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Standards and Regulations Concerning the Formaldehyde Emissions from Wood Panels

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Abstract
The formaldehyde is an issue for wood-based composites industry. Long exposure at high levels of formaldehyde led to severe health problems. The International Agency for Research on Cancer (IARC) recommended classification of formaldehyde from Group 2A-"probabil carcinogenic to humans" to Group 1-"carcinogenic to humans". As a consequence, new limits for formaldehyde emission were established for wood panels. These are set in specified standards in Europe, USA and Japan. There are also specific rules established at national levels that limit the values of formaldehyde emission in the range of 0.05 ppm - 0.11 ppm, for hardwood plywood, particleboard and medium density fibreboard known as CARB regulations, valid in California. Therefore, with the new requirements concerning the air quality and products, many wood composites companies at international level produce also panels according to the CARB rules. There are different standardised methods that are used in formaldehyde determination, each of them are characterised by test conditions and specific unit measure for emission and content respectively. This paper aims to review the formaldehyde regulations and methods used for formaldehyde determination in order to highlight the importance of formaldehyde evaluation by all manufacturers of wood-based panels increasing the quality of their products their products.

Keywords
formaldehyde, regulations, wood panel, methods

1. Introduction

Wood based composites are animportant category of products of economic and technical interest, having as major advantage the ability to achieve certain properties in a controlled manner even in the design stage. There are some issues that have led to the development of these products, such as: using wood resources more efficiently, improving properties, recovering waste at the end of life cycle and the conquest of new markets. There are known five main categories for conventional wood composite materials, based on the physical configuration of the wood used: plywood, oriented strandboard, particleboard, hardboard, and cellulosic fibreboard [1].

Particleboard (PB) remains one of the most important panel within the EU wood-based panels industry, with about 55% of the total production (37.2 million m^3 in 2011) followed by fibreboard MDF which has expanded its market share to 20% (14.1 million m^3 in 2011). Plywood represents the third panel in Europe, with about 6% (4.2 million m^3 in 2011) [2]. Particleboard and MDF are mostly used in furniture sector, considered as a major market for both products with a share of 37% for PB and 55% for MDF [3]. The building industry is the second market for particleboard, accounting for 23% of all sales, while flooring adds another 5%. The second market for MDF is laminate flooring with a share of 30% and only 8% for building industry [3]. As can be seen wood-based panels are widely used to manufacture furniture, home constructions (for wall partitioning ceiling, flooring, and furnishing). In 2014, global wood-based panel production reached 388 million m^3 with 5.5% greater than in 2013. Europe hold more than 20% of the world capacity for wood based panels and the five largest producers of wood based panels (WBP) are China, USA, Russia, Canada, Germany accounted for 68 % (263 million m^3) of global production in 2014. Formaldehyde represents a major concern in the wood-based panels' production and its emission is an important factor in evaluating the environmental and health effects of these wood composites.

Formaldehyde was found to be a primary irritant of the respiratory airways. Excessive inhalation of vapours can cause acute respiratory distress, chemical pneumonitis, and bronchial asthma. Skin contact may cause various skin reactions including irritation and sensitization [4]. The International Agency for Research on Cancer (IARC) recommended classification of formaldehyde from Group 2A-'probabil carcinogenic to humans" to Group 1-"carcinogenic to humans" (monograph vol.88 12/2006). US EPA (Environmental Protection Agency) classified formaldehyde also in probable human carcinogen (B1), in draft toxicological review of formaldehyde-inhalation assessment 2010 [5]. EU- European Chemicals Agency (ECHA) reclassified formaldehyde in category 1B "presumed human carcinogen" and "germ cell mutagen category 2 (acute toxicity)" – entering in force in June 2014 [6].

