

Update on the formaldehyde release from wood-based panels

The acceptable levels of formaldehyde emission from wood panel products have been continuously reduced over the last decades. The driving forces have been the increased public awareness and the consumer demand for non-hazardous products as well as the corresponding governmental regulations. The recent re-classification of formaldehyde by the International Agency for Research on Cancer as “carcinogenic to humans”, has triggered further concern and reactions by worker and consumer associations, “green” organisations, regulatory authorities and the industry itself. New studies on formaldehyde health effects were initiated since 2005 in both the USA and Europe and corresponding regulatory decisions on reclassification have been postponed until the results are available.

The issue of formaldehyde release from composite wood panels is mainly related to the use of urea-formaldehyde (UF) resins as bonding adhesives for their production. These high reactivity and low cost polymers are contributing to the panel formaldehyde emission by their low resistance to hydrolysis and the presence of free non-reacted formaldehyde. Resin copolymers produced with the use of melamine either at low (urea-melamine-formaldehyde resins, UMF) or at high levels (melamine-urea-formaldehyde resins, MUF) have improved hydrolytic stability but yet questionable performance in regard to very low formaldehyde emission levels.

Urea-formaldehyde resins have traditionally been used in the production of wood-based panels (mainly particleboard, fibreboard, plywood) and related products for decades. Indoor air quality and formaldehyde emissions from composite wood products first became subject to broad public and governmental concern in the late 1970s, when the energy crisis encouraged heat conservation through tight sealing of homes. This reduced the rate of outdoor air infiltration and overall ventilation rates leading to the entrapment of gaseous pollutants inside home air atmosphere. With Europe, North America and Japan as pioneers, test methods to accurately measure formaldehyde emissions from panels were developed and product emission guidelines were established. These were combined with work place exposure limits for formaldehyde. A total change in the formulation of UF resins was made by the resin industries to meet the low panel emission guidelines. Moreover, competitive bonding systems such as phenol-formaldehyde resins or polymeric diphenyl methane diisocyanate (PMDI) binders were proposed.

Formaldehyde classification

Until recently, formaldehyde was classified by the World Health Organization (WHO) as probably carcinogenic to humans (Group 2A). In 2004, the International Agency for Research on Cancer (IARC) of WHO, decided to recommend the reclassification of formaldehyde as “carcinogenic to humans (Group 1)”, on the basis of available scientific data (IARC 2004). This recommendation, although not legally binding, was received with concern and immediate reactions from worker and consumer associations, “green” organisations, regulatory authorities and the industry (producers and users of formaldehyde) associations (FormaCare and European Panel Federation in Europe, Formaldehyde Council and Composite Panel Association in N. America). The latter indicated that the decision of IARC had been based on studies regarding the exposure in 30-60 years ago, while the work place emission levels have declined dramatically the past three decades due to the technological progress made (Composite Panel Association 2004, Formaldehyde

Council 2004). Moreover, they stressed that the IARC classification was a “hazard identification” and not a full risk assessment.

In 2005, new toxicological and cancer studies were initiated by FormaCare and the Formaldehyde Council, involving various independent research institutes in Europe and the USA. In the meantime, there were proposals to reclassify formaldehyde in Europe by the French institute for occupational risk prevention (INRS) and the German Federal Institute for Risk Assessment (BfR). However, the European Chemicals Bureau (ECB) postponed its decision on the reclassification of formaldehyde until the results of the new studies were available (FormaCare 2006). Also the U.S. Environmental Protection Agency (EPA) delayed formaldehyde reclassification until the completion of the follow-up study of the National Cancer Institute.

The IARC recommendation was finally published in December 2006 through its monograph series Volume Number 88. In this report, it is stated that “there is sufficient evidence in humans and in experimental animals for the carcinogenicity of formaldehyde” and that “formaldehyde is carcinogenic to humans (Group 1)” (IARC 2006). It is further mentioned that the highest occupational exposure to formaldehyde were measured in varnishing, production of textiles, garments, furs, in certain jobs in board mills and foundries. Lower exposure levels have been encountered in formaldehyde production (mean concentration < 1ppm). A wide range of exposure levels has been observed in the production of resins production (all data were derived from the 1980s). In wood products manufacture, exposure occurs during glue mix preparation, laying of mat, hot pressing and sanding – all data were derived from the 1960s-70s-80s. The reported mean concentrations in the air were greater than 1ppm in particleboard mills and approximately 2ppm in plywood, however, recent studies reported concentrations lower than 0.4ppm in plywood and less than 0.16ppm in OSB and fibreboard plants.

