

REDUCTION OF FORMALDEHYDE EXPOSURE IN THE WOODWORKING INDUSTRIES

REF-WOOD
SOCIAL PARTNER PROJECT



Project carried out
with the financial support
of the European
Commission

February 2010



Acknowledgement

This project was realised by the European Panel Federation (EPF), the European Confederation of Woodworking Industries (CEI-Bois) and the European Federation of building and woodworkers (EFBWW).

The authors would like to acknowledge the cooperation of the participating companies, workers representatives, industry associations, researchers and government agencies.

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Foreword

The European Panel Federation, EPF, the Confederation of Woodworking Industries, CEI-Bois, and the European Federation of Building and Woodworkers, EFBWW, are aware of the health risks associated with the chemical substance formaldehyde and have therefore been active so that occupational exposure to this substance in the production of wood-based products has been decreasing over decades.

It is the overall goal of the social partners to offer safe occupational conditions for workers while maintaining the technical quality of the products expected by the customers. During the plenary meeting of the EU Social Dialogue Committee Wood that took place on 10 June 2008, CEI-Bois and EFBWW agreed to undertake a joint project 'Reduction of exposure to formaldehyde in the woodworking industries' resulting to this brochure.

This brochure takes into account the legislative context as well as the Social Dialogue discussions between the partners. By focusing on the co-operation and the participation of workers and their representatives concerning the evaluation of the exposure to formaldehyde and finding pathways for better prevention the project fosters social dialogue between the European Social Partner Organisations and their national affiliates.

It is expected that the findings of the project will incite comments and additional information and will lead to an intensive exchange of views about best practices and best solutions on this basis of which a continuation and deepening of the Dialogue could be envisaged. Deepening and further intensifying the Dialogue might lead to commonly agreed solutions with direct effects in the interest of the workers and the industry. We believe that voluntary activities, such as the current REF-Wood project as well as possible future projects, could very effectively support practical prevention activities.

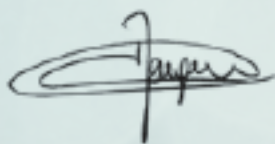
Signed,

For EPF,



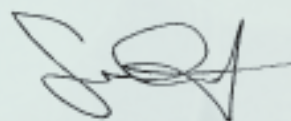
Kris Wijnendaele
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Glossary



AEC	Average exposure concentrations
BfR	German Federal Institute for Risk Assessment
CEI-Bois	European Confederation of Woodworking Industries
ECB	European Chemicals Bureau
EFBWW	European Federation of Building and Woodworkers
EPA	Environmental Protection Agency
EPF	European Panel Federation
EU	European Union
HPLC	High Performance Liquid Chromatography
HSE	Health and Safety Executive
IARC	International Agency for Research on Cancer
INRS	French institute for occupational risk prevention
LVL	Laminated veneer lumber
MDF	Dry process fibreboard, commonly also referred to as Medium Density Fibreboard
MF	Melamine-formaldehyde
mg/m ³	Milligrams per cubic metre of air
MSDS	Material Safety Data Sheet
MUF	Melamine-urea-formaldehyde
NCI	NCI/Hauptmann study
NOAEL	No observable adverse effect level
NPC	Nasopharyngeal cancers
OEL	Occupational Exposure Limits
OSB	Oriented Strand Board
PF	Phenol-formaldehyde
PPE	Personal protective equipment
ppm	Parts per million
SME	Small & medium-sized enterprises
STEL	Short term exposure limit
TWA	Time-weighted average
UF	Urea formaldehyde
UV	Ultra violet
VHI	Association of the German wood-based panel industries
WHO	World Health Organisation

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I. Introduction

1. Scope and purpose of the project

This brochure is a result of a European Social Partner project within the woodworking sector. The overall objectives were to facilitate the exchange of best practices between EU wood-based panel producers, trade unions and other stakeholders from all over Europe, especially small & medium-sized enterprises (SMEs) and to contribute in the short and medium term to reduce the exposure to formaldehyde at work thanks to the acquired knowledge and capacity.

The aim of this project was to collect techniques and technologies for reducing formaldehyde exposure at work as well as to evaluate the possibilities and hindrances to apply the indicative occupational exposure limits that were proposed by the European Commission in 2008.

It was also aimed to select a scientifically validated measurement method and representative workplaces for measuring exposure of the workers. Subsequently, a measurement campaign has been set up in representative¹ companies across five EU Member States aimed at establishing the state of the art exposure to formaldehyde in the main downstream user sector of the chemical industries: the wood-based panel industry, which is the main woodworking subsector using formaldehyde-based resins.

The results of the REF-Wood project are published in this brochure with practical guidelines on best practices that will be disseminated widely within the woodworking sector, in particular the wood-based panels producers and their workers.



2. Participating parties to the project

The EU Social Partner Project "Reduction of Exposure to Formaldehyde in the Woodworking Industries", REF-Wood Project, is an initiative from the European Confederation of Woodworking Industries (CEI-Bois), the European Federation of Building and Woodworkers (EFBWW) and the European Panel Federation (EPF) supported by the European Commission, DG Employment, Social Affairs and Equal Opportunities.

3. Data gathering

The content of this brochure is based on a wide variety of data including:

- ▶ Research and scientific data;
- ▶ Company policies;
- ▶ Information from industry associations;
- ▶ Regulatory requirements;
- ▶ Governmental recommendations.

In addition, a formaldehyde measuring campaign was set up in five representative wood-based panel companies in the European Union.

