalation** | |
| **Level of enclosure** | Largely enclosed process under negative pressure |
| **LEV provisions** | LEV fitted |
| **LEV TExT completed** | Minor defects at last TExT not addressed |
| **Clearance times/door interlocks** | Clearance manually timed |
| **Filtration/discharge arrangement** | Three-stage filter with high-efficiency filter for recirculating air |
| **Filter monitoring** | Filter gauge present and reviewed during start-up checks |
| **Maintenance regime** | Planned preventative maintenance includes daily maintenance checks of the machine, LEV and filter gauges |
| **Training** | Operators conversant in risk factors from inhalation and use of existing controls |
| **Fluid management** | Checks are undertaken monthly i.e. not at recommended intervals |
| **Health surveillance** | Spirometry in place and established avenues of ill health reporting have not identified concerns |
| **Overall Rating** | Moderate Risk |
| **Section A3: Exposure Assessment – Inhalation** | |
| **Number of operating machines in the area** | Spacious workspace with good general ventilation |
| **Machine run time duration** | Continuous machining: operatives run multiple machines; standard shift times |
| **Interaction frequency** | Frequent door openings for parts removal and inspection |
| **Qualitative assessment** | Misting observed in breathing zone and wider work area during parts cleaning with airlines |
| **Overall Rating** | High Risk from cleaning activities |

| | |
|---|---|
| **Section B1: Risk Factors – Skin Contact** | |
| **Cleaning methods** | High-pressure compressed air outside of the enclosure with parts handled |
| **Handling of machined parts** | Parts directly handled during unloading and cleaning; nitrile gloves worn |
| **Overall Rating** | High Risk |
| **Section B2: Controls Review – Skin** | |
| **Skin disease and wearing PPE** | Task-based glove use during unloading parts and mixing fluid; internally laundered work clothing |
| **Training** | Operators not conversant in risk factors and use of controls beyond PPE |
| **Fluid management** | Checks are conducted monthly i.e. not at recommended frequency |
| **Skin hygiene provisions** | Hand washing facilities are accessible in clean welfare areas; no pre-work or after-work creams provided |
| **Health surveillance** | None relating to identifying dermatitis/no skin checks in place |
| **Overall Rating** | High Risk |
| **Section B3: Exposure Assessment – Skin** | |
| **Tasks that expose skin to MWF** | Routine operations of machines, parts handling, mixing of fluids reliant on glove use; airlines directed towards hands and not fitted with splashguards expose skin to splashes |
| **Interaction frequency** | Continuous, or near continuous, parts handling and airline cleaning during unloading |
| **Overall Rating** | High Risk |

### A2.3 Audit tool for MWF quality management

This checklist aims to help audit the management of MWF quality and should be used in conjunction with the UKLA 'Good Practice Guide for Safe Handling and Disposal of Metalworking Fluids' (UKLA, 2023).

| Item | Question | Yes/No | |
|---|---|---|---|
| **Storage and preparation of MWF** | | | |
| Temperature | Is the MWF concentrate stored above 5ºC? | | |
| Dilution | Is water supplied from mains? | | |
| | Does the water used for dilution of the MWF concentrate meet the manufacturer's recommendations for pH and hardness? | | |
| **Monitoring the MWF** | | | |
| Concentration | Is the concentration of the MWF checked weekly in each machine? | | |
| | Is the concentration of MWF recorded to track changes? | | |
| | Is the concentration within the range advised by the supplier? | | |
| pH | Is the pH of the MWF tested each week? | | |
| | Is the method used for testing pH appropriate with any equipment used being serviced and calibrated where required? | | |
| | Is the pH of MWF recorded to track changes? | | |
| | Is the pH within the range advised by the supplier? | | |
| Appearance | Is there a daily visual check of the appearance of the MWF? | | |
| | Is the MWF free from unusual odour? | | |
| | Are there any signs of biofilm formation, tramp oil, foaming, fines swarf and other foreign bodies? | | |
| | Are the results of these visual checks recorded? | | |
| | Is tramp oil checked weekly? Should be kept to a minimum (recommended below 2%). | | |
| Metal contamination | Are checks performed on the build-up of swarf and metal fines in the sumps of machines? | | |
| Circulation and flow | Is the MWF free-flowing and fully circulating? For example, if the fluid supply system includes 'dead-ends' and 'dead-legs', are these cleaned and flushed regularly? | | |
| Monitoring bacterial growth | Are weekly dip slide tests undertaken? | | |
| | Are dip slide test results consistently below 10,000 CFU/ml ($10^4$ CFU/ml)? If so the frequency of dip slide tests can be reduced as long as evidence of the results are retained. | | |
| | If weekly dip slide tests are not undertaken, are other means used to demonstrate bacteria growth is consistently below 10,000 CFU/ml ($10^4$ CFU/ml)? | | |
| | Are the dip slide test results recorded to track changes? | | |
| Operating temperature | Is the temperature of the sumps in machines measured? | | |
| | Are MWF temperatures less than 30ºC unless required for the performance? | | |
| Procedures | Are documented procedures in place which describe the management of MWF? | | |
| | Do the procedures describe the actions which need to be taken depending on the monitoring results? | | |
| **Machine usage** | | | |
| Daily checks | Do operators of machines perform daily checks? | | |
| | Do daily checks cover a visual examination of the MWF? | | |
| **Maintenance of the MWF supply** | | | |
| Cleaning | Are machine sumps and supply lines cleaned when contaminated with biofilm and metal residues? | | |
| | Are the machine MWF supply systems thoroughly cleaned when the results of dip slide tests demonstrate heavy bacteria/fungal contamination? | | |
| | Are records kept when the machines are cleaned? | | |

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