Formaldehyde issue is related to urea-formaldehyde resin (UF) as traditional bonding adhesive used for the production of wood-based panels. Melamine urea formaldehyde (MUF) and phenol-formaldehyde (PF) adhesives are also known in wood panels industry but they are less dangerous in terms of their subsequent formaldehyde emission. The formaldehyde is released from panels during hot-pressing conditioning and also from wooden furniture. A further source of formaldehyde associated with wood and wood-based products are urea–formaldehyde lacquers, used as finishes on a wide range of furniture and fitments. As a consequence, humans may be exposed to formaldehyde in the environment and in the workplace. Formaldehyde concentrations in the environment generally are reported in parts per billion (ppb), but exposure levels are much higher in the workplace, occurring in the range of parts per million (ppm). Studies have done to reduce the formaldehyde emission levels from products bonded with urea-formaldehyde adhesive [7, 8, 9, 10]. With growing interest in the indoor air quality, efforts have been made to reduce exposure limits to formaldehyde both in the workplaces and in the living spaces.

The main objective of the paper was to present the international regulations concerning the limit impose for formaldehyde emission from wood-based panels and to compare the levels of formaldehyde based on the standardised methodologies in order to increase the indoor quality and lower the indoor pollutants and avoid any health risk of people.

2. Regulations Concerning Formaldehyde Emission (FE)

Many occupations were exposed to different levels of formaldehyde most of them belong to the healthcare sector, manufacture of furniture, manufacture of resins, and agriculture. The European Union has developed a strategic policy for protection of workers against risks from dangerous substances at workplaces, setting occupational exposure limits (OELs). For formaldehyde the European Union Scientific Committee on Occupational Exposure Limit Values (SCOEL) proposed in 2008 an eight hour exposure limit of 0.2 ppm and short term exposure limit (STEL) of 0.4 ppm [11]. In addition to basic standards for controlling the FE from wood-based composites produced by the manufacturer, various types of product labelling schemes are being developed. In 1980 some European countries started to regulate formaldehyde emissions and developed an obligatory emission class E1 (0.1 ppm boards) for wood-based panels. In 2004, Europe established the emission classes E1 and E2 (European Standard EN 13986) regarding wood products used in construction. In 2006 emission class E1 became obligatory for panel production. Both in Europe and America increased the requirements for the testing of products to determine the FE rate as part of product development and quality control procedures.

European formaldehyde limits for wood based panels are summarized in the harmonized standard EN 13986 - including 2 emission classes E1 and E2 (E1 ≤ 8mg/100g dry board; E2 > 8 - ≤ 30 mg/100g dry board. In Table 1 the limits of formaldehyde release for E1 and E2 class according to European standards are presented.

Germany, Austria, Denmark and Sweden require compliance with emission limits of 6.5mg/100g dry board. The European Panel Federation (EPF7) decided to draw up its own standard (e.g. for PB: 4mg/100g and for MDF: 5 mg/100g. (thickness > 8 mm) [12]. In 2011, EPF agreed on a reduction in formaldehyde emissions for CE labeled, uncoated wood panels for construction acc. to EN 13986[13]. The new limit value should be determined using the chamber test method described in EN 717-1 [14] and should not exceed 0.065ppm.

The Swedish concern IKEA also set an own emission limit that is half E1, so called class E0.5 (0.05 ppm)(IOS-MAT-003), which is not yet recognized officially by CEN [11].

In Japan, more strict regulations were established concerning formaldehyde emission limits. In 2003, testing and certification requirements were established for composite wood building materials that contain formaldehyde. The Japanese Standards JIS/JAS (Japan Industrial Standard-JIS; Japan Agricultural Standard-JAS) include four levels of emission labeled as F*, F**, F***, and F****. The emission standards are measured in mg/L and are difficult to compare with European standards, which are measured in ppm (parts per million).

The F** is more or less equivalent to European E1 class, the F*** and F*** are of much lower emission than the E1. F**** emission is close to the emission of solid untreated wood, between 0.5 and 2.0mg/100g, or 0.008-0.01ppm [15].