¹ Five small to medium sized manufacturing enterprises of considerably different ages were selected that are located in France, Germany, Poland, Spain and the UK. Four of the test sites manufacture particleboard and the other site manufactures MDF.

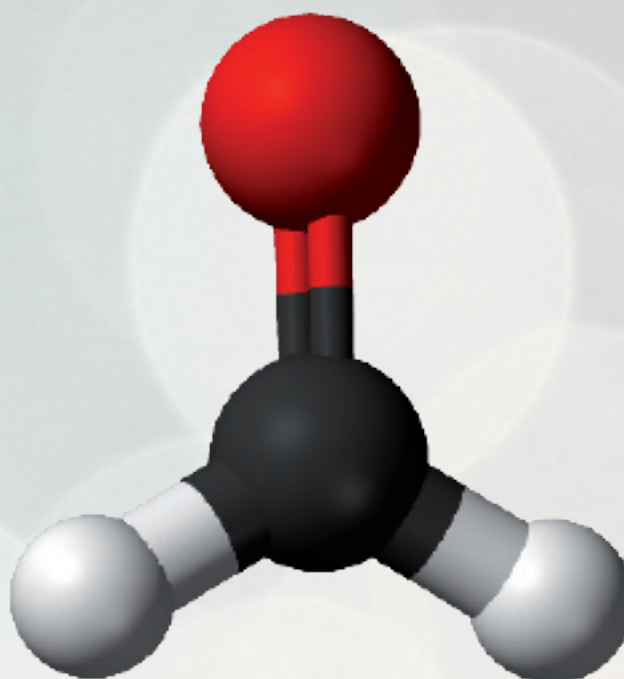
II. Formaldehyde



1. What is formaldehyde?

Formaldehyde is a pungent, colourless gas composed of the elements carbon, hydrogen and oxygen. It is a naturally organic substance that is present all around us. Formaldehyde is made by the human body and occurs naturally in the air that we breathe. It does not accumulate in the environment because it is broken down within a few hours by sunlight or by bacteria present in soil or water. Formaldehyde metabolises quickly so it does not accumulate in the body. For industrial use it is usually sold as a 36-50% solution in water. This solution is known as formalin.

Formaldehyde has been used in the manufacture and composition of industrial products for nearly 150 years. It is a raw material in as many as 85 industries and is used for the production of hundreds of everyday products. Annual worldwide production of formaldehyde is around 21 million tonnes. About half of this is used to make formaldehyde resins. These resins are extremely strong and are used as permanent adhesives in the majority of wood-based panels. The resins can be foamed to make insulation or in castings. Formaldehyde is also used in the textiles industry to make fabrics crease-resistant, and as a preservative in vaccines. Another common use is in embalming human remains. Formaldehyde, of all the aldehydes, works best at preserving human and animal tissues and as a disinfectant.



In October 2007, a study on the "Socio-Economic Benefits of Formaldehyde to the European Union (EU-25) and Norway" was released by FormaCare, quantifying the value of formaldehyde to society and the contribution of the formaldehyde industry to the economies of these countries. The study indicated that "consumers would have to spend an additional € 29.4 billion per year if formaldehyde-based products were replaced by substitute chemicals" and that alternative products are of inferior quality and often of higher cost than the formaldehyde-based products, leading to a pronounced consumer preference for these latter products. It was found that "people use products that contain formaldehyde every day, and that formaldehyde and the products made from it provide an enormous contribution to worldwide economies".

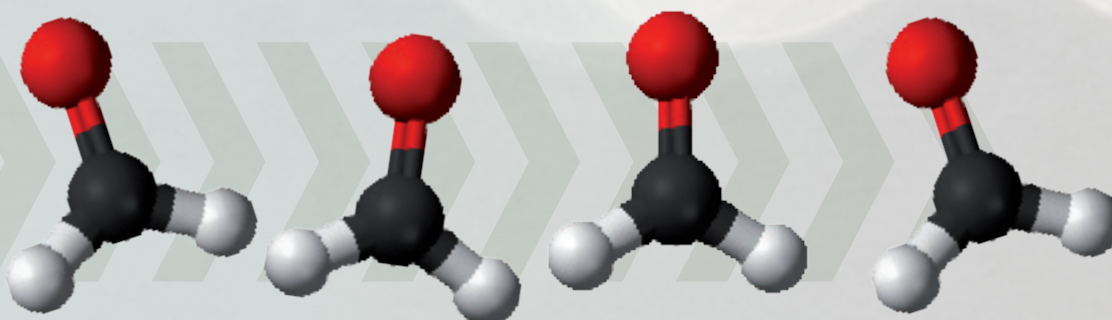


Table 1. Main physicochemical characteristics of formaldehyde

Chemical formula	HCHO
CAS number	50-00-0
Synonyms	Formalin, formic aldehyde, formol, formalith, methanal, methyl aldehyde, methylene glycol
Description	Colourless liquid, pungent odour
Solubility in water	Miscible
Solubility in solvents	Soluble in alcohol, acetone
pH	2.8 – 4.0
Boiling point	- 19°C (1 atm)
Autoignition temperature	424 °C
Lower explosion limit	7 %
Upper explosion limit	73 %
Odour detection limit	0.05 ppm – 1.00 ppm
Concentration representing an immediate danger to life or health	20 ppm (24.6 mg/m ³)
Molar mass	30.03 g/mol
Flash point of aqueous solutions of 37% formaldehyde	
-	without methanol
-	15 % methanol
83 °C (closed cup)	
50 °C (closed cup)	
Air concentration conversion factors (20 °C)	1 ppm = 1.23 mg/m ³
1 mg/m ³ = 0.81 ppm	

Formaldehyde is present in most life forms such as humans, animals, trees, plants etc. All normally functioning cells produce and use formaldehyde people breathe it in and eat it every day.



