

# **Occupational Chemical Exposure and Health Risks in Electronics Manufacturing in Cavite, Philippines**

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## **Introduction**

For this project, I worked with the Institute for Occupational Health and Safety Development (IOHSAD) to better understand chemical exposure risks in manufacturing facility in Cavite, Philippines. I held a meeting with IOHSAD's director, Nadia De Leon, to discuss working conditions and potential hazards in the facility.

During this meeting, Nadia noted that workers in MEC Electronics have reported symptoms such as headaches and dizziness, suggesting possible ongoing exposure to chemical vapors. She also mentioned that workers only have basic personal protective equipment (PPE), which may not provide sufficient protection.

My task was to identify key chemical hazards in facility and evaluate their health risks. This includes assessing the short-term and long-term health effects of selected chemicals, identifying relevant occupational exposure limits, and examining control measures and safer alternatives. The report also considers environmental and health surveillance strategies related to chemical exposure.

## **Part 1: MEC Electronics ( Electronics Manufacturing)**

MEC Electronics is a Philippine-based electronics manufacturing company that mainly produces components such as cables, power cords, and electronic connectors. According to the report by IOHSAD, the factory has approximately 576 employees, of which about 63% are female. This indicates that the employees are mainly female. The workers participated in multiple production processes, including crimping, soldering, degreasing, molding, varnishing, and manual putting, among others. Many of these processes require the use of chemicals such as solvents, lubricants, flux, varnishes, and adhesives. This exposes the workers to potential chemicals during their work. The report indicates that the workers typically work from 6 a.m. to 6 p.m., for a total of 12 hours a day, which leads to their long-term exposure to dangerous environments in the workplace and an increasing cumulative exposure to hazards over time. The report mentions that the factory's ventilation systems are often inadequate, and in some cases, due to the lack of proper local exhaust or ventilation systems, workers can only rely on temporary solutions such as personal electric fans. In addition, workers are reported to use basic personal protective equipment such as cotton or surgical masks, which are not designed to protect against chemical vapors or airborne contaminants. This suggests that current protective measures are insufficient for the types of exposures present in the facility. Health symptoms reported by workers include headaches, dizziness, coughing, and difficulty breathing, indicating ongoing exposure to airborne chemicals and poor air quality in the workplace. The report also emphasized the health problems of the workers, including respiratory diseases and difficulties in accessing effective occupational health services, further indicating the lack of health protection in the workplace. I focus on chemical exposures across all production processes at MEC. For each process, I selected one

representative hazardous chemical for closer analysis. For each chemical, I review scientific literature and occupational health guidelines to evaluate short-term and long-term health effects, identify relevant occupational exposure limits, and examine existing control measures. I also explore safer alternatives and consider strategies to reduce exposure risks through environmental and health surveillance.

## **1.1 Process and Chemical Hazard Analysis**

### **1. Crimping - lubricant (WD 40), petroleum hydrocarbons**

#### **Chemical Description**

WD-40 is a petroleum-based hydrocarbon mixture that is commonly used as a lubricant in mechanical operations such as crimping. It helps to handle metal components, reduce friction, and loosen parts. Besides petroleum-based oils and aliphatic hydrocarbons, this product also contains carbon dioxide as a propellant when used as an aerosol. Workers are more likely to be exposed during use because the spray releases vapor and fine mist into the air.<sup>1</sup>

#### **Exposure Routes**

The main route of exposure for WD-40 is inhalation, as it is used in the form of a spray.<sup>1</sup> Workers are prone to inhaling vapors or mist when the spray is close to their faces or when it is applied in poorly ventilated areas.<sup>1</sup> In the MEC facility, workers rely on basic cotton or surgical masks, which are unable to protect against chemical vapors, and the report mentions that ventilation is also inadequate. The risk of inhaling vapors or mist increases further due to prolonged working hours. Skin contact may occur when workers handle lubricated components or come into contact

with the liquid product. Ingestion is not common, but if workers do not wash their hands properly after handling lubricants and then touch their mouths or food, ingestion could occur.

This is relevant to MEC because the IOHSAD report found that 68 out of 107 workers, or 63.55%, felt workplace ventilation was inadequate, and workers identified chemical dust, fumes, and gases as major workplace hazards.

### **Short-Term Health Effects**

Short-term exposure to WD-40 mainly occurs through inhalation of vapors or mist. Workers may feel dizziness, fatigue, or difficulty concentrating. Additionally, some people may experience irritation in their throat, nose, or eyes, particularly in poorly ventilated areas.<sup>1</sup> These effects are usually temporary and tend to improve once exposure is reduced.<sup>1</sup> These effects are especially relevant to MEC because workers reported headaches, cough, difficulty breathing, red eyes, chest pain, easy fatigability, and dizziness-like symptoms in IOHSAD's worker health assessment. In the MEC report, headache was the most frequently reported symptom, followed by cough and difficulty breathing among the leading symptoms. These symptoms do not prove that WD-40 alone caused workers' health problems, but they are consistent with the types of irritation and nervous system symptoms that can occur when petroleum-based aerosols are used repeatedly in poorly ventilated areas.<sup>2</sup>

### **Long-Term Health Effects and Disease Links**

WD-40 itself is not classified as a carcinogen. However, since it is a petroleum-based mixture, the potential health risks depend on its composition, the way it is used, and the duration of workers' exposure.<sup>1</sup> Studies of workers exposed to crude oil vapors and petroleum mixtures have shown that workers with higher cumulative inhalation exposure reported more symptoms, such as headache, dizziness, difficulty concentrating, numbness or tingling, blurred vision, and

memory problems. Some studies have also found that workers exposed to higher levels of volatile hydrocarbons have slight changes in cognitive performance, including attention, memory, and executive function. This means that repeated exposure to petroleum vapors may lead to persistent neurological symptoms, especially in poorly ventilated workplaces.<sup>8</sup>

There is no current evidence that indicates WD-40 causes specific cancers in workers. Therefore, WD-40 has not been proven to cause cancer, but workers should still avoid inhaling petroleum hydrocarbon vapors as much as possible. This is particularly important in workplaces with poor ventilation and when workers are exposed to multiple chemicals simultaneously.<sup>1</sup>

### **Exposure Limits and Occupational Guidelines**

WD-40 does not have a single exposure limit because it is a mixture.<sup>1</sup> Exposure guidance is based on relevant components and exposure form.<sup>1</sup> For the petroleum-based oil fraction, the WD-40 SDS lists 5 mg/m<sup>3</sup> TWA as mineral oil mist, consistent with OSHA's mineral oil mist limit in Table Z-1.<sup>16</sup> For petroleum distillates/naphtha-like hydrocarbons, NIOSH lists a REL of 350 mg/m<sup>3</sup> TWA and 1800 mg/m<sup>3</sup> as a 15-minute ceiling, while OSHA lists a PEL of 500 ppm, or 2000 mg/m<sup>3</sup>, for similar hydrocarbon mixtures.<sup>56</sup> The WD-40 SDS also lists 1200 mg/m<sup>3</sup> TWA for aliphatic hydrocarbons as a manufacturer-recommended value.<sup>1</sup> Cal/OSHA adopts similar limits for mineral oil mist and related petroleum hydrocarbons in Title 8, Section 5155 on airborne contaminants.<sup>7</sup>

### **Control Measures and Alternatives**

To reduce exposure during the crimping process, the first step should be to reduce the amount of WD-40 vapor and mist that workers breathe in.<sup>1</sup> MEC needs to improve ventilation. The MEC investigation report shows that ventilation in the factory is not good enough, and in some areas, workers have to rely on personal fans because proper exhaust systems are not available. Studies

in metal-processing workplaces have shown that better ventilation can reduce airborne chemical levels and lower workers' exposure.<sup>2</sup>

Work practices should also be improved. Workers should avoid spraying WD-40 close to their faces, use only the amount needed, and avoid repeated or unnecessary spraying.<sup>1</sup> The company should also provide better PPE. At MEC, workers mainly use cotton or surgical masks, but these masks do not protect workers from chemical vapors. If workers need to use WD-40 spray, the company should provide properly fitted respirators for organic vapors when needed. Gloves should also be used to reduce skin contact with the lubricant.<sup>5</sup>

There is no evidence that WD-40 itself is banned in electronics or cable manufacturing in other countries. The WD-40 SDS also states "Restrictions on Use: None identified."<sup>1</sup> However, since WD-40 is a petroleum-based aerosol product, it still needs to be regulated by relevant regulations on volatile organic compounds, occupational exposure limits, and safer alternatives. WD-40 spraying does not appear to be a banned process based on the available sources, but safer application methods and substitution should still be recommended.

One safer alternative is to reduce or eliminate aerosol spraying. Instead of spraying WD-40, workers could apply the lubricant with brushes, droppers, or applicator bottles. Even if the same product is still used, changing the application method can reduce how much vapor or mist becomes airborne.<sup>1</sup>

Another option is to consider bio-based lubricants. Some studies show that bio-based lubricants are being explored as alternatives to petroleum-based products because they are generally less toxic and better for the environment. They could be a practical alternative to reduce long-term exposure to petroleum-based chemicals.<sup>3</sup>

Case study<sup>4</sup>: The Acushnet Company reduced chemical exposures by changing both the materials used and the production process. It worked with suppliers to switch to “vanishing oils” for metal parts, which helped reduce the need for many solvent-based degreasing steps. For parts that still needed cleaning, the company replaced more hazardous chemicals with less toxic alternatives. It also improved degreasing equipment and adjusted process conditions to reduce emissions. These changes reduced hazardous chemical use, lowered air emissions, and decreased worker exposure. After these improvements, fewer workers reported irritation and other symptoms.

### Sources Table:

	Name of document / Author & publication	URL	Comments
1.	WD-40 Multi-Use Product Aerosol Safety Data Sheet	<a href="https://files.wd40.com/pdf/sds/mup/wd-40-multi-use-product-aerosol-low-voc-sds-us-ghs.pdf">https://files.wd40.com/pdf/sds/mup/wd-40-multi-use-product-aerosol-low-voc-sds-us-ghs.pdf</a>	Useful for WD-40 composition, exposure routes, short-term symptoms, PPE, ventilation, and manufacturer exposure guidance.
2.	Occupational Exposure to Metalworking Fluid and the Effect on Health Symptoms—An Intervention Study / Erik Thornéus, Pål Graff, Ing-Liss Bryngelsson, Eva Nordenberg, Bijar Ghafouri, Henrik Johansson, and Louise Fornander, Journal of Occupational and Environmental Medicine, 2021	<a href="https://pmc.ncbi.nlm.nih.gov/articles/PMC8478316/">https://pmc.ncbi.nlm.nih.gov/articles/PMC8478316/</a>	Useful for control measures and case study. It shows that ventilation improvements and stopping recirculated contaminated air reduced worker symptoms.
3.	Advances and Challenges in Bio-Based Lubricants for Sustainable Tribological Applications / MDPI, Lubricants	<a href="https://www.mdpi.com/2075-4442/13/10/440">https://www.mdpi.com/2075-4442/13/10/440</a>	Useful for safer alternatives. It supports bio-based lubricants as possible alternatives to petroleum-based lubricants.