Table 1. Formaldehyde limits from wood based panels according to European standards

Emission class/ Board type	Limit value for formaldehyde release	European standard / Test method
E1/PB, MDF, OSB, PLY* (coated and uncoated)	≤0.124 mg/m^3 air (0.099 ppm**) ≤8.0 mg/100g oven dry board ≤3.5 mg/m^{2}h	EN 13986 / EN 717-1- Chamber EN 120 - Perforator EN 717-2- Gas analysis
E2/PB, MDF, OSB, PLY	>0.124 mg/m^3 air (0.099 ppm**) >8.0 mg/100g ≤ 30 mg/100 o. d. board >3.5 mg/m^{2}h≤ 8 mg/m^{2}h	EN 13986 / EN 717-1- Chamber EN 120 - Perforator EN 717-2- Gas analysis

*PB (particle board); MDF (medium density fibreboard); OSB (oriented strand boards); PLY (plywood)
**[16]

All composite wood products should be marked with a formaldehyde emission grade that determines the use of the product e.g.:

- F**** plywood can be used interior without limitations;
- F**, F***, plywood can be used interior with some limitations.
- F* plywood is not allowed to be used interior.

In Table 2 are presented the emission classes in Japan determine by Desiccator method acc. to JIS A 1460[17] and the correspondence with Perforator method acc. to EN 120[18] and other standards [11].

Table 2. Relationship between Japan standard and others concerning formaldehyde limits values

Emission class	Limit value (Desiccator-Japan method)	Perforator value (European method-formaldehyde content)	Chamber method EN 717-1	Emission ASTM E1333
F**	≤1.5 mg/L	6.5 mg/100 g o. d. board	-	~0.143ppm
F*** ~E0	≤0.5 mg/L	2.5 mg/100 g o. d. board	≤0.054mg/m^{3}air[a]	≤0.055ppm[a]
F****~SE0 (superE0)	≤0.3 mg/L	1.5 mg/100 g o. d. board	≤0.034mg/m^{3}air[a]	≤0.035ppm[a]

[a] values after Alves da Costa [19]

The Air Resources Board (ARB) evaluated formaldehyde exposure in California and on April 26, 2007, ARB approved an airborne toxic control measure (ATCM) to reduce formaldehyde emissions from composite wood products including hardwood plywood, particleboard, medium density fibreboard, thin medium density fibreboard (thickness ≤ 8mm), and also furniture and other finished products made with composite wood products [20]. Since 1967, the ARB has worked with the public, the business sector and local governments to find solutions to California's air pollution problem with the objective to promote and protect public health, welfare and ecological resources through the effective and efficient reduction of air pollutants. The first CARB (California Air Resource Board) emission standards were implemented on January 1, 2009.

The CARB regulation is only valid in California but with the new requirements concerning the air quality and products many wood composites companies at international level produced panels according to the CARB rules (Table 3).

Table 3. The CARB regulation* for formaldehyde emission, Phase 1 and Phase 2

Effective date	Emission values, Phase 1 (P1) and Phase 2 (P2), in ppm				
	HWPW-VC	HWPW-CC	PB	MDF	Thin MDF*
01.01.2009	P1-0.08	-	P1-0.18	P1-0.21	P1-0.21
01.07.2009	-	P1-0.08	-	-	-
01.01.2010	P2-0.05	-	-	-	-
01.01.2011	-	-	P2-0.09	P2-0.11	-
01.01.2012	-	-	-	-	P2-0.13
01.07.2012	-	P2-0.05	-	-	-
E1- EN 717-1	**0.124 /m^3= 0.099 ppm**				

*Based on the primary test method ASTM E 1333-96, in parts per million (ppm) [21].

HWPW-VC- hardwood plywood- veneer core, HWPW-CC- hardwood plywood composite core, PB-particleboard, MDF- medium density fibreboard

3. Formaldehyde Release from Wood Based Panels

Formaldehyde is considered a health hazard, thus the composite wood products must be within the limits imposed by the strictest regulations in terms of formaldehyde release. Industry has already reduced formaldehyde emission (FE) of raw panels by more than 80% over the past twenty years to minimize indoor air contaminants [22]. European, USA and Japanese regulations were developed for formaldehyde emission limits as they are presented above.

Market demands for low emitting products that lead to an increased requirement from companies for the formaldehyde testing as part of their product development and quality control procedures.