2. Why the concern over formaldehyde?

In June 2004, the International Agency for Research on Cancer (IARC) recommended that formaldehyde should be regarded as an IARC Group 1 carcinogen. This recommendation is not legally binding. In the preamble to monographs it is explicitly emphasized by the IARC that, "no recommendation is given with regard to regulation or legislation". At European level, the IARC recommendation triggered a review of formaldehyde's existing category 3 classification, the lowest available EU category for suspected carcinogens.

IARC primarily bases its 2004-recommendation on one epidemiological study, the so-called NCI³/Hauptmann (NCI) study, which showed a slight excess in the total number of nasopharyngeal cancers (NPC) among workers exposed to formaldehyde. The NCI underestimated the fact that over half of the NPC cases observed in the NCI study originated from one single plant in the US. This suggests that factors other than formaldehyde exposure may have been at play.

Some chemical compounds in special conditions of use and exposure have been classified by the International Agency for Research on Cancer (IARC) as carcinogenic to humans, without any special regulatory action being taken by national or European authorities, due to the fact that IARC classification is not always relevant for health and safety at work or consumer health protection. Following a meeting on 20-27 October 2009 in Lyon, the IARC concluded that there is sufficient evidence in humans of a causal association of formaldehyde with myeloid leukaemia. IARC doesn't pronounce on dose response relationship and health threshold. Based on a very large amount of technical and scientific data on formaldehyde, the industry has constantly worked over the years to develop a comprehensive scheme of chemical control such that the level of exposure is minimised.

Formaldehyde's use as a component of the resin binder is strictly controlled within the board manufacturing process, and for the most part is handled in closed systems. In board forming and pressing areas extraction systems are used and climate controlled cabins are provided for in many companies. Consequently, in most parts of the production area occupational exposure to formaldehyde in the European wood-based panel industry is far below the levels considered by IARC and well under the applicable exposure limits.

For indoor domestic exposure, the World Health Organisation still recommends an advisory limit of concentration of formaldehyde in domestic indoor air of 0.1 mg/m^3 (for short and long-term exposure) from all sources combined (at this level or below transient sensory effects should be avoided). The WHO is planning an official publication of this advisory limit in March 2010, which will include a toxicological substantiation taking into account the results of the most recent IARC meeting. Comprehensive European indoor air studies confirm that the level of formaldehyde in homes is typically one third of the WHO guideline value.





III. Formaldehyde use in the woodworking industries

1. Formaldehyde and occupational health

A wealth of scientific understanding exists concerning formaldehyde's potential effects on human health. In fact, the health effects of formaldehyde have been under scientific review for several decades by government agencies worldwide, academic institutions, and industry, making formaldehyde one of the most studied chemicals in use today. Based on the extensive amount of data, there is widespread scientific recognition that when formaldehyde is handled and used properly and in accordance with government and industry guidelines, standards and regulations, consumers and workers are appropriately protected against health effects related to formaldehyde.

The IARC has established that at concentrations of less than 0.1 ppm formaldehyde is undetectable by smell. At concentrations from 0.1 ppm to 0.5 ppm, formaldehyde is detectable by smell with some sensitive individuals experiencing slight irritation to the eyes, nose and throat. At levels from 0.5 to 1.0 ppm, formaldehyde will produce irritation to the eyes, nose and throat of most people. At concentrations above 1.0 ppm exposure to formaldehyde will produce extreme discomfort.

A recent controlled human exposure study measuring chemosensory irritation (Lang et al., 2008) came to the conclusion that eye irritation is the most sensitive parameter and minimal objective eye irritation effects were measured at a level of 0.5 ppm with peaks of 1 ppm. It was concluded that the *no observable adverse effect level* (NOAEL) for eye irritation due to formaldehyde exposure and based on objective measurements was 0.5 ppm in the case of constant exposure level and 0.3 ppm with peaks of 0.6 ppm in case of short-term peak exposures.

The Scientific Committee on Occupational Exposure Limits (SCOEL) is concerned on the reliability of the study made by Lang et al (2008) since the number of subjects that could be examined in such a laboratory volunteer study is limited and potentially sensitive subgroups were not specifically considered. To address these issues, the European Panel Federation (EPF) in strong support with the German Association of the wood-based panel industries (VHI), acknowledge that more information on interindividual differences is essential to substantiate the derivation of a health based occupational exposure limit. Therefore the panel industries initiated a new experimental study in human volunteers in March 2009.

2. Exposure to formaldehyde in the wood-working industries

In wood-based panels (particleboard, MDF, OSB) the pieces of wood are bonded with urea formaldehyde (UF), melamine-formaldehyde (MF), melamine-urea-formaldehyde (MUF) or phenol-formaldehyde (PF) resins, and then formed into the mat. Hot pressing, where the mat is compacted to the desired density and thickness, allows the resin to be polycondensated to bind the particles and stabilise the panel. Presses are single-stage, multi-stage or continuous. The boards are then transferred to a cooling system, and left for a period of time to cure. The different stages of finishing, storage and shipping follow.

For plywood, the only step requiring formaldehyde-based resin is bonding wood sheets in the longitudinal or transverse plane. Plywood and laminated veneers consist of different layers (panels, sheets of veneer, boards) bonded and hot pressed. Coating also involves gluing a laminated or melaminated décor paper on the panels, followed by hot pressing. The pieces of wood are bonded with urea-formaldehyde (UF), melamine-formaldehyde (MF), melamine-urea-formaldehyde (MUF) or phenol-formaldehyde (PF) resins.