In September 2007, an International Formaldehyde Science Conference took place in Barcelona, Spain, organized by FormaCare (the European Formaldehyde Industry Association, sector group of CEFIC, the European Chemical Industry Council). The results of newly available scientific studies on the epidemiology and toxicology of formaldehyde were presented and discussed by representatives of institutes from Europe, the USA and Brazil, European Commission representatives and industry scientists (FormaCare 2007, Press Release). Main conclusions include the following points: a) the evidence for NasoPharyngealCancer formation is highly ambiguous, b) the leukemia formation related to formaldehyde exposure is highly improbable, c) no mutagenic effects were observed in experiments and d) in the normal living environment or at the workplace, formaldehyde exposure is not expected to lead to sensory irritation. The threshold for sensory irritation is clearly lower than that leading to cell death. Concentrations of 0.5 ppm or 0.3 ppm with peaks of 0.6 ppm will not lead to objective signs of sensory irritation. The bottom line of the conference was that “the common use of formaldehyde in consumer products and other applications does not pose a risk to human health”. The IARC recommendation was challenged by presenting the weak points of the studies on which it was based (old data, lack of statistical robustness of data analysis, no consideration of confounding effects) (also in FormaCare 2007, Scientific fact sheet). Such weak points and the newly available data suggest that there is no clear connection between formaldehyde exposure at current levels of exposure and cancer in humans.

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 (Global Insight 2007). 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. Prior to this European study a report had been released on the “The Economic Benefits of Formaldehyde to the United States and Canadian Economies”, showing even higher economic benefits from the use of formaldehyde products (Global Insight 2005). 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 the U.S. and Canadian economies”.

Within the EU, formaldehyde is currently classified as a Category 3-R40 substance (“limited evidence of carcinogenic effect”), which is the lowest available EU category for suspected carcinogens. According to the findings of the Barcelona conference this category is still appropriate (Gelbke 2008). The classification of formaldehyde in the EU will be reviewed under the new REACH regulation on chemicals and their safe use. In the U.S. the current classification by EPA is that of a probable human carcinogen.

Occupational Exposure Limits

The Occupational Exposure Limits (OELs) for formaldehyde are presented in Table 1. In countries with higher limits there are discussions to lower them following the recommendation of IARC (e.g. in Australia, the OEL of 1.0ppm will be set to 0.3ppm in 2008).

Table 1: Occupational Exposure Limits (OELs) for formaldehyde (IARC 2006, FormaCare 2007, Q&A on formaldehyde)

Country	Concentration, ppm	Type^a
Australia	1.0	TWA
Austria	0.3	TWA
Belgium	0.3	Ceiling
Brazil	1.6	Ceiling
Canada-Alberta	2.0	Ceiling
Canada-Ontario	0.3	Ceiling
Canada-Quebec	2.0	Ceiling
Denmark	0.3	TWA & STEL
Finland	0.3	TWA
France	0.5	TWA
Germany	0.3	TWA
Greece	2.0	TWA
Hong Kong	0.3	Ceiling
Ireland	2.0	TWA
Italy	0.3	Ceiling
Japan	0.5	TWA
Malaysia	0.3	Ceiling
Mexico	2.0	Ceiling
Netherlands	1.0	TWA
New Zealand	1.0	Ceiling
Norway	0.5	TWA
South Africa	2.0	TWA
Spain	0.3	STEL
Sweden	0.5	TWA

Switzerland	0.3	TWA
United Kingdom	2.0	TWA
USA-ACGIH ^b	0.3	Ceiling
USA-NIOSH ^b	0.016	TWA
USA-OSHA ^b	0.75	TWA

^aTWA: time-weighted average, STEL: short-term exposure limit.

Formaldehyde emission standards for wood-based panels

In Table 2, the classification of wood-based panels in respect to formaldehyde emission according to the European, Australian, U.S.A. (also valid in Canada) and Japanese standards is given.