There are different standardised methods used for formaldehyde evaluation like: chamber, gas analysis, perforator, desiccator and flask. These methods can be classified as "measurable emission" (really emitted amount of formaldehyde under the test conditions) and the "emittable potential" of formaldehyde in the panel (maximum emittable formaldehyde under conditioning at forceful conditions) [23]. Each method measures the formaldehyde released from wood panels (covered and uncovered) and frequently produces results in different and non-interchangeable units [24].

The testing conditions, the sample dimensions, the equipment are different depending on the methods used and these differences are shown in Table 4. Formaldehyde is retained in water and analysed by acetyl-acetone method. The determination is based on the Hantzsch reaction in which formaldehyde reacts with ammonium ions and acetyl-acetone to yield diacetyl-dihydrolutidine (DDL) presenting a maximum absorbance at 412 nm.

The testing methods, some of them presented in Table 4, may be divided into three categories [25]:

a. Reference methods which simulate a standard indoor environment, the most known being the Chamber method acc. to EN 717-1.
b. Certification methods used especially for certifying products for sale, such as Perforator and Desiccator methods.
c. Quality control methods, for a quick and regularly control of production. There are flask method and some others, based on the specialised devices such as Dynamic Micro Chamber (DMC) and Field and Laboratory Emission Cell (FLEC).

There are differences between methods not only by test conditions, methodology but also by the unit measure of formaldehyde and several researches were developed to establish correlations between formaldehyde testing methods. However, for quality control of production all industries use a rapid test by gas analysis or desiccator methods for emission and Perforator method for content evaluation these methods being known as derived methods. The chamber is more accurate simulating the human environment and became known as reference method. It is frequently used by laboratories to test the formaldehyde emission from different wood panels, or furniture products (the large chamber) to check the requirements of E1 or E0 emission class.

Table 4. Standard methods and differences between general conditions used for formaldehyde determination

Test method/ Standard	Equipment characteristics	Sample dimensions/total surface area	Test conditions	Sample conditioning	E1 class limit
Chamber/ EN 717-1	0.25, 1, 40 (12-52)m^3	Loading ratio: $1m^2/m^3$ Edge sealing	Temperature: 23±0.5^{0}C RH: 45±3% Air velocity: 0.1-0.3m/s Time:1-4weeks	No (0,225L) T-20 °C, RH-65%	≤0.124mg /m^3, or 0.1ppm
Gas analysis/ EN 717-2	4L cylindrical chamber	400x50mm Edge sealing	Temperature: 60±.0.5^{0}C RH:≤3% Air velocity: 1L/min Time: 4hours	Varied T-20 °C, RH-65%	≤3.5mg/ m^2h
Perforator/ EN 120	Extractor apparatus	25x25mm (110g) No edge sealing	Extraction with 600ml toluene at 110^{0}C Time: 3h	T-23°C RH- 45%	≤ 8 mg /100 g o.d. board
Flask/ EN 717-3	500 ml flask	25x25mm (20g) No edge sealing	Temperature: (40 ±1) ^{o}C Time: 3 hours	No	No official limit are stated
Desiccator / JIS A1460	40L – 240 mm nominal dimension; 120mm outside diameter crystallizing dish/ 60-65mm depth	150x50mm±1mm/ close to 1800 cm^2 No edge sealing	Temperature: 20^{0}C±0.5^{0}C Time:24h±5min.	7-10 days 65%RH/20°C	F**~E1- ≤1.5mg/L F**** ≤0.3mg/L (SE0)

4. Conclusions

The formaldehyde emission represents a big challenge for wood-based panel industry because of new regulations concerning the limits of formaldehyde release. Emission databases reveal the interest of consumers for low emitting products in the future. These will lead to an increased requirement for the testing of products to determine the level of formaldehyde emission. To measure the levels of FE, many different methods have been used and the most reliable is the chamber method. A new class (SE0 and EO) of low formaldehyde emitting panels was established by Japanese standards and European Panel Federation (EPF) launch its own formaldehyde standards that corresponds to a perforator value below 4 mg/100 g oven dry board for P Band 5 mg/100 g oven dry board for MDF, which is half of the actually limit stated in the EN standard. These new trends force the wood panels' manufacturers and the glue producers to look for alternatives for formaldehyde free wood panels.

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