2.1 Formaldehyde measuring campaign in the wood-based panel industry

Table 2 presents the fabrication process of a wood-based panel factory with the results of the measuring campaign for the sampling location (work area) and tasks of interest. The Table presents the results from a Europe-wide formaldehyde-in-air monitoring campaign within the wood-based panel manufacturing industry. Five small to medium sized manufacturing enterprises of considerably different ages were selected that are located in France, Germany, Poland, Spain and the UK. Site work was conducted over the 3-week period Wednesday 30th September to Saturday 17th October 2009.





At each of these sites, ten [nine at x1 site] virtually identical samples were collected during pre-planned periods of routine production. The samples included:

- ▶ personal long term samples [minimum 3-hours, maximum 5-hours to suit each sites' production status]. Associated duties were Press Operator, Press Cleaner, Dryer Operator and Sanding or Cutting Area Operator;
- ▶ personal short term [15-minutes] samples. These tests relate to the Press Operator when working outside the Control Cabin or the Press Inspector and to the Press Cleaner during press cleaning duties;
- ▶ static samples positioned typically at head height along an access walkway immediately adjacent to the Forming Station, the outlet from the Main Press, the Star Cooler and adjacent to the Sanding Line.

Similar tests for formaldehyde-in-air concentrations have been conducted at each of the five nominated European sites four of which manufacture particleboard and one of which manufactures medium density fibre board. All five of these sites operate the continuous design of Main Press; press lengths range from 33 to 49-metres. Staffing arrangements/work duties differ slightly between these sites, therefore testing at these sites has accordingly had to differ slightly. All sites were primarily using urea-formaldehyde resin during testing. One site also included melamine in the resin formulation. The degree of enclosure of the main press at these sites varied considerably as did the procedures for provision of extract ventilation. Additionally, there was a significant difference between procedures at these sites with respect to the use of access doorways to aid natural ventilation within production areas.



Table 2. Exposure to formaldehyde in the wood-based panel industry

Fabrication process	Sampling location	Task of interest
	Static sampling (all values mg/m ³)	Time weighed average sampling (TWA) and Short Term exposure levels (STEL) (all values mg/m ³)
 Mat former	Forming station: from 0.043 to 0.283	Press operator: TWA: from 0.017 to 0.176
 Prepressing, mat conveying and board pressing	Main press outlet: from 0.506 to 2.987	Press cleaner: TWA: from 0.311 to 0.766 STEL: from 0.130 to 1.667 Press inspector: STEL: from 0.183 to 1.187
 Sawing and cooling	Star cooler: from 0.171 to 1.253	Dryer operator: TWA: from 0.040 to 0.137
 Sanding and cutting to size	Sanding line: from 0.073 to 0.210	Sander operator: TWA: from 0.043 to 0.154

2.2 Sources of exposure in the woodworking industries

Formaldehyde comes primarily from the resin used in the adhesive when it is heated. Several factors affect formaldehyde emission, such as the type of resin, the pressing time, the thickness of the panel, etc. The most exposed workers are those assigned to the press operating tasks (usually in the control rooms) and maintenance tasks (press operator, mechanic, electrician, cleaner, foreman, etc.) when action must be taken during a breakdown or a production shutdown. Sample collection can also expose workers to high concentrations for short periods.

In the furniture industry, formaldehyde comes primarily from the type of coating used and from the use of formaldehyde-based resins to glue elements and components together. This is also the case for the parquet industry and for the production of laminated wood.

For formaldehyde to be released, the coating has to be aminated-resin-based or phenolic-resin-based. The latter is used only for metal furniture; aminated resins are used in the manufacture of wood and metal furniture. Formaldehyde is released during the preparation of varnishes and paints, their application (mainly when spraying with a pneumatic gun) and drying. When paint is applied inside a well-ventilated booth, the formaldehyde is exhausted and does not contaminate the work environment. However, the painter inside the booth can be significantly exposed if he is located in the direction of flow of the varnish mist. For other tasks such as finishing, hardware installation and shipping, airborne formaldehyde can come from furniture that is drying, from applying the varnish and from drying zones. The most exposed workers are finishing painters, preparation painters, colorists and some manual labourers, including those working at the dryer or oven outfeeds, as well as maintenance personnel (mechanics, electricians), foremen and supervisors.



Table 3. Exposure sources in the manufacture of wood products

Sector	Emission source	Tasks of interest
Plywood	Gluing machine	Glue preparation Glue application
	Panel board press	Manual feed Outfeed and stacking Repair and maintenance
	Drying and storage area	Finishing operations Packaging operations Transportation by lift truck
Laminated wood	Gluing machine	Glue preparation Glue application
	Panel board press	Manual feed Outfeed and stacking Transportation by lift truck
	Drying and storage area	Finishing operations Packaging operations Transportation by lift truck
Coating	Resin preparation	
	Impregnation tank	Paper feed Press infeed
	Drying and storage area	Finishing operations Packaging operations Transportation by lift truck
Furniture	Storage of varnishes Paint booth Drying of furniture Storage of furniture	Paint preparation Application of preparation coat-ings Application of varnish Sanding between coats of varnish Unloading of furniture (from the oven) Repairing of imperfections Installation of hardware Cleaning of guns

2.3 Wood dust in the woodworking industry

Many workers in workplaces such sawmills, veneer and plywood plants, woodchip operations, joineries and furniture plants may be exposed to high levels of wood dust. The major woodworking processes are debarking, sawing, sanding, milling, lathing, drilling, veneer cutting, chipping and mechanical defibrating. Sanding and sawing processes produce fine airborne dust particles. High moisture content in fresh wood makes it less airborne than dry wood, which produces more dust during processing. Softwood particles are more fibrous and usually larger and as a result are also less capable of becoming airborne. Wood dust can present both health and safety hazards. Wood dust can also be the transmitter for other chemicals. In this connection, the combined effect of exposure to different hazardous substances is of high concern for workplace prevention.