4.	Toxics Use Reduction Case Study: Acushnet Rubber Company Achieves ISO 14001 Certification / Massachusetts Office of Technical Assistance, Case Study No. 46, 1997	<a href="https://archives.lib.state.ma.us/bitstreams/f167b9b1-d41e-44ec-a8ea-7cbd1194f32c/download">https://archives.lib.state.ma.us/bitstreams/f167b9b1-d41e-44ec-a8ea-7cbd1194f32c/download</a>	Useful case study for substitution and process changes. Acushnet reduced toxic solvent use through vendor changes, vanishing oil, aqueous cleaning, and less toxic alternatives.
5.	NIOSH Pocket Guide to Chemical Hazards: Petroleum Distillates (Naphtha) / National Institute for Occupational Safety and Health (NIOSH), CDC	<a href="https://www.cdc.gov/niosh/npg/npgd0492.html">https://www.cdc.gov/niosh/npg/npgd0492.html</a>	Useful for exposure limits, symptoms, target organs, exposure routes, and respirator guidance for petroleum distillates.
6.	OSHA Annotated Table Z-1 / Occupational Safety and Health Administration (OSHA)	<a href="https://www.osha.gov/annotated-pels/table-z-1">https://www.osha.gov/annotated-pels/table-z-1</a>	Useful for OSHA occupational exposure limits, especially mineral oil mist and petroleum-related airborne contaminants.
7.	California Code of Regulations, Title 8, Section 5155: Airborne Contaminants / California Division of Occupational Safety and Health (Cal/OSHA)	<a href="#">California Code of Regulations, Title 8, Section 5155. Airborne Contaminants.</a>	Useful for Cal/OSHA airborne contaminant limits and comparison with OSHA/NIOSH standards.
8.	Associations between Airborne Crude Oil Chemicals and Neurological Symptoms among Workers in the Gulf Long-Term Follow-Up Study / Kristen N. Cowan, Emily J. Werder, Kaitlyn G. Lawrence, Richard K. Kwok, Patricia A. Stewart, Mark R. Stenzel, Caroline P. Groth, Tran B. Huynh, Sudipto Banerjee, Gurumurthy Ramachandran, W. Braxton Jackson II, Frankie LaPorte, Dale P. Sandler, and Lawrence S. Engel, Science of the Total Environment, 2025	<a href="https://www.sciencedirect.com/science/article/pii/S048969725017991">https://www.sciencedirect.com/science/article/pii/S048969725017991</a>	Useful for long-term health effects. It supports a cautious statement that petroleum-related hydrocarbon mixtures may be associated with neurological symptoms, but it should not be used to claim WD-40 directly caused disease.

## **2. Degreasers Thinning and Cleaning - toluene**

### **Chemical Description**

Toluene is a common industrial solvent, often used in degreasing, thinning, and cleaning processes. Its function is to remove oil residues and other residues, and it is also used in products such as paint thinners, adhesives, and other solvent-containing materials. Toluene is usually not used alone but is used as part of a mixture with alcohols, ketones, acetates, and petroleum-derived hydrocarbons.<sup>34</sup> In the MEC report, toluene is listed under the category of degreasers, thinning, and cleaning chemicals, which also includes many other solvents.

### **Exposure Routes**

Workers are mainly exposed to toluene by inhaling vapors released during the cleaning process, especially in enclosed spaces or areas with poor ventilation.<sup>34</sup> This is more concerning in the MEC facility, where workers rely only on basic PPE such as cotton or surgical masks, which do not protect against organic vapors, and where ventilation has been reported to be inadequate. Workers may also be exposed to liquid solvents through skin contact. If they repeatedly come into contact with the solvents during long periods of continuous work, the overall risk of exposure will increase. The possibility of ingestion is relatively low, but if workers accidentally come into contact with the solvents and do not wash their hands properly before eating or drinking, swallowing could still occur.<sup>34</sup> Risk is further increased by long 12-hour shifts, which extend the duration of exposure and increase cumulative inhalation of solvent vapors.<sup>34</sup>

### **Short-Term Health Effects**

Short-term exposure to toluene mainly affects the central nervous system.<sup>346</sup> After workers inhale solvent vapors, they may experience dizziness, fatigue, or difficulty concentrating. Some workers

may also experience irritation of the eyes, nose, or throat, especially when exposed to harmful substances in poorly ventilated environments.<sup>34</sup> The symptoms mentioned in the MEC report are directly relevant, as workers reported many symptoms that overlap with the known effects of solvent exposure, including headache, cough, difficulty breathing, red eyes, chest pain, easy fatigability, forgetfulness, and insomnia. The report also states that although the exhaust system was adjusted, workers still came into contact with smoke, noxious substances, and fumes in the workplace. Since the workers are exposed to multiple solvents and other hazardous substances simultaneously, it cannot be conclusively stated that all these symptoms are caused by toluene.

### **Long-Term Health Effects and Disease Links**

Long-term exposure to toluene may lead to persistent neurological problems, including memory loss, decreased attention, difficulty concentrating, and impaired coordination. Furthermore, long-term exposure may have an impact on the liver and kidneys, and may cause problems in the respiratory system or cardiovascular system, especially when workers repeatedly expose themselves to the vapors of mixed solvents during long working periods.<sup>3</sup>

California's Proposition 65 includes toluene because it may cause birth defects or other reproductive harm, so extensive exposure during pregnancy may affect fetal development.<sup>8</sup> This is particularly important for MEC, as the factory has a large number of female employees.

During degreasing, thinning, and cleaning processes, repeated exposure to solvents may occur due to long working hours of up to 12 hours.<sup>8</sup>

Toluene has not been classified as a carcinogen.<sup>3</sup> Some research reports indicate that there is a connection between bladder cancer and exposure to mixtures of solvents that may contain toluene. However, these studies usually involve combined exposure scenarios and thus cannot consider toluene as a single causative factor.<sup>2</sup> Therefore, the association between toluene and

diseases mainly lies in its neurotoxicity and reproductive toxicity, while cancer should be regarded as uncertain.<sup>23</sup>

### **Exposure Limits and Occupational Guidelines**

Toluene has well-established occupational exposure limits. According to OSHA, the permissible exposure limit is 200 ppm with an 8-hour TWA.<sup>7</sup> NIOSH recommends a more protective limit of 100 ppm over a workday.<sup>6</sup> ACGIH recommends 20 ppm as an 8-hour TWA.<sup>3</sup> Cal/OSHA uses 10 ppm as an 8-hour TWA.<sup>5</sup>

### **Control Measures and Alternatives**

To reduce exposure to toluene during degreasing and cleaning, the most important step is to control airborne vapors. Ventilation also plays a key role here. The MEC must install local exhaust ventilation in the area where solvents are used to capture the volatile substances before they reach the breathing zone of the workers.<sup>346</sup> General ventilation alone is usually not sufficient to deal with the process where solvents are frequently used. Then, employees should avoid using excessive amounts of solvents, minimize the use of open containers, and avoid working in enclosed spaces without ventilation. In a small change in the way solvents are used, the exposure risk during long periods of working hours can be reduced.<sup>34</sup>

The company should also provide proper PPE. Current PPE use in the facility is insufficient. Workers are reported to rely on basic cotton or surgical masks, which do not protect against solvent vapors. Surgical masks are not effective against solvent vapors. Instead, respirators designed for organic vapors should be used when needed, along with gloves to reduce skin contact.<sup>346</sup>

Evidence shows that toluene can be replaced with safer alternatives. One is switching from solvent-based cleaners to water-based or low-VOC cleaning systems. In many manufacturing

facilities, companies replaced traditional solvent cleaners with aqueous or other low-toxicity cleaning systems, which reduced the use of hazardous air pollutants and volatile organic compounds while maintaining cleaning performance. In some cases, these substitutions also lowered overall cleaning costs and improved worker protection.<sup>1</sup>

Others have explored alternative cleaners, such as those made from bio-based or less volatile materials, that tend to have lower toxicity and produce fewer harmful emissions.<sup>1</sup> In many situations, these alternatives performed as well as traditional solvents while reducing both environmental impact and worker exposure. There are also examples where companies redesigned their cleaning process entirely. Instead of relying on solvent-heavy cleaning, they adjusted production methods or used less volatile materials, which reduced the need for hazardous chemicals in the first place. The effects of these changes are that workers experience fewer symptoms, such as irritation and discomfort, overall exposure levels decrease, and in many cases, companies also save costs over time due to reduced chemical use and improved efficiency.<sup>1</sup>

Worker-Engaged Case Study<sup>9</sup>: A relevant worker-centered case for MEC's degreasing, thinning, and cleaning process is the Chicony Electronics Factory TenSquared case study in China.

Chicony is an electronics manufacturer, and workers frequently use chemicals for cleaning keyboards. Workers reported that strong chemical smells and poor ventilation were major problems, and direct skin contact occurred when workers used cloths to clean products. The TenSquared team addressed seven chemical-risk areas through root-cause analysis, new cleaning tools, ventilation improvements, safer chemical storage, updated SDS access, PPE stations, worker training, daily PPE checks, and worker surveys.

The results are useful for MEC because they show that cleaning-chemical exposure can be reduced through practical workplace changes and worker engagement. After the project,

chemical consumption for cleaning decreased by 62.88%, 100% of chemicals used by employees had SDS available, 100% of employees had access to and wore PPE, 100% of chemical users were trained, direct skin contact with chemicals was eliminated, ventilation satisfaction improved, worker exposure to chemicals decreased by 90%, and 71% of workers said management became more open to worker suggestions.

This case supports the recommendation that MEC should not rely only on cotton or surgical masks. Instead, the company should involve workers in identifying which cleaning tasks produce the strongest odors, where ventilation is weakest, where skin contact occurs, and whether safer cleaning tools, closed containers, local exhaust ventilation, or lower-toxicity cleaning products can be introduced.