Table 2: Formaldehyde emission standards for wood-based panels in Europe, Australia, the U.S.A. and Japan

Country	Standard	Test method	Board class ^a	Limit value
Europe	EN 13986	Chamber EN 717-1	E1-PB, MDF,	≤0.1ppm
		Perforator EN 120	OSB	≤8mg/100g
		Chamber EN 717-1	E1-PW	≤ 0.1ppm
		Gas analysis EN 717-2		≤ 3.5mg/h*m ²
		Chamber EN 717-1	E2-PB, MDF,	>0.1ppm
Perforator EN 120	OSB	>8 - ≤30mg/100g		
		Chamber EN 717-1	E2-PW	> 0.1ppm
		Gas analysis EN 717-2		> 3.5 ≤÷ 8.0mg/h*m ²
Australia	AS/NZS 1859-1 & 2	Desiccator AS/NZS 4266.16	E0-PB, MDF	≤0.5mg/L
			E1-PB	≤1.5mg/L
			E1-MDF	≤1.0mg/L
			E2-PB, MDF	≤4.5mg/L
U.S.A.	ANSI A208.1 & 2 (PB & MDF)	Large chamber ASTM E1333	PB, MDF	≤0.3ppm
			Industrial PW	≤0.3ppm
		Large chamber ASTM E1333	PW wall panels	≤0.2ppm
Japan	JIS A 5908 & 5905 (PB & MDF)	Desiccator JIS A 1460	F**	≤1.5mg/L
			F***/E0	≤0.5mg/L
			F****/SE0	≤0.3mg/L

^aPB: particleboard, MDF: medium density fibreboard, OSB: oriented strand board, PW: plywood

In Europe, Germany pioneered in issuing regulations as well as in reducing panel formaldehyde emissions in actual industrial practice. Currently the German regulation requires compliance with E1 emission limits of 6.5mg/100g for particleboard and 7.0mg/100g for fibreboard (tested by the perforator method) (Roffael 2006). Also other European countries like Austria, Denmark and Sweden

followed Germany in producing boards of only these E1 levels. However, most European countries still have legislation allowing the production and distribution of E2 boards (according to EN 13986). Recently, the members of EPF agreed to only produce E1 boards and that compliance should be monitored through a system of internal and external checks (EUWID 2007). At the same time, the members firmed up the E1 limit values for ongoing production monitoring.

The emission limit of the Japanese F** class is more or less equivalent to European E1-class according to the German regulations, while the F*** and F**** emission limits are much lower than the E1-class. The emission of F**** boards is close to the emission of solid untreated wood (e.g. between 0.008-0.01ppm or 0.5-2.0mg/100g for spruce wood flakes, Marutzky et al. 2004).

The Air Resources Board of California (CARB) adopted a new regulation in April 2007 to reduce the formaldehyde emissions from composite wood products, including particleboard, MDF and hardwood plywood (Airborne Toxic Control measure, ATCM, CARB 2007). The final approval of its modified version is due by late April 2008. This regulation proposes the reduction of formaldehyde emission standards in two phases (Figure 1). Phase 1 limits (effective from January 2009) are roughly equivalent to the European E1 emission class that is the Japanese F** class (Figure 2). Phase 2 limits (effective from January 2010 and January 2011) are comparable to the Japanese F*** limits, the so-called E0 levels in Europe. The new regulation will establish the most stringent formaldehyde emission limits on wood products in the United States. The measure requires that wood panels and products manufactured from wood panels be certified by a “third party” laboratory (Third Party Certifier, TPC) approved by the CARB. The emission standards of Table 1 apply to panels sold, supplied, offered for sale, or manufactured for sale in California, also to panels used in finished goods and there are special provisions for manufacturers using NAF (No-Added Formaldehyde) & ULEF (Ultra-Low-Emitting Formaldehyde) resins.