Best practice control measures for wood dust include local exhaust ventilation, notably integral extraction for hand tools, vacuum cleaning methods rather than compressed air or sweeping, isolation of dusty processes, external exhaust rather than recirculation through sock filters, separately enclosed areas for workers, and provision of overhead filtered air supply or air fed masks for non-mobile workers

3. Measuring formaldehyde in woodworking industry

If formaldehyde-containing glues are used in a work area, then air monitoring should be conducted by industrial hygienists to determine formaldehyde exposures for each job classification in each potentially affected work area. The quality of the evaluation of workers' exposure to chemical substances depends on the strategy applied in the workplace as well as on the precision, accuracy and detection limits of the sampling and analytical method.

3.1 Measurement of formaldehyde-in-air concentrations and assessment of the exposure

When performing workplace measurements, the Council Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work, as well as Council Directive 89/391 (Framework Directive) have to be taken into account. A workplace measurement programme should be established with the following European Standards as general guidelines:

- ▶ EN 482: Workplace atmospheres - General requirements for the performance of procedures for the measurement of chemical agents
- ▶ EN 689: Workplace atmospheres - Workplace atmospheres. Guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy

Not all methods for the determination formaldehyde-in-air concentrations are suitable for evaluating compliance with occupational exposure limit values. Samples taken for determining compliance with the STEL (short term exposure limit) for example, differ from those that measure the time weighted average concentration over an 8 hour shift (TWA) in important ways. Some methods have inadequate detection limits or present unacceptable interferences. The detection limit is particularly critical when performing STEL-measurements.



The sampling periods must be representative of the work performed during the shift; it is therefore important that the workers' tasks be properly understood. For a majority of the workers, samples can be collected 2-4 hours each before and after the noon break. When the expected concentrations are low, the same sampling system can be used throughout the day. Shorter duration tests can be used for some specific short-duration tasks that are likely to release formaldehyde. Samples can also be collected at stationary workstations considered representative of the workers' exposure, namely during specific tasks or close to emission sources where they have to work in the context of their jobs. The sampling time then varies according to the targeted task and the expected formaldehyde concentration.

The average exposure concentrations (AEC) over eight hours, which are then compared to TWA, are calculated as follows:

$$AEC = \frac{C_1T_1 + C_2T_2 + \dots C_nT_n}{T_1 + T_2 + \dots + T_n}$$

where C_n: concentration measured in the breathing zone or at the workstation
T_n: time in minutes of the sampling period
1, 2, ... n: indication of the sampling period
T₁ + T₂ + ... + T_n = 480 minutes (eight hours)

For periods not sampled, the arithmetic mean obtained for the sampling period corresponding to the same task is applied.

3.2 Recommended sampling and analyses method

The REF-Wood Project's Steering Group, with the help of an independent expert and the working group of technical experts, selected a suitable method for conducting a sampling campaign in five European wood-based panel manufacturing factories.

This project has demonstrated the acceptability of formaldehyde exposure sampling by use of low flow positive displacement sampling pumps with formaldehyde being sampled on to a solid adsorbent cartridge formed from silica gel coated with 2,4-dinitrophenylhydrazine (2,4-DNPH) followed by laboratory analysis using extraction with acetonitrile then High Performance Liquid Chromatography (HPLC) determination utilizing diode array detection. Diode array detection is a highly accurate procedure of ultra violet (UV) analysis. The basis of this procedure is the internationally recognized and validated sampling and analytical method for formaldehyde in ambient air - U.S. Environmental Protection Agency - Compendium method - 11A (January 1999).

This method has been deemed appropriate in terms of its accuracy, low detection limit plus its ease and safety in use. Benefits of this technique are:

- * Use of the low flow positive displacement type pumps ensures the highest possible accuracy in sample volumes;
- * The technique robustly respects health & safety issues as employees are protected against risk of exposure to chemicals;
- * The same technique can be used for both personal and static sampling and for both long term time weighted average [TWA] determinations and for 15-minute short term exposure [STEL] determinations that now feature in many European standards;
- * An analytical detection level of 0.05 µg of the carbonyl in the sampling cartridge is achieved by the accredited laboratory. Accordingly, for a 15-minute STEL sample collected at the low flow rate of 100 ml minute⁻¹ gives a reportable detection of exposure to formaldehyde of 0.03 mg m⁻³, namely:

$$\frac{0.05 \text{ µg of carbonyl}}{100 \text{ ml min}^{-1} \times 15 \text{ minutes} \times 10^{-3}} = 0.03 \text{ mg m}^3 \text{ HCHO}$$

There are no issues within the wood-based panel manufacturing operations of analytical interference when only formaldehyde is being determined

IV. Strategies to reduce formaldehyde exposure

1. Hierarchy of prevention

Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work (also known as the Framework Directive), is a European Union directive that sets out general principles for protection of workers' Occupational safety and health. It provides the enabling framework for a number of other individual directives concerned with specific aspects of health and safety.