## Sources

	Name of document / Author & publication	URL	Comments
1.	Solvent Substitution Information Brief / U.S. Environmental Protection Agency (EPA), 2022	<a href="https://www.epa.gov/system/files/documents/2022-08/TRI_SolventSubstitution.pdf">https://www.epa.gov/system/files/documents/2022-08/TRI_SolventSubstitution.pdf</a>	Useful for safer alternatives to toluene and other solvents, including water-based and low-VOC cleaning systems.
2.	Investigating the General Effects of Different Types of Toluene Exposure on the Health of Workers: An Integrative Review of the Literature / Ahmed Mohsen Abbas El-Hagrasy et al., BMJ Public Health (2025)	<a href="https://pmc.ncbi.nlm.nih.gov/articles/PMC11222140/">https://pmc.ncbi.nlm.nih.gov/articles/PMC11222140/</a>	Study examining occupational solvent exposure, including toluene, and possible associations with bladder cancer risk in workers.
3.	Occupational Exposure to Solvents and Bladder Cancer: A	<a href="https://pmc.ncbi.nlm.nih.gov/articles/PMC11843485/">https://pmc.ncbi.nlm.nih.gov/articles/PMC11843485/</a>	Useful for chronic, short-term, and long-term occupational health effects of toluene exposure, including neurological, respiratory, cardiovascular, and

	Population-Based Case-Control Study in Nordic Countries / K. Hadkhale et al., International Journal of Cancer (2017)		genotoxic effects. Also discusses PPE, ventilation, and exposure limits.
4.	ToxFAQs™ for Toluene / Agency for Toxic Substances and Disease Registry (ATSDR), CDC	<a href="https://wwwn.cdc.gov/TS/SP/ToxFAQs/ToxFAQsDetails.aspx?faqid=160&amp;toxid=29&amp;">https://wwwn.cdc.gov/TS/SP/ToxFAQs/ToxFAQsDetails.aspx?faqid=160&amp;toxid=29&amp;</a>	Useful for short-term and long-term health effects, target organs, and reproductive toxicity.
5.	California Code of Regulations, Title 8, Section 5155: Airborne Contaminants / California Division of Occupational Safety and Health (Cal/OSHA)	<a href="https://www.dir.ca.gov/title8/5155.html">https://www.dir.ca.gov/title8/5155.html</a>	Useful for occupational exposure limits.
6.	NIOSH Pocket Guide to Chemical Hazards: Toluene / National Institute for Occupational Safety and Health (NIOSH), CDC	<a href="https://www.cdc.gov/niosh/npg/npgd0619.html">https://www.cdc.gov/niosh/npg/npgd0619.html</a>	Useful for exposure limits, symptoms, exposure routes, and respirator recommendations.
7.	OSHA Annotated Table Z-2 / Occupational Safety and Health Administration (OSHA)	<a href="https://www.osha.gov/annotated-pels/table-z-2">https://www.osha.gov/annotated-pels/table-z-2</a>	Useful for OSHA permissible exposure limits for toluene.
8.	Toluene Fact Sheet / California Proposition 65	<a href="https://www.p65warnings.ca.gov/fact-sheets/toluene">https://www.p65warnings.ca.gov/fact-sheets/toluene</a>	Useful for reproductive toxicity information and a more in-depth study can be conducted because MEC has many female employees.
9.	Reducing Chemical Exposure in a Chinese Electronics Factory: A TenSquared Case Study / Social Accountability International (SAI), TenSquared Program	<a href="https://sa-intl.org/resources/tensquared-case-studies/reducing-chemical-exposure-in-a-chinese-electronics-factory-tensquared-case-study/">https://sa-intl.org/resources/tensquared-case-studies/reducing-chemical-exposure-in-a-chinese-electronics-factory-tensquared-case-study/</a>	Useful case study showing successful reduction of worker chemical exposure in an electronics factory through ventilation improvements, PPE access, worker training, SDS management, and elimination of direct skin contact with chemicals.

### **3. Tinning and Soldering - lead-free solder**

#### **Chemical Description**

Lead-free solder is a metal alloy commonly composed of tin, silver, and copper, often combined with a rosin-based flux core used to facilitate metal bonding during soldering processes.<sup>1</sup> During heating, the solder itself may generate metal oxide fumes, while the rosin flux decomposes into airborne irritants and sensitizers that pose occupational exposure risks.<sup>23</sup>

#### **Exposure Routes**

The primary route of occupational exposure is inhalation of fumes generated during soldering, particularly from the thermal decomposition of rosin flux and metal particulates.<sup>6</sup> The secondary exposure occurs through dermal contact with molten solder or residues, as well as eye exposure to irritating fumes.<sup>5</sup> Ingestion is also a route of exposure. Usually, in situations where the working environment is poorly controlled, contaminants are brought into the body through the hand-to-mouth route.<sup>7</sup> In the MEC facility, where ventilation has been reported to be inadequate, workers rely on basic PPE like surgical masks, which do not protect against fumes and increase cumulative inhalation of airborne contaminants.

#### **Short-Term Health Effects**

Short-term exposure to soldering fumes can irritate the nose, throat, and respiratory tract.

Workers may experience symptoms such as coughing, throat discomfort, eye inflammation, or overall breathing difficulties. Skin contact with soldering materials or residual soldering flux can also cause some workers to have mild irritation reactions.<sup>57</sup> These effects are more likely to occur when repetitive soldering operations are carried out, when workers place their faces directly above the fumes, or when ventilation is poor. In the IOHSAD's report, it was mentioned

that workers experienced symptoms such as headache, coughing, breathing difficulties, red eyes, chest pain, and fatigue easily. These symptoms are consistent with exposure to soldering fumes and other air pollutants, especially in poor ventilation conditions. However, without conducting air monitoring and medical assessment, it cannot be completely attributed to the soldering process alone.

### **Long-Term Health Effects and Disease Links**

The main long-term hazard of soldering is respiratory diseases, especially occupational asthma caused by the smoke from rosin or colophony-based flux fumes.<sup>236</sup> Rosin soldering flux is a substance that causes sensitization of the respiratory system, so repeated exposure can lead to allergic reactions in workers. After an allergic reaction occurs, even a low exposure level may trigger symptoms such as wheezing, coughing, chest tightness, or shortness of breath. This is relevant to MEC because cough and difficulty breathing were among the most commonly reported symptoms, and IOHSAD identified fumes, dust, and gases as major workplace concerns.

### **Exposure Limits and Occupational Guidelines**

Lead-free solder does not have a single occupational exposure limit because it is a mixture. Exposure limits are instead evaluated by their main metal components and the fumes they generate, especially tin/tin oxide, silver, and copper.<sup>57</sup> For silver compounds, OSHA chemical data list a time-weighted average limit of 0.01 mg/m<sup>3</sup> for many soluble forms.<sup>8</sup> For tin and copper in fume or dust form, applicable occupational limits are typically in the low mg/m<sup>3</sup> range as 8-hour TWAs in general metal fume guidelines, rather than solder-specific values.<sup>7</sup>

### **Control Measures and Alternatives**

Effective control of exposure during soldering depends primarily on reducing inhalation of fumes at the source. The most important engineering control is local exhaust ventilation, which captures soldering fumes before they reach the worker's breathing zone.<sup>4</sup> However, the report shows that MEC's ventilation is poor, so workers rely on improvised solutions such as personal fans due to the absence of proper exhaust systems.

In soldering environments without proper ventilation, airborne contaminant levels can become elevated, increasing the risk of inhalation exposure.<sup>7</sup> In contrast, the use of well-designed ventilation systems has been shown to significantly reduce fume concentrations and improve overall air quality in the workspace.<sup>4</sup> These findings indicate that ventilation is a critical control measure, not an optional improvement. These control measures are particularly important in the MEC facility because workers have already reported symptoms, and given that workers are on 12-hour shifts, which increases cumulative exposure over time. In addition, workers rely on basic surgical masks that do not protect against soldering fumes or chemical vapors. Therefore, reducing long shift durations and limiting continuous exposure time can help lower cumulative dose and reduce the risk of long-term health effects. Personal protective equipment should be used when engineering controls are not sufficient. However, not all PPE is appropriate. Surgical masks do not protect against chemical fumes, and workers should instead be provided with respiratory protection designed for airborne contaminants, along with gloves and eye protection.<sup>5</sup> For safer alternatives, lead-free solder is already a substitute for traditional lead-containing solder and reduces risks related to lead toxicity. But it does not eliminate exposure risks, as rosin flux fumes are still a hazard.<sup>6</sup> Therefore, further risk reduction should focus on minimizing emissions and exposure. This includes improving ventilation, reducing direct inhalation, and modifying work conditions to limit prolonged exposure.

## Sources

	Name of document / Author & publication	URL	Comments
1.	Assessing the replacement of lead in solders: effects on resource use and human health / C.M.V.B. Almeida, M.A. Madureira, S.H. Bonilla, B.F. Giannetti. Journal of Cleaner Production (2013)	<a href="https://www.sciencedirect.com/science/article/pii/S0959652612004088?_cf_chl_tk=QFR3dFY74EtOf9zI47pv7sBIzYK5WAAkd3F4nGDMf2I-1777927702-1.0.1.1-BxJABUAKY52KDTMGsa_4bf7qlFsTOxQ_zodXy3R2Yu8">https://www.sciencedirect.com/science/article/pii/S0959652612004088?_cf_chl_tk=QFR3dFY74EtOf9zI47pv7sBIzYK5WAAkd3F4nGDMf2I-1777927702-1.0.1.1-BxJABUAKY52KDTMGsa_4bf7qlFsTOxQ_zodXy3R2Yu8</a>	Useful for explaining why lead-free solder was adopted as a substitute for traditional tin-lead solder. The article discusses worker exposure to lead fumes, environmental concerns, and compares lead-containing and lead-free solder. It is useful for the “Chemical Description,” “Long-Term Health Effects,” and “Safer Alternatives” sections. The paper also explains that lead-free solder still produces occupational exposure risks from fumes and particulate matter during soldering.
2.	Occupational asthma in a factory making flux-cored solder containing colophony / P. Sherwood Burge, Geraldine Edge, Rosemarie Hawkins, Vanessa White, A.J. Newman Taylor. Thorax (1981)	<a href="https://pmc.ncbi.nlm.nih.gov/articles/PMC471823/">https://pmc.ncbi.nlm.nih.gov/articles/PMC471823/</a>	The study found workers exposed to colophony/rosin solder fumes experienced work-related wheezing, breathlessness, rhinitis, headaches, and reduced lung function. It also showed occupational asthma prevalence increased with exposure level.
3.	Colophony (Solder) / Sherwood Burge, OccupationalAsthma.com	<a href="https://www.occupationalasthma.com/occupational_asthma_causative_agent.aspx?id=82">https://www.occupationalasthma.com/occupational_asthma_causative_agent.aspx?id=82</a>	Useful for disease links. It explains that colophony/rosin solder flux is a common cause of occupational sensitization and occupational asthma, and that solder flux fumes can cause rhinitis, eye irritation, headache, and asthma. It also mentions tip extraction, local exhaust ventilation, respiratory protection, and enclosing areas where fumes are produced.
4.	Soldering fumes: KAC Alarms – case study / Health and Safety Executive (HSE), UK	<a href="https://www.hse.gov.uk/lev/case-studies/soldering-case-study.htm">https://www.hse.gov.uk/lev/case-studies/soldering-case-study.htm</a>	Useful case study for control measures. KAC Alarms improved LEV after a staff member was diagnosed with occupational asthma. New LEV hoods reduced solder fume exposure by 98%. This directly supports recommendations for local exhaust ventilation and worker involvement.
5.	Lead Free, Rosin Free Flux-Cored Solder Wire Health	<a href="https://www.anglia.com/product_guide/solder/cel_he">https://www.anglia.com/product_guide/solder/cel_he</a>	Useful for chemical description, exposure routes, short-term effects, and controls. It states lead-free