Table 1 Phase 1 and Phase 2 Formaldehyde Emission Standards for Hardwood Plywood (HWPW), Particleboard (PB), and Medium Density Fiberboard (MDF) ⁽¹⁾					
Effective Date	---- Phase 1 (P1) and Phase 2 (P2) Emission Standards (ppm) ----				
	HWPW-VC	HWPW-CC	PB	MDF	Thin MDF
1-1-2009	P1: 0.08	-----	P1: 0.18	P1: 0.21	P1: 0.21
7-1-2009	-----	P1: 0.08	-----	-----	-----
1-1-2010	P2: 0.05	-----	-----	-----	-----
1-1-2011	-----	-----	P2: 0.09	P2: 0.11	-----
1-1-2012	-----	-----	-----	-----	P2: 0.13
7-1-2012	-----	P2: 0.05	-----	-----	-----

⁽¹⁾ Based on the primary test method [ASTM E 1333-96(2002)] in parts per million (ppm).
HWPW-VC = veneer core; HWPW-CC = composite core.

Figure 1: The California Air Resources Board new standards (CARB 2008)

P1 (ppm)	E1	F☆☆	F☆☆☆
HWPW (0.08)	More	Comparable	Less
PB (0.18)	Less	Less	Less
MDF (0.21)	Less	Less	Less
P2 (ppm)	E1	F☆☆	F☆☆☆
HWPW (0.05)	More	More	Comparable
PB (0.09)	More	Comparable	Less
MDF (0.11)	Comparable	Less	Less

(1) Values in parentheses are the proposed Phase 1 or Phase 2 standards in ppm. "More" means the proposed standard is "more stringent" than applicable E1, F☆☆, or F☆☆☆ standards.

Figure 2: CARB versus European and Japanese standards (CARB 2008, h)

Discussions on a new emission class are currently under way in Europe. Industry insiders believe that the limit will be similar to that of the Blue Angel certification for environmentally-friendly products and services (EUWID 2007). Wood-based panels meeting this certification have to remain at least 50% below a formaldehyde emission value of 0.1ppm set out in class E1 and thus produce emissions of less than 0.05ppm. This new emission value should be fixed as a voluntary guideline outside of standardisation. It may, however, serve as the basis for a future standard.

The Industry response

Facing the developments in formaldehyde re-classification and new emission standards, the wood panel manufacturers provided products with reduced formaldehyde release (Figure 3).

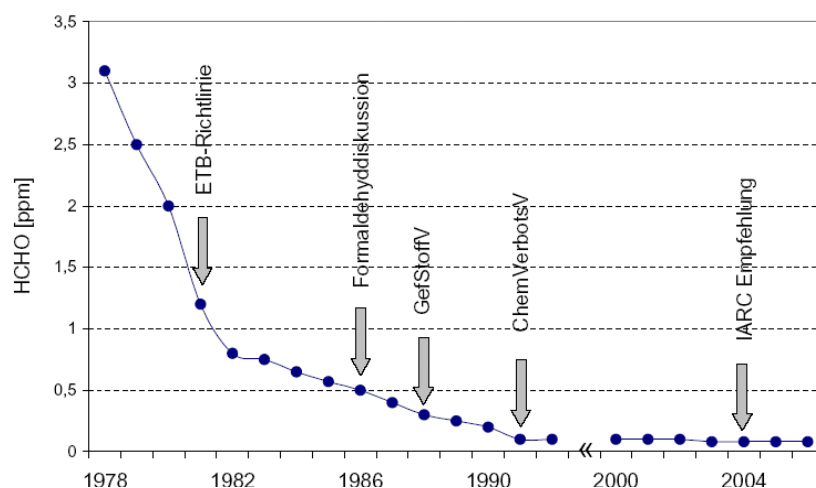


Figure 3: Formaldehyde reduction for particleboards between 1978-2006 (Marutzky 2008)

This was mainly the result of applying adhesive resins with improved formaldehyde performance, a problem solved by the resin industry through either of the following:

- **New formulation** urea-formaldehyde resins (with/without melamine).
- **Alternative gluing systems** (PF, PMDI).
- **Resins based on biomass products or by-products** (e.g. soy, tannin, lignin).

Such efforts and products aimed to meet the new demands for very low formaldehyde emission from composite panel products without any deterioration in panel performance or significant modification of manufacturing plant operating conditions and above all with due respect to production costs. Lately, formaldehyde-based resin products providing panels with formaldehyde emission values **at the level of natural wood** were offered (Athanassiadou *et al* 2007, Kantner 2008).

As in the case of all chemicals, the wise use of formaldehyde together with the respect of formaldehyde emission standards and exposure limits are the means for safeguarding the worker and consumer health and quality of life levels.

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