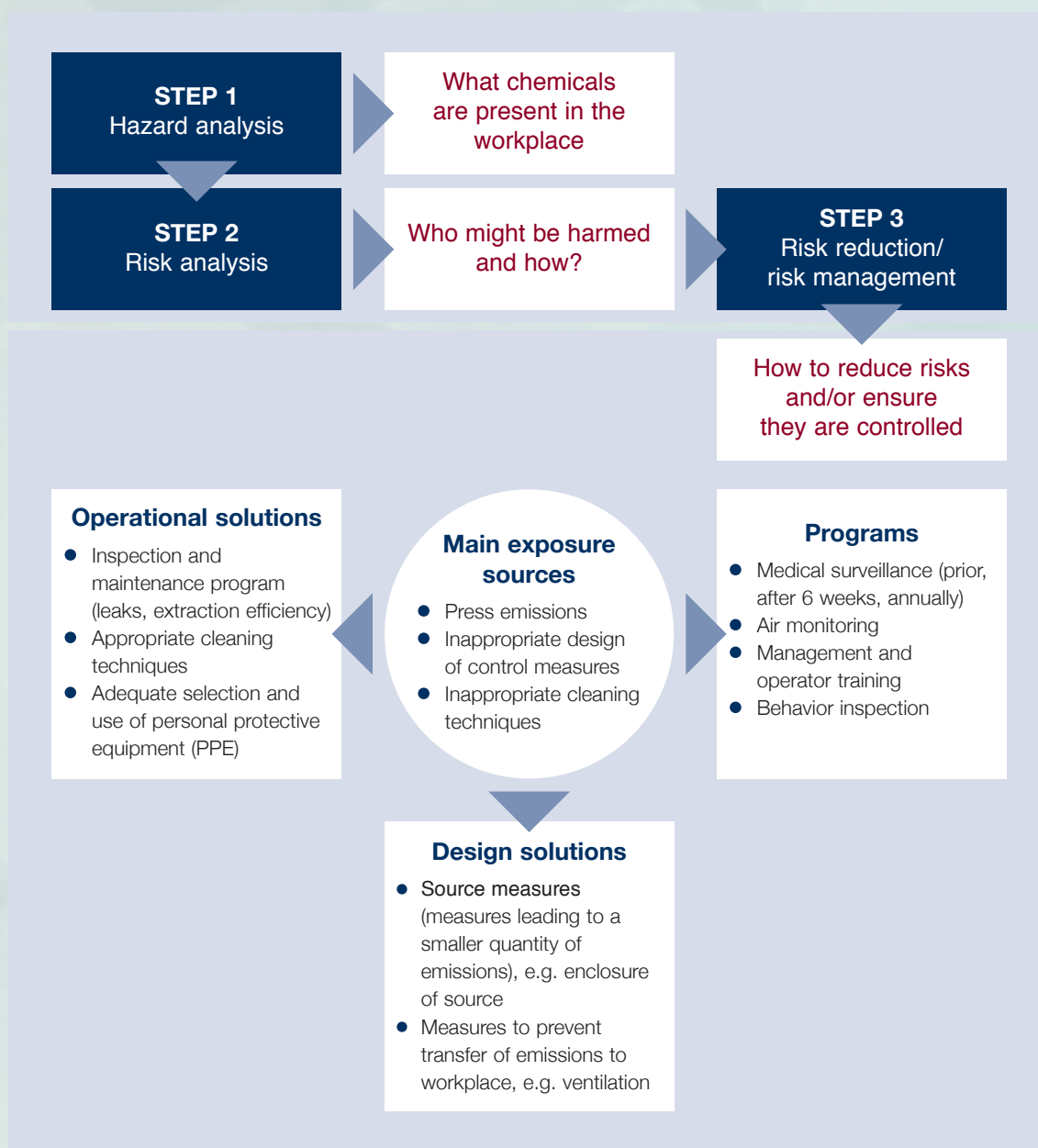
The general principles of prevention set out in Article 6(2) of Council Directive 89/391/EEC are specified in the following schedule:

- (a) avoiding risks;
- (b) evaluating the risks which cannot be avoided;
- (c) combating the risks at source;
- (d) adapting the work to the individual, especially as regards the design of workplaces, the choice of work equipment and the choice of working and production methods, with a view, in particular, to alleviating monotonous work and work at a predetermined work-rate and to reducing their effect on health;
- (e) adapting to technical progress;
- (f) replacing the dangerous by the non-dangerous or the less dangerous;
- (g) developing a coherent overall prevention policy which covers technology, organisation of work, working conditions, social relationships and the influence of factors relating to the working environment;
- (h) giving collective protective measures priority over individual protective measures; and
- (i) giving appropriate instructions to employees.

For making this brochure aiming the reduction of formaldehyde exposure in woodworking industries, the following general safety guidelines were always taken into account: hazard prevention and hazard control.



Figure 1: Risk management of occupational hazards in the woodworking industry (Huntsman, 2007)



1.1 Hazard prevention

Three methods are used to control the impact of hazards. The first, and preferred, is to prevent the hazard at the design stage. The second is to identify and eliminate existing hazards. The third is to reduce the likelihood and severity of mishaps from hazards that cannot be eliminated.

Hazards may be prevented through appropriate actions during the design process, when operating procedures are developed, and when equipment is purchased. The hazard would never exist if we anticipated problems and eliminated them before they reached the worker.

1.2 Hazard control

When hazard prevention is not possible, one must control their effects by reducing the severity of the hazards. Several methods to control hazard possibilities exist.

These methods are developed into benchmarks in the following order: (1) reduction through engineering & warnings, (2) reduction through practices at organisational level, and (3) reduction through protective equipment.