	and Safety Data Sheet / Anglia Components Ltd.	<a href="#">alth_safety/lead_free_rosin_free.pdf</a>	solder can contain tin/copper or tin/silver/copper, flux fumes can irritate the nose, throat, lungs, eyes, and skin, and fumes should be extracted away from the worker's breathing zone. It also says rosin-free flux may remove respiratory sensitization risk, but LEV is still needed.
6.	Workplace Exposure to Rosin-based Solder Flux Fume During Hand Soldering / I. Pengelly, J. Groves, A. Simpson, C. Northage. Annals of Occupational Hygiene (1998)	<a href="https://www.sciencedirect.com/science/article/pii/S003487898000325">https://www.sciencedirect.com/science/article/pii/S003487898000325</a>	Useful for workplace exposure assessment and engineering controls. The article explains that inhalation exposure to rosin-based solder flux fumes can cause occupational asthma, eye irritation, respiratory irritation, and dermatitis. It also evaluates local exhaust ventilation systems and states that on-tool tip extraction was one of the most effective control measures.
7.	Soldering Safety Fact Sheet / University of Pennsylvania, Environmental Health and Radiation Safety (EHRS), 2021	<a href="https://ehrs.upenn.edu/sites/default/files/2021-10/2021-10%20Soldering%20Fact%20Sheet.pdf">https://ehrs.upenn.edu/sites/default/files/2021-10/2021-10%20Soldering%20Fact%20Sheet.pdf</a>	Useful for exposure routes, PPE, and controls. It explains that rosin flux smoke contains chemicals and particles irritating to the eyes and the respiratory system. It recommends not placing the face directly in the smoke path, using ventilation, reading SDS, using lead-free solder when possible, and washing hands to prevent hand-to-mouth metal exposure.
8.	Silver, Metal & Soluble Compounds (as Ag) / Occupational Safety and Health Administration (OSHA), Chemical Data	<a href="https://www.osha.gov/chemicaldata/519">https://www.osha.gov/chemicaldata/519</a>	Useful for exposure limits and sampling information for silver compounds, one metal component that may appear in lead-free solder.

## **4. Insertion or Molding - PVC injection**

### **Chemical Description**

PVC(Polyvinyl chloride) is a plastic material used in many industrial and consumer products.<sup>1</sup>

Vinyl chloride is the chemical monomer used to make PVC.<sup>3</sup> For the MEC company, vinyl chloride should be discussed as a PVC-related concern. According to the IOHSAD report, molding work involves heat and a strong burnt-plastic odor. Still, it does not provide air sampling data for vinyl chloride

### **Exposure Routes**

The main route of exposure to vinyl chloride is inhalation. If vinyl chloride or related gases are released during plastic processing, it is likely that workers will inhale their vapor or fumes. If workers come into contact with hot plastics, residues, or contaminated surfaces, there may also be cases of skin and eye contact.<sup>12</sup> The possibility of ingestion is relatively low, but if workers eat or drink without washing their hands, they may ingest it through hand-to-mouth contact.<sup>1</sup> In MEC, IOHSAD reported that workers in the molding process experience heat and a strong odor that smells like burnt plastic. This supports treating PVC-related fumes as a potential exposure concern in this process, even though vinyl chloride itself was not directly measured in the report.

### **Short-Term Health Effects**

Short-term exposure concerns in PVC injection are inhalation of heated plastic fumes, VOCs, and other thermal degradation products. If vinyl chloride is present, acute inhalation exposure may affect the respiratory system and central nervous system, causing symptoms such as

headache, dizziness, nausea, fatigue, weakness, confusion, and respiratory irritation. At very high concentrations, vinyl chloride can cause more serious central nervous system depression.<sup>12</sup>

From the MEC report, workers have already reported symptoms such as headache, dizziness, coughing, and difficulty breathing. These symptoms overlap with the common effects caused by inhaling chemical fumes. However, since there is no mention of air monitoring in the report, it is impossible to determine whether these symptoms are attributed to vinyl chloride. Instead, they support the need to investigate PVC-related fumes and improve ventilation in the molding area.

### **Long-Term Health Effects and Disease Links**

Long-term health effects of PVC injection depend on which chemicals are actually released during heating.<sup>1-3</sup> Vinyl chloride is a known human carcinogen and the monomer used to make PVC.<sup>1-3</sup> However, for MEC, vinyl chloride exposure has not been directly measured, so these effects should be presented as potential concerns.

Long-term exposure to vinyl chloride suggest that the evidence supports significant liver toxicity and cancer risk.<sup>1-3</sup> Moreover, the findings could indicate that hepatic angiosarcoma, a rare liver cancer, has been identified among workers exposed to vinyl chloride in PVC production.<sup>4</sup>

Furthermore, the significant evidence suggest that vinyl chloride appears associated with hepatocellular carcinoma, and the results could indicate possible cancers of the brain, lung, skin, and hematopoietic system.<sup>1-3</sup> In light of these findings, the data might indicate that chronic exposure could affect the liver, immune system, and nervous system, and may contribute to peripheral neuropathy.<sup>12</sup> Exposure links liver, immune, and nervous damage. The significant findings suggest that vinyl chloride disease appears associated with Raynaud-like symptoms, scleroderma-like skin changes, acro-osteolysis, and other skin or connective tissue effects.<sup>7-9</sup>

A major occupational disease case study is from the history of vinyl chloride regulation. In the 1970s, rare liver cancers were identified among workers exposed to vinyl chloride in PVC production.<sup>13</sup> Worker health surveillance and union reporting of these cancer clusters played a key role in bringing the problem to regulators' attention and prompting investigation.<sup>23</sup> This evidence led OSHA to sharply reduce the workplace exposure limit from 500 ppm to 1 ppm.<sup>3</sup> Evidence shows that vinyl chloride regulation changed exposure limits. However, the IOHSAD report for MEC may indicate that the findings include health concerns such as respiratory complaints, pneumonia, tuberculosis, ovarian cysts, myoma, miscarriage, and other reproductive health issues among workers. These conditions might suggest that the evidence could demonstrate that claims of causation by vinyl chloride require air monitoring or medical investigation. The key findings may indicate that the combination of molding work, heat, strong burnt-plastic odor, respiratory symptoms, and inadequate ventilation could support that further environmental monitoring and health surveillance appear necessary.

### **Exposure Limits and Occupational Guidelines**

Vinyl chloride has strict occupational exposure limits because it is a confirmed human carcinogen.<sup>12</sup> For the federal OSHA standard of vinyl chloride, no employee may be exposed to concentrations greater than 1 ppm as an 8-hour time-weighted average.<sup>2</sup> In addition, short-term concentrations are not allowed to exceed 5 ppm when averaged over any period not exceeding 15 minutes.<sup>2</sup> Cal/OSHA has an exposure limit of 1 ppm as an 8-hour TWA and 5 ppm over any 15 minutes.<sup>3</sup> NIOSH classifies vinyl chloride as a potential occupational carcinogen and recommends that exposures be reduced to the lowest feasible concentration. It also has the 1 ppm 8-hour TWA and 5 ppm 15-minute ceiling used in regulatory standards.<sup>4</sup>

### **Control Measures and Alternatives**

The priority control is to confirm the airborne contaminants in the molding area. MEC can indicate the need to conduct air monitoring during molding, especially when workers report burnt-plastic odors, visible fumes, or heat-related emissions. The monitoring should include vinyl chloride if PVC is suspected, but it might also indicate the need for broader VOCs and PVC thermal degradation products because vinyl chloride exposure has not been confirmed.<sup>12</sup> Given that the evidence demonstrates these risks, the significant findings could suggest that engineering controls appear essential to address the identified hazards. Monitoring shows controls needed. Molding machines should be enclosed where feasible, and local exhaust ventilation should be used to capture fumes at the source. Temperature control might indicate that overheated plastics are likely to significantly increase fume generation.<sup>12</sup> IOHSAD reported heat and a strong burnt-plastic odor in the molding process, which makes ventilation and temperature control especially important in this section.

Worker relevance is also important. MEC workers reported symptoms such as headache, dizziness, coughing, and breathing difficulties during chemical use, and the ventilation in the work area was insufficient. This indicates that the current control measures may not be sufficient to prevent inhalation exposure. Moreover, the surgical masks issued by MEC cannot protect against gases or chemical fumes. It is necessary to provide workers with appropriate respiratory protection, gloves, and eye protection, and to train them on chemical hazards and the correct use of PPE.<sup>23</sup>

For safer alternatives, the best strategy is to reduce or replace PVC when technically feasible. Taiwan has provided an example of policy-level PVC substitution. Since July 1, 2023, Taiwan has restricted the production, import, and sale of PVC food packaging to reduce environmental

and health risks.<sup>5</sup> This is different from the molding process of electronic products, but it shows that there is a way to reduce the use of PVC in certain product categories.

A practical substitution case is Kaiser Permanente, which replaced PVC- and DEHP-containing intravenous infusion equipment with safer alternatives. Kaiser Permanente agreed to purchase 100% PVC-free and DEHP-free intravenous infusion solution bags. Therefore, when safer materials are available, procurement of PVC-free products is possible.<sup>6</sup> For MEC, a similar approach is to use safer materials, such as thermoplastic elastomers, thermoplastic polyolefins, silicone, or other non-PVC materials, which can be used to replace PVC components. These alternatives may reduce concerns related to PVC and vinyl chloride-related hazards, though each alternative should still be evaluated for its own health, safety, and performance profile. However, if PVC cannot be replaced immediately, exposure reduction should focus on enclosed molding systems, local exhaust ventilation, strict temperature control, routine air monitoring, and shorter continuous exposure periods.<sup>123</sup>

## Sources

	Name of document / Author & publication	URL	Comments
1.	Toxicological Profile for Vinyl Chloride / Agency for Toxic Substances and Disease Registry (ATSDR), CDC, 2024	<a href="https://www.ncbi.nlm.nih.gov/books/NBK601954/">https://www.ncbi.nlm.nih.gov/books/NBK601954/</a>	Useful for chemical description, exposure routes, short-term/long-term health effects, and disease links. It explains vinyl chloride is used to produce PVC, workers are mainly exposed by inhalation, and major health concerns include liver toxicity, neurological effects, immune effects, developmental effects, and cancer.
2.	Vinyl Chloride and the Workplace / Communications Workers of America (CWA)	<a href="https://cwa-union.org/national-issues/health-and-safety/health-and-safety-factsheets/vinyl-chloride-and-workplace">https://cwa-union.org/national-issues/health-and-safety/health-and-safety-factsheets/vinyl-chloride-and-workplace</a>	Useful worker-centered source. It explains vinyl chloride workplace risks, symptoms, disease links, and the importance of worker protections.

3.	Vinyl Chloride (Chloroethylene) Chemical Data / Occupational Safety and Health Administration (OSHA)	<a href="https://www.osha.gov/chemicaldata/566">https://www.osha.gov/chemicaldata/566</a>	Useful for occupational exposure limits and regulatory guidance.
4.	Exposure to Sub-Parts Per Million Levels of Vinyl Chloride Monomer Is Associated with Liver Injury / Matthew C. Cave et al., Hepatology Communications (2018)	<a href="https://journals.lww.com/hepcomm/fulltext/2018/03000/exposure_to_sub_parts_per_million_levels_of_vinyl.2.aspx">https://journals.lww.com/hepcomm/fulltext/2018/03000/exposure_to_sub_parts_per_million_levels_of_vinyl.2.aspx</a>	Useful for long-term health effects and disease links. This study supports the point that even low-level vinyl chloride exposure may be associated with liver injury. Explaining why monitoring is needed even when exposure levels may appear low.
5.	Taiwan Bans Food Packaging Containing Polyvinyl Chloride (PVC) / NYC Food Policy Center, Hunter College	<a href="https://www.nycfoodpolicy.org/food-policy-snapshot-taiwan-pvc-ban/">https://www.nycfoodpolicy.org/food-policy-snapshot-taiwan-pvc-ban/</a>	Useful for policy-level safer alternative/substitution discussion. It shows Taiwan restricted PVC food packaging starting July 1, 2023 because of health and environmental concerns.
6.	The Long, Winding Road to Market Reform: A Case Study of a Phthalate / Ted Schettler, Science and Environmental Health Network (SEHN), 2024	<a href="https://www.sehn.org/sehn/2024/7/19/the-long-winding-road-to-market-reform-a-case-study-of-a-phthalate">https://www.sehn.org/sehn/2024/7/19/the-long-winding-road-to-market-reform-a-case-study-of-a-phthalate</a>	Useful case study for PVC/DEHP substitution. It discusses pressure to replace PVC/DEHP medical devices and describes Baxter's non-PVC, DEHP-free IV solution containers. This can support the point that PVC-free alternatives are possible when safer materials are available.
7.	<b>Vinyl Chloride: A Case Study of Data Suppression and Misrepresentation</b> / Jennifer Beth Sass, Barry Castleman, and David Wallinga, <i>Environmental Health Perspectives</i> (2005)	<a href="https://pmc.ncbi.nlm.nih.gov/articles/PMC1257639/">https://pmc.ncbi.nlm.nih.gov/articles/PMC1257639/</a>	Useful case study for vinyl chloride regulation and disease links. It explains that rare liver cancers were identified among vinyl chloride workers and that OSHA reduced the workplace exposure limit from 500 ppm to 1 ppm after worker cancer evidence became public.
8.	<b>Public Health Risks, Dermatological Manifestations, and Environmental Justice Associated With Vinyl Chloride Exposure: Narrative Review</b> / Rachel S. Goodman, Lavanya Mittal, and Eva Rawlings Parker, <i>JMIR Dermatology</i> (2023)	<a href="https://pmc.ncbi.nlm.nih.gov/articles/PMC10514763/pdf/derma_v6i1e48998.pdf">https://pmc.ncbi.nlm.nih.gov/articles/PMC10514763/pdf/derma_v6i1e48998.pdf</a>	Useful for long-term health effects and disease links. It summarizes acute symptoms such as respiratory irritation, headache, nausea, dizziness, fatigue, weakness, and confusion, and long-term effects including hepatic angiosarcoma, hepatocellular carcinoma, peripheral neuropathy, immune disorders, Raynaud disease, sclerodermatous skin changes, acro-osteolysis, and skin malignancies.

9.	<b>Epidemiological Studies of Vinyl Chloride Health Effects in the United States</b> / Henry Falk and Richard J. Waxweiler, <i>Proceedings of the Royal Society of Medicine</i> (1976)	<a href="https://pmc.ncbi.nlm.nih.gov/articles/PMC1864489/">https://pmc.ncbi.nlm.nih.gov/articles/PMC1864489/</a>	Useful historical epidemiology source. It reports early U.S. epidemiological findings on vinyl chloride workers, including known cases of hepatic angiosarcoma among polymerization workers and concern about respiratory system cancer in PVC polymerization plant cohorts. Useful for disease links and occupational cancer history.
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## **5. Recovery and varnishing - Varnish(Xylene)**

### **Chemical Description**

Xylene is a hydrocarbon solvent commonly used in varnish, paint, lacquer, adhesive, and coating processes.<sup>1</sup> In industrial settings, it is usually present as a mixture of isomers, including o-xylene, m-xylene, and p-xylene. Commercial mixed xylene may also contain ethylbenzene.<sup>3</sup> In varnishing processes, xylene is useful because it can dissolve resins and help coatings spread and dry properly.

### **Exposure Routes**

The primary route of exposure to xylene is inhalation. During varnishing, spraying, or brushing, coatings can release vapors into the air, which workers may inhale, particularly when ventilation is insufficient.<sup>1</sup> Dermal exposure is also common when workers handle liquid varnish, cleaning solvents, or contaminated surfaces.<sup>4</sup> Xylene can penetrate the skin due to its lipophilic properties. Eye exposure may occur through splashes or vapor irritation. Ingestion is less common but can occur when workers eat without washing their hands.<sup>1</sup>

### **Short-Term Health Effects**

Short-term exposure to xylene mainly affects the central nervous system, respiratory system, skin, and eyes. Workers who inhale xylene vapors may experience symptoms such as headache, dizziness, nausea, fatigue, blurred vision, and lack of concentration. <sup>1</sup> At higher concentrations, symptoms such as irritation of the nasal and pharyngeal areas, coughing, wheezing, decreased coordination, slower reaction time, and imbalance may also occur. <sup>4</sup> Xylene can also irritate the eyes and skin. Direct or repeated skin contact may cause dryness, redness, rashes, or dermatitis because xylene removes the natural protective oils of the skin. <sup>4</sup>

### **Long-Term Health Effects and Disease Links**

Long-term or repeated exposure to xylene mainly affects the nervous system. Repeated exposure can damage attention, memory, vision, and muscle coordination.<sup>1</sup> Some studies on repeated exposure to organic solvents indicate that long-term neurological symptoms may occur, including fatigue, poor coordination, lack of concentration, memory problems, and mood changes.<sup>4</sup>

Xylene also affects the liver and kidneys at high exposure levels.<sup>4</sup> Because xylene is often used in solvent mixtures, workers in real workplace settings may be exposed to multiple solvents at the same time. This makes it difficult to attribute symptoms to xylene alone. Xylene itself is not currently classified as a known human carcinogen. EPA classifies mixed xylenes as not classifiable as to human carcinogenicity.<sup>3</sup> Toxicological reviews have also found no clear indication of genetic toxicity or carcinogenesis for xylene.<sup>5</sup> Some studies of mixed solvent exposure have reported associations with cancers such as lymphoma and leukemia, but these findings are difficult to apply specifically to xylene because workers may also be exposed to other chemicals, including known carcinogens such as benzene.<sup>5</sup> Therefore, it is more accurate to describe xylene as a solvent with neurological, respiratory, skin, liver, kidney, hearing, and possible reproductive concerns, rather than as a confirmed human carcinogen.

### **Exposure Limits and Occupational Guidelines**

OSHA sets a Permissible Exposure Limit of 100 ppm as an 8-hour time-weighted average. NIOSH recommends a 100 ppm as a TWA and a short-term exposure limit of 150 ppm, not to be exceeded during any 15-minute work period. ACGIH lists a TLV of 100 ppm as an 8-hour TWA and 150 ppm as a STEL.<sup>1</sup>

### **Control Measures and Alternatives**

Controlling airborne vapors suggests that engineering controls should be the main priority for reducing xylene exposure during varnishing operations. Moreover, local exhaust ventilation should be used to capture vapors at the source, particularly in spraying or coating operations.<sup>4</sup> Furthermore, containers should be covered when possible, and work processes may benefit from isolation, enclosure, or automation where feasible.<sup>4</sup> In light of these concerns, the risk at MEC is particularly concerning, given that the IOHSAD report describes inadequate ventilation, long 12-hour shifts, and reliance on limited PPE. The reported facility-wide symptoms, including headache, cough, difficulty breathing, itchy skin, chest pain, fatigue, forgetfulness, red eyes, insomnia, and skin eruptions or allergies, are consistent with possible exposure to solvent vapors such as xylene. However, these symptoms should not be interpreted as proof that xylene alone caused them, given that workers are exposed to multiple chemicals and workplace hazards. Additionally, personal protective equipment should be used when engineering controls are not sufficient. Surgical or cotton masks are inadequate for organic solvent vapors. Workers should be provided with appropriate respirators with organic vapor cartridges when needed.<sup>1 4</sup> Chemical-resistant gloves and eye protection are also essential because these measures help reduce inhalation, dermal, and eye exposure. Additionally, personal protective equipment should be used when engineering controls are not sufficient. Surgical or cotton masks are inadequate for organic solvent vapors. Workers should be provided with appropriate respirators with organic vapor cartridges when needed. Chemical-resistant gloves and eye protection are also essential because these measures help reduce inhalation, dermal, and eye exposure.<sup>1 4</sup> For safer alternatives, one way is switching from solvent-based coatings to water-based, low-VOC, or non-flammable coating systems. The findings from hardwood floor finishing show that water-borne products and very-low-VOC solvent-borne products can reduce harmful solvent

vapor exposure.<sup>6</sup> Furthermore, the Smith & Wesson wood finishing process suggests that replacing a VOC lacquer containing xylene with a carnauba wax-based finishing system is a feasible industrial substitution. Given that the original lacquer contained 26% xylene along with other solvents, the replacement eliminated VOC lacquer constituents, including xylene, n-butanol, MIBK, MEK, toluene, acetone, and isopropanol. The substitution also reduced hazardous waste costs and allowed old spray equipment to be shut down.<sup>7</sup> Additionally, the Franklin Paint Company case shows that solvent substitution in industrial coating and paint settings is broadly feasible. The company eliminated approximately 50,000 pounds of xylene and 500,000 pounds of toluene annually while increasing overall production.<sup>9</sup> In light of these findings, replacing xylene-based solvent systems appears technically feasible, though it may require reformulation, supplier collaboration, product testing, and process adjustment.<sup>9</sup> Nevertheless, the VietAID hardwood floor finishing case shows that community-based outreach and worker engagement can support safer substitution. Evidence from the case shows that a community-university partnership reduced hazards from flammable, high-VOC products. Moreover, the campaign promoted non-flammable, low-VOC, and water-borne products, provided multilingual safety outreach and training, and contributed to broader policy changes restricting lacquer sealers in wood floor finishing.<sup>6</sup> Thus, the key results from this case indicate that safer products are more likely to be adopted when workers receive training, understand the health risks, and have practical support for changing work practices. Notwithstanding these findings, the varnishing process at MEC may present significant solvent exposure risks due to the use of xylene-containing products, inadequate ventilation, long shifts, and insufficient PPE. These risks are preventable. Furthermore, the findings from industrial and community-based case studies suggest that substitution with water-based, low-VOC, or less hazardous coating systems

is a feasible way to reduce risk. In light of these results, combining improved ventilation, appropriate PPE, and worker training can support meaningful reductions in exposure and improve worker health protection.