1.3 Prevention through the use of benchmarks

To reduce formaldehyde exposure in the woodworking industries, several benchmarks have been created. Whilst developing these benchmarks the principles from the Framework Directive, hazard prevention and hazard control have been taken into account. These resulted in:

- a) Reduction at the source;
- b) Best practices related to engineering & warnings;
- c) Best practices at organizational level;
- d) Personal protection.



A. Reduction at the source

Elimination and substitution of one product by another requires a structured approach that must be technically applicable in the workplace and feasible from the standpoint of performance, cost and equipment. The resin content in the board must be on the lowest possible level in respect to quality. The quantity of the resin is a function of the quality of the board and this is a demand of the customer.

In the manufacture of panels and other wood products, the use of resins without or at lower formaldehyde emission rates is one option to be considered. However, substitution and elimination are rarely feasible, especially in the case of formaldehyde where it is required in so many manufacturing processes. In some processes it is possible to use isocyanate-based binders or other resin systems without formaldehyde. Regretfully, however, so far none of these alternatives are available in sufficient quantities and at affordable cost.

B. Best practices related to engineering and warnings

Important elements are the exhaust air extraction systems for relevant parts (where the highest concentrations are expected, e.g. at the end of the press) and a good ventilation system of the production. To improve the exhaust system, it makes sense to maintain extraction at optimum design rate, to partially enclose machinery when feasible and to mark areas with high formaldehyde emission.

B.1	Enclose of machinery	<p>Partial enclosure of process equipment such as by curtains, walls or skirts, machinery, and containers can restrict the emission of formaldehyde gases. It must though be supplemented by ventilation to prevent the accumulation of heat, dissemination of vapours or dust into the air of the work area.</p> <p>In general, enclosure of the press is not feasible because it is absolutely necessary for the operators to see what is going on in the press and to have the possibility to intervene as quick as possible, and especially in case of an emergency, they do not have the time to take down the enclosure.</p>
B.2	Ventilation ▶ Local ventilation	<p>Airborne concentrations of formaldehyde gas and of formaldehyde-generating substances can be controlled and kept below the recommended concentration limits by properly designed ventilation systems of adequate capacity. Regular inspection and maintenance of the ventilation system is necessary for its continued effectiveness.</p> <p>When ventilation is necessary, secondary impact on ambient climate conditions (e.g. temperature, airflow) has to be taken into account, especially in winter time.</p>

	<p>► General exhaust</p>	<p>The purpose of local ventilation is to collect a pollutant as it is emitted to prevent its dispersion in the work environment. Ventilation must be the preferred method of control when the emission source is well identified. It is even more effective when the source is contained and isolated. This type of ventilation includes slot hoods and snorkel exhausts, which are placed at the source of emission. Local exhaust moves the vapours away from the employee and exhausts the pollutant out of the building.</p> <p>When evaluating the operation of extraction at optimum design rate it must be noted that increasing the extraction rate may be restricted under the environmental operating permit of the factory.</p> <p>When the formaldehyde source is large or has many locations within a room or area, general exhaust ventilation can be used to remove vapours from the work area. The purpose of general ventilation is to dilute the pollutants by introducing a sufficient flow of outdoor air. This requires a large quantity of air that will itself be dependent on the homogeneity of the mixture of fresh air with polluted air. As with local ventilation, the design of an efficient system requires a good understanding of the air-flow patterns in the building. It is also important to consider that flow rates and air flows (velocity, direction, temperature, etc.) will vary with the ambient conditions (temperature, door opening, etc.) and can reduce dilution. General or dilution ventilation is recommended in zones adjoining those containing the emission sources and in buildings such as warehouses where the emission sources are diffused.</p>
B.3	<p>Mark areas with elevated formaldehyde emission</p>	<p>Areas with elevated formaldehyde emissions could be clearly demarcated.</p> <p>Foot ways should be built at a sufficient distance from the press. Special foot ways for employees who are not working directly in these areas should be demarcated and selected in such a way that elevated formaldehyde concentrations can be avoided when walking around.</p>