## Sources

	Name of document / Author & publication	URL	Comments
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2.	ToxFAQs™ for Xylene / Agency for Toxic Substances and Disease Registry (ATSDR), CDC	<a href="https://wwwn.cdc.gov/TSP/ToxFAQs/ToxFAQsDetails.aspx?faqid=295&amp;toxid=53">https://wwwn.cdc.gov/TSP/ToxFAQs/ToxFAQsDetails.aspx?faqid=295&amp;toxid=53</a>	Useful for short-term and long-term health effects.
3.	Xylenes / U.S. Environmental Protection Agency (EPA), 2016	<a href="https://www.epa.gov/sites/default/files/2016-09/documents/xylenes.pdf">https://www.epa.gov/sites/default/files/2016-09/documents/xylenes.pdf</a>	Useful for safety recommendations, ventilation, gloves, respirators, and safer work practices.
4.	Xylene / California Department of Public Health, HESIS	<a href="https://www.cdph.ca.gov/Programs/CCDCPHP/DEODC/OHB/HESIS/CDPH%20Document%20Library/xylene.pdf">https://www.cdph.ca.gov/Programs/CCDCPHP/DEODC/OHB/HESIS/CDPH%20Document%20Library/xylene.pdf</a>	Useful detailed toxicology source for exposure effects and workplace exposure discussion.
5.	Xylene / National Research Council, Emergency and Continuous Exposure Limits for Selected Airborne Contaminants, NCBI Bookshelf	<a href="https://www.ncbi.nlm.nih.gov/books/NBK208297/">https://www.ncbi.nlm.nih.gov/books/NBK208297/</a>	Useful case study for safer alternatives, worker outreach, and low-VOC or water-borne product substitution.
6.	Results of a Community-University Partnership to Reduce Deadly Hazards in Hardwood Floor Finishing / VietAID	<a href="https://vietaid.org/2012/05/26/results-of-a-community-university-partnership-to-reduce-deadly-hazards-in-hardwood-floor-finishing/">https://vietaid.org/2012/05/26/results-of-a-community-university-partnership-to-reduce-deadly-hazards-in-hardwood-floor-finishing/</a>	Useful case study for replacing xylene-containing VOC lacquer with a lower-hazard finishing system.
7.	VOC Lacquer Replacement for Wood Finishing / Toxics Use Reduction Institute (TURI), University of Massachusetts Lowell	<a href="https://www.turi.org/publications/voc-lacquer-replacement-for-wood-finishing/">https://www.turi.org/publications/voc-lacquer-replacement-for-wood-finishing/</a>	Useful for OSHA exposure limit comparison.
8.	OSHA Annotated PELs / Occupational Safety and Health Administration (OSHA)	<a href="https://www.osha.gov/annotated-pels">https://www.osha.gov/annotated-pels</a>	

9.	Franklin Paint Company: Toxics Use Reduction and an Integrated Contingency Plan / Massachusetts Office of Technical Assistance and Technology (OTA), 2015	<a href="https://www.mass.gov/doc/franklin-paint-company-case-study/download">https://www.mass.gov/doc/franklin-paint-company-case-study/download</a>	Useful case study for safer alternatives and solvent substitution. It substituted acetone for the xylene-toluene mixture and also worked with suppliers to reformulate products.
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## 6. Marking - H-1 hardener

### **Chemical Description**

H-1 hardener is a solvent-based hardener used in marking. The H-1 SDS describes it as a polyfunctional aliphatic isocyanate in solvents. Its hazardous ingredients include aliphatic polyisocyanate, xylene, 2-methoxy-1-methylethyl acetate, ethylbenzene, and a small amount of hexamethylene diisocyanate (HDI).<sup>1</sup> Therefore, H-1 hardener should be treated as a chemical mixture, with risks from both organic solvents and isocyanate-containing components.

### **Short-Term Health Effects**

Short-term exposure to H-1 hardener may have effects on the respiratory system, skin, eyes, and central nervous system. H-1 SDS indicates that exposure to solvent vapors above the occupational standard may cause effects on the mucous membranes, respiratory system, kidneys, liver, and central nervous system. The main symptoms may include headache, dizziness, fatigue, muscle weakness, sleepiness, and in extreme cases, it may even lead to loss of consciousness.<sup>1</sup> Because H-1 hardener contains isocyanate components, inhalation exposure may also cause coughing, wheezing, chest tightness, and shortness of breath. HDI can irritate the eyes, nose, throat, and lungs.<sup>3</sup> OSHA also identifies isocyanates as occupational chemicals that can cause skin irritation, mucous membrane irritation, chest tightness, cough, wheezing, and shortness of breath.<sup>4</sup>

Skin and eye contact are also important exposure concerns. Repeated or prolonged skin contact may remove natural oils from the skin, causing non-allergic contact dermatitis and possible absorption through the skin. Eye splashes may cause severe burning pain.<sup>1</sup> Therefore, these

short-term effects show the need for appropriate ventilation, respiratory protection, gloves, and eye protection during H-1 hardener use.

### **Long-Term Health Effects and Disease Links**

The main long-term health effects are respiratory allergies and occupational asthma. The H-1 SDS indicates that the isocyanate component may cause respiratory irritation and allergic reactions, leading to asthma symptoms, wheezing, and chest tightness. Workers who are allergic may develop asthma symptoms even at exposure levels below the occupational exposure limit, and repeated exposure may lead to permanent respiratory system dysfunction.<sup>1</sup> This is consistent with the findings of the OSHA in the United States and the OEHHA. OSHA believes that isocyanate exposure is associated with occupational asthma, dermatitis, mucosal irritation, allergic pneumonia, and chest tightness.<sup>4</sup> The California Office of Environmental Health Hazard Assessment reports that the vapor of hydrogenated phthalic anhydride isocyanate monomer and multi-isocyanate aerosols based on hydrogenated phthalic anhydride can cause respiratory irritation, allergic reactions, asthma, and long-term lung function decline.<sup>5</sup> Regarding the issue of cancer, the current evidence is relatively limited. The U.S. Environmental Protection Agency has not classified HDI as a carcinogenic substance.<sup>3</sup> Therefore, for the H-1 hardener, the most obvious disease associations are occupational asthma, respiratory allergic reactions, and possible long-term lung function impairment.

### **Exposure Limits and Occupational Guidelines**

There is no single exposure limit for “H-1 hardener” because it is a mixture. For HDI monomer, OEHHA lists an ACGIH TLV-TWA of 0.005 ppm. NIOSH lists 0.005 ppm TWA and a 0.02 ppm short-term ceiling limit. Cal/OSHA has a daily TWA PEL of 0.005 ppm. U.S. OSHA does not

have a specific occupational exposure value for monomeric HDI.<sup>5</sup> For solvent components, the H-1 SDS lists xylene at 100 ml/m<sup>3</sup> / 441 mg/m<sup>3</sup> LTEL and 150 ml/m<sup>3</sup> / 662 mg/m<sup>3</sup> STEL.

Ethylbenzene is listed at 100 ml/m<sup>3</sup> / 441 mg/m<sup>3</sup> LTEL and 125 ml/m<sup>3</sup> / 552 mg/m<sup>3</sup> STEL.<sup>1</sup>

### **Control Measures and Alternatives**

The primary task is to reduce inhalation exposure and skin contact. When using H-1 hardener, ensure good ventilation conditions. It is best to adopt local exhaust ventilation and good general ventilation measures. When H-1 hardener is used, providing appropriate respiratory protection for workers is necessary to avoid inhaling vapors, fumes, or spray mist.<sup>12</sup> H-1 SDS recommends using air-supplied respiratory protection during spray painting operations. For other operations in well-ventilated areas, a respirator combining activated carbon and particulate filters, equipped with gas filter type A and particulate filter type P2, can be used.<sup>1</sup> Wearing respiratory protection equipment should include fit testing, training, a filter replacement schedule, and written respiratory protection procedures. Workers should also wear chemical-resistant gloves, protective eyewear, and protective clothing. H-1 SDS recommends using protective gloves, protective glasses, and anti-static clothing. Remove contaminated clothing and wash skin with soap and water instead of using solvents or thinners.<sup>1</sup> OSHA also recommends using engineering controls, conducting exposure monitoring, providing appropriate gloves, goggles, protective clothing, respiratory protection equipment, training workers, and conducting medical surveillance in cases where there is a possibility of isocyanate exposure.<sup>4</sup>

For safer alternatives, the existing resources have not found a specific case study that directly matches the H-1 hardener. No directly matched source was found showing that the exact H-1 hardener marking process is banned in another country, and no directly matched worker

campaign case study was identified for H-1 hardener or HDI-based marking products. Based on the available information, the strongest recommendations are substitution where feasible, local exhaust ventilation, reduced open handling, appropriate respirators, gloves, eye protection, protective clothing, worker training, exposure monitoring, and early symptom reporting.

## Sources

	Name of document / Author & publication	URL	Comments
1.	H-1 Hardener Safety Data Sheet / Marabu GmbH & Co. KG	<a href="https://www.indpad.com/seguridad%20solventes/marabu/H1%20(SDS)%20EN.pdf">https://www.indpad.com/seguridad%20solventes/marabu/H1%20(SDS)%20EN.pdf</a>	Useful for chemical description, hazardous ingredients, exposure routes, short-term symptoms, PPE, and ventilation recommendations. Identifies H-1 as a polyfunctional aliphatic isocyanate mixture containing xylene, ethylbenzene, and trace HDI.
2.	H1-10 Hardener Safety Data Sheet / Soll Surface Technology	<a href="https://www.osterhaugs.no/wp-content/uploads/2024/01/MS_DS_SOLL-H1-10-Hardener_EN.pdf">https://www.osterhaugs.no/wp-content/uploads/2024/01/MS_DS_SOLL-H1-10-Hardener_EN.pdf</a>	Supports exposure routes, respiratory sensitization, and PPE recommendations.
3.	ToxFAQs™ for Hexamethylene Diisocyanate (HDI) / Agency for Toxic Substances and Disease Registry (ATSDR), CDC	<a href="https://wwwn.cdc.gov/TSP/ToxFAQs/ToxFAQsDetails.aspx?faqid=873&amp;toxid=170">https://wwwn.cdc.gov/TSP/ToxFAQs/ToxFAQsDetails.aspx?faqid=873&amp;toxid=170</a>	Useful for health effects and disease links.
4.	National Emphasis Program for Isocyanates / Occupational Safety and Health Administration (OSHA), CPL 03-00-017	<a href="https://www.osha.gov/sites/default/files/enforcement/directives/CPL_03-00-017.pdf">https://www.osha.gov/sites/default/files/enforcement/directives/CPL_03-00-017.pdf</a>	Recommends engineering controls, exposure monitoring, respiratory protection, worker training, and medical surveillance for isocyanate-exposed workers.
5.	Evidence on the Developmental and Reproductive Toxicity of Hexamethylene Diisocyanate / California Office of Environmental Health Hazard Assessment (OEHHA), 2019	<a href="https://oehha.ca.gov/sites/default/files/media/downloads/crn/hidrel090519.pdf">https://oehha.ca.gov/sites/default/files/media/downloads/crn/hidrel090519.pdf</a>	Useful for long-term health effects and exposure limits.

## **7. Manual putting - benzene**

### **Chemical Description**

Benzene is a volatile, colorless, and highly flammable aromatic hydrocarbon compound, often used as a solvent in industrial production.<sup>12</sup> It is commonly found in petroleum products, fuels, and some industrial solvents.<sup>9</sup> During manual assembly, if petroleum-based adhesives, cleaners, or solvent mixtures are used during assembly, then this substance, benzene, may be present.<sup>6</sup>

### **Exposure Routes**

The main route of occupational exposure to benzene is inhalation. During manual operations, if benzene-containing or petroleum-based solvents, adhesives, or cleaners are used in an open working area and the ventilation is insufficient, workers may inhale vapors. Benzene can also affect workers through skin or eye contact, as pointed out by the Occupational Safety and Health Administration (OSHA) of the United States. Exposure to benzene through inhalation, ingestion, or contact can have an impact on health. Skin contact is also very important in manual operations, as workers may come into direct contact with liquid solvents, adhesives, cleaners, or contaminated surfaces.<sup>7</sup> Ingestion is relatively rare, but it can occur if workers do not wash their hands after handling chemical substances and then eat, drink, or touch their faces.

The manual operation process is particularly concerning because the pollutants generated may be close to the breathing area, and this pollution may persist throughout the long working period.

The relevance of the research on printing workers lies in the fact that it shows that petroleum-based cleaners may contain benzene, and benzene has been detected in air samples from some workplaces.<sup>6</sup>

### **Short-Term Health Effects**

Short-term overexposure to benzene primarily affects the central nervous system and can also irritate the respiratory tract. OSHA states that acute overexposure to high concentrations of benzene may cause breathlessness, irritability, euphoria or giddiness, eye, nose, and respiratory tract irritation, headache, dizziness, nausea, intoxication-like symptoms, convulsions, and loss of consciousness.<sup>2</sup> Furthermore, NIOSH identifies benzene as an inhalation hazard, and its immediate danger to life or health guidance is necessary because high exposures can be dangerous or fatal.<sup>3</sup> Given these effects, reported symptoms such as headache, dizziness, coughing, and difficulty breathing could be consistent with exposure to airborne chemicals, including solvent vapors. Symptoms alone cannot confirm benzene exposure without monitoring data. However, these key symptoms should not be attributed specifically to benzene without exposure monitoring or product ingredient confirmation, and workers may face multiple chemical and physical workplace hazards with overlapping symptom profiles.

### **Long-Term Health Effects and Disease Links**

Long-term exposure to benzene is associated with effects on the blood-forming system. OSHA states that repeated or prolonged exposure to benzene may result in blood disorders ranging from anemia to leukemia, and that some benzene-related blood effects may occur without obvious symptoms.<sup>2</sup> The strongest disease link is leukemia, especially acute myeloid leukemia. The breast cancer meta-analysis also notes that IARC classifies benzene as a Group 1 human carcinogen based on sufficient evidence for leukemia, particularly AML.<sup>7</sup> California Proposition 65 also states that benzene exposure can cause leukemia.<sup>9</sup> Investigative case studies have confirmed that workers who are exposed to benzene in industrial environments for a long time will develop leukemia. The report shows that enterprises are aware of the health risks associated with benzene, but still continue to use benzene, thereby causing serious health problems for the

workers.<sup>45</sup> These cases highlight the importance of strictly controlling exposure and implementing replacement measures.

There is new evidence suggesting that occupational exposure to benzene may be associated with breast cancer. A systematic review and meta-analysis conducted in 2024 revealed a positive correlation between occupational benzene exposure and the risk of breast cancer, especially at higher exposure levels. However, the authors also stated that bias and confounding could not be excluded.<sup>7</sup> Therefore, this evidence should be interpreted cautiously. This point may be relevant to MEC because the workforce is predominantly female, but it should not be presented as proof that benzene exposure at MEC causes breast cancer.

### **Exposure Limits and Occupational Guidelines**

OSHA sets a permissible exposure limit of 1 ppm as an 8-hour time-weighted average and a short-term exposure limit of 5 ppm over 15 minutes.<sup>2</sup> NIOSH recommends an exposure level of 0.1 ppm.<sup>3</sup> Cal/OSHA follows similar standards and emphasizes controlling airborne contaminants to minimize worker exposure.<sup>8</sup>

### **Control Measures and Alternatives**

Reducing exposure to benzene in manual putting processes requires controlling both inhalation and dermal contact. Moreover, engineering controls are the most important layer of protection available. Local exhaust ventilation (LEV) should be used to capture vapors at the source, especially in areas where adhesives or solvents are applied manually.<sup>1</sup> Furthermore, without such controls, worker exposure may present a substantial risk during routine operations. LEV helps capture vapors at the source.

The most effective safer alternative is to make a replacement. Replace petroleum-based products containing benzene or contaminated with benzene with certified benzene-free materials or

formulations with lower toxicity. Studies in industrial environments have shown that even if benzene is not intentionally used, it can still cause exposure due to the contamination of petroleum-based products. This highlights the importance of choosing certified benzene-free materials and adopting safer formulations.<sup>6</sup> Research on small industries such as the printing industry and manual cleaning processes has shown that workers may come into contact with benzene through cleaning agents containing petroleum components. In many cases, workers are unaware of the presence of benzene, and this exposure occurs in poorly ventilated environments without appropriate protective measures.<sup>6</sup>

### Sources

	Name of document / Author & publication	URL	Comments
1.	Benzene – Evaluating Exposure / Occupational Safety and Health Administration (OSHA)	<a href="https://www.osha.gov/benzene/exposure-evaluation">https://www.osha.gov/benzene/exposure-evaluation</a>	Useful for exposure routes, exposure evaluation, sampling, and control measures. OSHA explains that workers in industries using benzene or petroleum products may be exposed, and recommends engineering controls such as hoods, canopies, and proper ventilation.
2.	Substance Safety Data Sheet, Benzene: 1910.1028 App A / Occupational Safety and Health Administration (OSHA)	<a href="https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1028AppA">https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1028AppA</a>	Useful for chemical description, acute health effects, chronic health effects, leukemia risk, and OSHA safety guidance.
3.	Immediately Dangerous to Life or Health Concentrations: Benzene / National Institute for Occupational Safety and Health (NIOSH), CDC	<a href="https://www.cdc.gov/niosh/idlh/71432.html">https://www.cdc.gov/niosh/idlh/71432.html</a>	Useful for exposure limits and emergency exposure concerns.
4.	Benzene and Worker Cancers: “An American Tragedy” / Jim Morris, Chris Hamby, and Ronnie Greene, Center for	<a href="https://publicintegrity.org/environment/benzene-and-worker-cancers-an-american-tragedy/">https://publicintegrity.org/environment/benzene-and-worker-cancers-an-american-tragedy/</a>	Useful investigative case study for disease links and worker cancer history. Explaining how long-term benzene exposure has been connected to worker leukemia cases.

	Public Integrity		
5.	A Dozen Dirty Documents / Center for Public Integrity	<a href="https://publicintegrity.org/environment/a-dozen-dirty-documents/">https://publicintegrity.org/environment/a-dozen-dirty-documents/</a>	Useful case-study source on industry knowledge and benzene risk.
6.	Benzene Exposure Assessment of Printing Workers Treating Petroleum-Based Cleaner in South Korea / Doo-Young Kim, Hyun-Soo Kim, Dae-Sung Lim, and Ki-Youn Kim. Industrial Health (2023)	<a href="https://pmc.ncbi.nlm.nih.gov/articles/PMC10398173/">https://pmc.ncbi.nlm.nih.gov/articles/PMC10398173/</a>	Useful exposure case study. The study found benzene in all 25 petroleum-based cleaning products tested, detected benzene in 3 workplace air samples, and recommends controls such as substitution, isolation/enclosure, ventilation, respirators, gloves, and worker training.
7.	Occupational Exposure to Benzene and Risk of Breast Cancer: Systematic Review and Meta-Analysis / Monireh Sadat Seyyedsalehi, Vincent DeStefano, Darshi Shah, Veer Shah, Mattia Bonetti, and Paolo Boffetta. La Medicina del Lavoro (2024)	<a href="https://pmc.ncbi.nlm.nih.gov/articles/PMC11562665/pdf/MDL-115-34.pdf">https://pmc.ncbi.nlm.nih.gov/articles/PMC11562665/pdf/MDL-115-34.pdf</a>	Useful for disease links. The meta-analysis found a positive association between occupational benzene exposure and increased breast cancer risk, especially at higher exposure levels, but it also states that bias and confounding cannot be excluded. This is relevant to MEC because the workforce is predominantly female, but it should be written cautiously.
8.	California Code of Regulations, Title 8, Section 5155: Airborne Contaminants / California Division of Occupational Safety and Health (Cal/OSHA)	<a href="https://www.dir.ca.gov/titl/e8/5155.html">https://www.dir.ca.gov/titl/e8/5155.html</a>	Useful for Cal/OSHA exposure limits, airborne contaminant control, workplace monitoring, skin notation, and medical surveillance concepts.
9.	Benzene Fact Sheet / California Proposition 65	<a href="https://www.p65warnings.ca.gov/fact-sheets/benzene">https://www.p65warnings.ca.gov/fact-sheets/benzene</a>	Useful for cancer and reproductive toxicity warning information. Good supporting source for benzene as a cancer-related chemical, especially leukemia.

## **1.2 Environmental and Health Surveillance**

Environmental and health surveillance is critical to understand the actual level of chemical exposure in the MEC facility and to detect early signs of work-related illness. Based on IOHSAD findings, workers are exposed to multiple chemicals across different processes, including solvents, lubricants, soldering fumes, varnishes, plastic-related emissions, and adhesives, while ventilation is reported to be inadequate, and workers rely on basic PPE. These conditions suggest that surveillance should be used to collect information, identify high-risk processes, support early intervention, and guide future prevention measures.