C. Best practices at organisational level

C.1	General safety management	<p>The effectiveness of good work practices is entirely dependent on the knowledge and the cooperation of employers and employees. Therefore the employer must take all necessary steps to ensure that:</p> <ul style="list-style-type: none"> ▶ Each employee receives adequate instruction and training in safe work procedures, the proper use of all operational equipment, the correct use of protective devices and practices, and all emergency procedures; ▶ Each employee periodically receives refresher sessions and drills to maintain a high level of competence in safe work practices and emergency procedures; ▶ Each employee is provided with proper tools, equipment, and personal protective clothing or devices; and ▶ Each employee is given adequate, responsible supervision to assure that all safety requirements and practices are followed. <p>Only properly trained individuals should be permitted to access to areas in which exposures to elevated formaldehyde are likely. All such areas should be clearly identified by appropriate posted warnings.</p> <p>For the prevention of injuries from contact by formaldehyde-based resins and adhesives with the eyes, skin or other sensitive tissues, good work practices include, but are not limited to, the wearing of personal protective garments and equipment as recommended (See Best practices 5: Personal equipment)</p> <p>Work practices, procedures and protective equipment and devices should be developed and utilised so that the likelihood of employees suffering injurious contact with formaldehyde-based resins and adhesives is minimal. The wearing of personal protective garments and equipment is necessary for additional, positive protection in those activities and accidental situations where exposures are likely in spite of other precautions.</p> <p>The following work practices and procedures should be observed by all employees:</p> <ul style="list-style-type: none"> ▶ Respiratory and clothing protection and equipment should be worn in accordance with recommendations and requirements; ▶ Tanks, machines, pumps, valves, and lines must be drained and flushed thoroughly with water before doing maintenance or repair work on them. Care must be exercised to avoid contact with the drained or flushed fluids; ▶ Employees shall properly utilise ventilation, enclosures, remote controls, and other engineering or administrative controls provided.
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C.2	Training	<p>All employees who are assigned to workplaces where there is exposure to formaldehyde should participate in a training program. The work area supervisor or a designated person shall provide training to employees at the time of initial assignment, whenever a new exposure to formaldehyde is introduced into the work area and periodically thereafter. The training programme should at least include the following:</p> <ul style="list-style-type: none"> ▶ A discussion of the contents of related regulations and the contents of the applicable Material Safety Data Sheet (MSDS); ▶ The purpose for and a description of the medical surveillance programme required including: <ul style="list-style-type: none"> ▶ A description of the potential health hazards associated with exposure to formaldehyde and a description of the signs and symptoms of exposure to formaldehyde. As a minimum, specific health hazards that the employer shall address are as follows: cancer, irritation and sensitization of the skin and respiratory system, eye and throat irritation, and acute toxicity; ▶ Instructions to immediately report to the work area supervisor and to Occupational Health upon the development of any adverse signs or symptoms that the employee suspects are attributable to formaldehyde exposure; ▶ A description of operations in the work area where formaldehyde is present and an explanation of the safe work practices appropriate for limiting exposure to formaldehyde in each job; ▶ The purpose for, proper use of, and limitations of personal protective clothing and equipment; ▶ Instructions for handling spills, emergencies, and clean-up procedures; ▶ An explanation of the importance of engineering and work practice controls for employee protection and instructions in the use of these controls; ▶ A review of emergency procedures including the specific duties or assignments of each employee in the event of an emergency.
C.3	Minimise working time in areas with elevated formaldehyde emission	To the extent feasible, the working time in areas with elevated formaldehyde emission shall be minimised. Rotation of the work can be implemented to minimise formaldehyde exposure.
C.4	Special requirements during repair and control of machinery	Workers who have to control and repair in areas with elevated formaldehyde emissions should have personal protective equipment and should be trained and instructed regularly.
C.5	Formaldehyde monitoring in the work area	By monitoring the concentrations of formaldehyde in a company, it is possible to ensure that the environment is healthy and to identify leaks. Any technological change, or process or task modification justifies a new evaluation to determine that the work environment remains acceptable.

C.6	Medical surveillance	The purpose of a medical surveillance programme is to prevent or detect a disease at the subclinical or presymptomatic stage, in order to take appropriate action to reverse the effects, or to slow down the progression of the disease towards the clinical status. In addition, the objective is not only to detect adverse effects in employees, but also to relate the findings to the effectiveness of exposure control measures.
C.7	Recordkeeping	<p>Exposure Monitoring records should be kept and include:</p> <ul style="list-style-type: none"> ▶ The date of measurement; ▶ The operation being monitored; ▶ The methods of sampling and analysis and evidence of their accuracy and precision; ▶ The number, durations, time, and results of samples taken; ▶ The types of protective devices worn; ▶ The names, job classifications, social security numbers, and exposure estimates of the employees whose exposures are represented by the actual monitoring results.



D. Personal protective equipment (PPE)

Each employee potentially exposed to gaseous formaldehyde or likely to come in contact with formaldehyde in solutions must be provided with, and required to wear, adequate protective clothing and equipment for the tasks and the area of work. Adequate supervision must be exercised to ensure that the protective clothing and equipment are regularly and properly worn. The garments and equipment must be inspected and maintained on a regular basis. Items damaged by wear or abuse to the extent that the effectiveness of protection is impaired or doubtful must be repaired or replaced. All personal protective devices must be washed thoroughly after each wearing and before being reused. If any such items becomes contaminated with formaldehyde adhesives during the work shift, it should be immediately flushed with water; when such flushing makes the item unsuitable for continued wear, it must be removed and replaced by a clean one.

The type of PPE necessary will vary depending on the concentration, amount used and the potential for splashing, and may include goggles, face shield, gloves, gowns, lab coats, aprons and arm sleeves.

D.1	Protective clothing and gloves	<p>Gloves must be worn whenever formaldehyde-based chemicals are handled. While latex gloves provide some protection against formaldehyde liquids, butyl or nitrile gloves are recommended and should be worn when contact is anticipated.</p> <p>When there is a risk of spraying or splashing of formaldehyde-based chemicals, protective clothing must be worn.</p>
D.2	Safety goggles	<p>Eye protection is of importance because of the irritant effects of formaldehyde. Well-fitted chemical safety goggles must be worn from irritating concentrations of formaldehyde-yielding substances and as protection from mists, splashes and spills of formaldehyde-containing chemicals.</p>
D.3	Respiratory protection	<p>It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimising exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practices controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations.</p> <p>In addition to respirator selection, a complete respiratory protection programme should be instituted which as a minimum complies with the requirements of the safety and health standards. A respiratory protection programme should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection and cleaning. The implementation of an adequate respiratory protection programme, including selection of the correct respirators, requires that a knowledgeable person be in charge of the programme and that the programme be evaluated regularly.</p>
D.6	Personal hygiene	<p>To prevent and limit contact dermatitis from formaldehyde the employee should practice good personal hygiene. Washing facilities and change rooms should be provided. Employees should exercise care not to transfer formaldehyde from contaminated gloves or other protective garments to unprotected eye or skin surfaces.</p>



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