### **Environmental Monitoring**

Environmental monitoring should first focus on air sampling in the main production processes where chemical exposure is most likely to occur. Monitoring should be conducted during actual work activities, especially during normal and peak production periods, instead of only during cleaned-up or inspection periods. This is important because MEC workers reportedly work 12-hour shifts, which increases cumulative exposure over time. In addition, many occupational exposure limits are based on 8-hour time-weighted averages, so longer shifts may require more careful interpretation of exposure results.

For crimping, monitoring should focus on petroleum hydrocarbon vapors, oil mist, and aerosol mist from WD-40 or similar lubricants. Since WD-40 may be used as a spray, workers may inhale vapors or fine mist, especially when spraying close to the face or working in poorly ventilated areas. Surface contamination monitoring may also be useful in this area because workers may touch lubricated parts, tools, or work surfaces.

For tinning and soldering, monitoring should focus on soldering fumes, rosin or flux fumes, and metal fumes generated during heating. This is especially important because lead-free solder does not mean hazard-free solder. Even when lead is reduced or removed, workers may still inhale flux fumes and metal particulates. Since soldering is one of the processes that workers are most concerned about, air monitoring in this area would help determine whether symptoms such as coughing, breathing difficulty, headaches, and dizziness are related to inadequate fume control.

For varnishing, monitoring should focus on xylene and other solvent vapors from varnishes or coatings. Xylene exposure can irritate the eyes, nose, throat, and respiratory system, and may also affect the nervous system. Monitoring should be conducted near the worker's breathing zone and in areas where varnish is mixed, applied, or dried.

For insertion and molding processes involving PVC-related materials, monitoring should focus on fumes or emissions generated during heating. Vinyl chloride should only be specifically monitored if product information, SDS documents, or process conditions suggest possible residual vinyl chloride or PVC decomposition concerns. This distinction is important because PVC processing may produce hazardous emissions, but vinyl chloride exposure should not be assumed unless material information or sampling results support it.

For manual putting, adhesive use, or other solvent-related tasks, monitoring should focus on total volatile organic compounds and specific solvent ingredients listed in the safety data sheet. If benzene is listed or suspected in adhesive or solvent products, benzene should be prioritized because of its known hematologic toxicity and carcinogenic risk. However, benzene exposure should not be treated as confirmed unless the SDS, product label, or workplace sampling indicates its presence.

In addition to air monitoring, surface wipe sampling should also be considered in areas where workers directly handle solvents, adhesives, lubricants, flux residues, or contaminated parts. This can help identify dermal exposure and possible contamination on worktables, gloves, tools, or eating/rest areas. Surface contamination results can also show whether current cleaning and hygiene practices are sufficient.

## **Health Surveillance**

Health surveillance should be implemented to detect early symptoms of work-related diseases among workers exposed to these chemicals as early as possible. Moreover, targeted surveillance should be conducted for the specific health impacts caused by each chemical substance used in the production process. This aims to treat workers when they become ill, detect early warning signs, and reduce exposure before more severe diseases occur.

Respiratory health is important to concerns. Workers exposed to soldering fumes, flux fumes, solvent vapors, varnish fumes, and plastic-related emissions should undergo examinations for symptoms such as coughing, shortness of breath, wheezing, chest tightness, throat irritation, and breathing difficulties. For workers in soldering, varnishing, molding, and solvent cleaning areas, pulmonary function tests may be helpful, especially when respiratory symptoms recur.

Then, neurological symptoms should be examined. Since multiple chemicals used at MEC Electronics, including toluene, xylene, petroleum hydrocarbons, and possibly benzene-containing solvents, can affect the central nervous system, regular symptom screening may be helpful.

Regular inquiries should be made to workers about symptoms such as headache, dizziness, fatigue, difficulty concentrating, memory problems, numbness or tingling, sleep problems, and decreased coordination. These symptoms are particularly important because they may be

mistaken for ordinary fatigue, even though they may be related to repeated exposure to solvents or vapors during long working hours. For workers who may be exposed to benzene or benzene-containing products, hematologic surveillance should be conducted. This may include complete blood count tests to observe early changes in white blood cells, red blood cells, or platelets. However, this measure should only be implemented if benzene exposure is confirmed or highly suspected based on safety data sheets, product information, or air monitoring. If abnormal blood test results are found, medical referrals should be made, and a workplace exposure investigation should also be initiated.

Workers with long-term exposure to solvents, particularly those involved in degreasing, cleaning, varnishing, and adhesive-related work, are advised to have liver and kidney function evaluations. Solvents such as toluene and xylene can affect internal organs after repeated exposure, so regular liver and kidney function tests may help detect early health problems. Skin and eye health conditions should also be included in the examination, as workers may directly contact solvents, adhesives, lubricants, varnishes, or flux residues. Symptoms such as redness, itching, rash, dryness, burns, eye irritation, red eyes, tearing, or blurred vision could indicate areas where gloves, eye protection, handwashing, or chemical handling practices are inadequate. Findings show reproductive health needs confidentiality and non-punitive approaches. Moreover, some solvents, including benzene, may be associated with reproductive or developmental problems, so workers may need education about reproductive hazards, safer work arrangements during pregnancy, and medical consultations when necessary. This should not be used to exclude women from work. Instead, it should be used to reduce hazardous exposure for all workers and provide additional protection when reproductive risks are relevant.

## **Worker Symptom Tracking and Follow-Up**

A structured symptom tracking system should be created so workers can report health problems related to chemical exposure more consistently. Moreover, this system should be simple, confidential, and written in a language that workers can understand. These materials helped workers understand exposures, recognize symptoms, and protect themselves.

The symptom checklist should include common symptoms that match the chemical hazards identified in this report, such as headache, dizziness, fatigue, coughing, shortness of breath, chest tightness, red eyes, eye irritation, skin irritation, nausea, difficulty concentrating, forgetfulness, and sleep problems. Workers should also report which process they were working in when symptoms occurred, whether symptoms improved after leaving work, and whether others in the same area experienced similar symptoms. This symptom tracking system should be used to identify patterns rather than assign blame to individual workers.

Tracking symptoms over time can help determine whether interventions are working. If ventilation is improved, safer chemicals are substituted, or better PPE is provided, symptom reports should be reviewed to see whether headaches, dizziness, coughing, and irritation decrease. In this way, IOHSAD could use worker-reported data as part of a practical surveillance and prevention system.

Subsequently, regular testing should be carried out to monitor the changes in their physical conditions over time. The recommended medical monitoring items include conducting lung function tests for workers exposed to fumes or vapors; screening for neurological symptoms for workers exposed to solvents; conducting liver and kidney function tests for workers repeatedly exposed to solvents; and conducting blood tests for workers who have confirmed or suspected

exposure to benzene. For workers who continue to experience symptoms or have abnormal test results, a follow-up assessment by occupational health experts is recommended. Medical monitoring serves to immediately initiate workplace investigations, reduce exposure risks, and, if necessary, transfer employees from high-exposure positions upon detecting abnormal conditions. For example, if multiple employees in the same process report similar symptoms, the company should inspect the ventilation conditions, chemical usage, personal protective equipment, work pace, and exposure duration in that area.

### **Worker Participation and Communication**

Worker participation suggests that the surveillance system could demonstrate significant improvement when built upon direct input from those on the floor. Moreover, workers are often the first to recognize which tasks have the strongest odors, where ventilation appears weakest, and when symptoms emerge during production. Furthermore, the evidence suggests that workers could identify high-risk tasks more reliably than external assessors, given that their daily exposure provides key observational data. In light of these significant findings, control measures might demonstrate greater practical effectiveness when workers are involved in evaluating whether such measures are actually usable.

Worker participation also supports IOHSAD's documentation work. Worker-facing materials should explain what symptoms to look for, when to report them, and what actions should follow. Materials that avoid overly technical language can support more consistent reporting of symptoms such as dizziness or strong odors. Practical messages about avoiding direct inhalation, using proper gloves and respirators, and seeking medical attention when symptoms persist may have a meaningful impact.

Communication shows SDS access matters. Moreover, the evidence suggest that workers could demonstrate stronger hazard awareness when trained on the key parts of an SDS, including hazard statements, exposure routes, first aid measures, and PPE recommendations. Furthermore, the significant findings indicate that training on storage requirements could appear equally critical to overall chemical safety in the facility. Simplified summaries could provide useful support when SDS documents are missing or available only in technical English.

### **Using Surveillance Results for Prevention**

The findings from environmental and health surveillance should guide prevention through the hierarchy of controls. Elimination and substitution should remain the highest priority.

Benzene-containing solvents, high-VOC cleaners, and high-VOC coatings should be replaced with safer alternatives, such as water-based cleaners, low-VOC coatings, or less hazardous lubricants, when feasible. Reducing aerosol spraying or switching to controlled application methods should also be considered when technically feasible. Substitution can reduce exposure risk.

Engineering controls should be the next priority for areas where fumes and vapors are generated.

Soldering, degreasing, varnishing, and adhesive application areas require targeted ventilation installation. General ventilation alone may be insufficient because it may dilute contaminants without removing them from the worker's breathing zone. Local exhaust ventilation is more protective because it captures fumes and vapors near the source before workers inhale them.

Ventilation helps capture fumes at the source.

Administrative controls should also be considered alongside engineering measures. Since MEC workers reportedly work 12-hour shifts, reducing continuous exposure time is important.

Scheduled breaks away from chemical-use areas, task rotation, limits on time in high-exposure tasks, and improved housekeeping could provide additional benefits. However, task rotation should not be used as a substitute for reducing exposure at the source. Task rotation should only supplement source controls.

PPE improvements are also needed, but reliance on PPE alone is not adequate as the only control measure. Cotton masks and surgical masks do not provide sufficient protection against organic solvent vapors, soldering fumes, or many airborne chemical contaminants. Workers should be provided with appropriate respirators, along with fit testing, training, cartridge replacement schedules, gloves, eye protection, and protective clothing. Glove selection depends on the specific chemical used because not all gloves protect against all solvents. PPE selection should match chemical-specific requirements.

## **Conclusion**

The findings from IOHSAD, combined with the analysis of chemical hazards across multiple processes, indicate that workers in the MEC facility are likely experiencing ongoing exposure to hazardous chemicals under conditions of inadequate ventilation, long working hours, and insufficient protective measures.

The reported symptoms among workers, including headaches, dizziness, and respiratory issues, are consistent with known effects of solvent and fume exposure. While specific chemical exposure levels have not been measured, the existing evidence strongly suggests the need for immediate improvements in environmental monitoring, health surveillance, and exposure control.

Implementing a comprehensive surveillance system, along with stronger engineering controls and safer chemical alternatives, is essential to reduce occupational health risks and protect workers in this facility.