New regulations on the formaldehyde emission from wood-based panels

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Abstract: Formaldehyde is considered a health hazard, hence the wood-based panels must be within the limits imposed by the strictest regulations regarding the formaldehyde release. New national and international international regulations of formaldehyde emission from wood-based panels widely used in furniture industry were investigated in this study. The results of the study can be useful for the wood-based panel factories to follow the standards and regulations in terms of formaldehyde emission.

KEYWORDS: *FORMALDEHYDE EMISSION, WOOD-BASED PANEL, ADHESIVE, FURNITURE, PARTICLEBOARD, MDF*

1. Introduction

Wood-based panel and furniture industries have already reduced formaldehyde emission of raw panels by more than 80% over the past twenty years to minimize indoor air contaminants [1]. Wood based panels such as medium-density fiberboard, particleboard (MDF) and particleboard are increasingly being specified for residential and office furniture applications, especially the use of particleboard in inexpensive bookshelves and similar items. MDF uses more adhesive than particleboard, which causes higher initial formaldehyde emission of MDF than particleboard. Li [2] determined the amount of volatile organic compound (VOC) emission and its composition of six kinds of commercial wood-based panels in a period of time for 28 days. It was found that the formaldehyde emission level from high to low was high-density fiberboard (HDF), MDF, plywood, veneer-faced MDF, and oriented strand board (OSB).

Most of the adhesives currently used in the particleboard industry are formaldehyde-based adhesives (UF, MUF), which have a molar ratio of formaldehyde to urea (F:U) between 1.00 and 1.10. The majority of thermosetting resins used in the wood-based panel industry are based on the formaldehyde-based resins. Among them, the UF resin is the most used resin. Due to its significant advantages such as cheaper, colorless, easy-supply, shorter hot pressing time and temperature than others, good mechanical properties of particleboard in dry conditions. The disadvantages of the UF resin are higher formaldehyde emission from other resins and lower water and moisture resistance. Off-gassing of formaldehyde from wood-based panels can be one of the main contributors to the elevated formaldehyde levels and exposure in the homes. Sensitive people against to the formaldehyde start to experience irritation at 0.6mg/m^3 and most of us will be irritated at 1.2 mg/m^3. This range of 0.6 to 1.2 mg/m^3 is the official IARC (International Agency for Research on Cancer) threshold for eye, nose and throat irritation [3]. A correlation was determined between the formaldehyde emission of the resin and the formaldehyde emission factor of the wood-based panel. That is, the higher the content of formaldehyde in the adhesive, the higher the level of formaldehyde emission from wood-based panel, and there is a good linear relationship between them [4].

Urea-formaldehyde is classified according to its formaldehyde emission from the wood-based panels (from the lowest to highest level):

1. Super E0
2. E0
3. E1
4. E2
5. E3

For indoor and furniture applications, a lower formaldehyde content is required, if classified under the E1 emission class. Formaldehyde emission classes in finished panels, defined in Annex B of EN 13986:2014+A1:2015 standard are as follows:

- Class E1: ≤ 8mg/100g dry board according to EN 120 or < 0.124 mg/m^3 according to EN 717-1;
- Class E2: > 8 to < 30mg/100g dry board according to EN 120 or > 0.124– < 0.3 mg/m^3 according to EN 717-1.

Formaldehyde emission values (perforator value) of various materials (MDF, particleboard, blockboard, laminate flooring, and parquet) characterized by the perforator extraction method of the Chinese national standard GB 18580 is given in Figure 1.

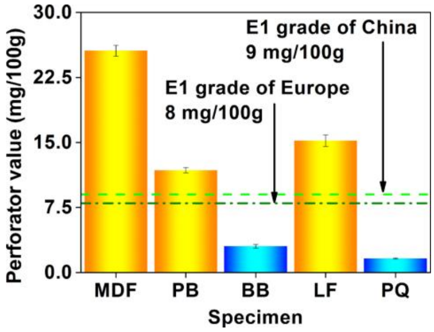

Figure 1. *Formaldehyde emission values (perforator value) of various [5].*

According to the International Composite Board Emission Standards (ICBES), there are three European formaldehyde classes, which are E0, E1 and E2, respectively. This classification is based on the measurement of formaldehyde emission levels from the wood-based panels. For example, E0 is classified as having less than 3 milligrams of formaldehyde out of every 100 grams of the glue used in particleboard and plywood fabrication. E1 and E2, conversely, are classified as having 9 and 30 milligrams of formaldehyde per 100 grams of the panel, respectively. All around the world variable certification and labeling schemes are there for such products that can be explicit to formaldehyde release, like that of Californian Air Resources Board (CARB). In addition, the production of wood-based panels is increasingly influenced by product emission quality standards applied outside Europe, most importantly CARB standards, originating from Californian legislation. The emission limit values in the wood-based panels used in furniture applications are at levels much lower than the corresponding lowest emitting standard in the EN standards. Formaldehyde emission classes defined by ATCM (Airborne Toxic Control Measure) 93120:

- CARB phase 2 standard for MDF: 0.11 ppm;
- CARB phase 2 standard for particleboard: 0.09 ppm.

2. Formaldehyde emission methods and regulations

There are different standardized methods used in the determination of formaldehyde emission from the wood-based panels such as 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) [6]. Each method measures the formaldehyde released from wood panels (covered and uncovered) and frequently produces results in different and non-interchangeable units. Standard methods and differences between general conditions used for formaldehyde determination from the wood-based panels are presented in Table 1.

Table 1. *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)m³	Loading ratio: 1m²/m³ Edge sealing	Temperature: 23±0.5°C RH: 45±3% Air velocity: 0.1-0.3m/s Time:1-4weeks	No (0,225L) T-20 °C, RH-65%	≤0.124mg /m³, or 0.1ppm
Gas analysis/ EN 717-2	4L cylindrical chamber	400x50mm Edge sealing	Temperature: 60±.0.5°C RH:≤3% Air velocity: 1L/min Time: 4hours	Varied T-20 °C, RH-65%	≤3.5mg/ m²h
Perforator/ EN 120	Extractor apparatus	25x25mm (110g) No edge sealing	Extraction with 600ml toluene at 110°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) °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 cm² No edge sealing	Temperature: 20°C±0.5°C Time:24h±5min.	7-10 days 65%RH/20°C	F**~E1- ≤1.5mg/L F**** ≤0.3mg/L (SE0)

The formaldehyde emission shows 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 particleboard 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.

Fig. 2. *Typical formaldehyde chamber based on EN 717-1 standard (Guangdong grande automatic test equipment limited, China).*

Formaldehyde scavengers, often called formaldehyde catchers, are chemical compounds added to the glue mix in order to decrease the formaldehyde emission from the finished wood panels. They are widely used today in the European particleboard and MDF industry. Mostly, aqueous solutions of urea (40% or 45% solids content) are applied. Furthermore, some scavengers such as sodium metabisulfite ($Na_2S_2O_5$), ammonium bisulfite ($(NH_4)HSO_3$), or ammonium phosphates, are also applicable in the European panel industry [7]. Formaldehyde scavengers are also added directly on the wood chips ahead of gluing. In some particleboard manufacturers, urea is added as a solid material ahead of blending to keep moisture content of chips as low as possible. They are used up to a maximum 10-15% on the liquid resin, achieving thus reduction in the formaldehyde emission up to 50% [8]. Experience in Europe has shown that instead of using a very low F:U ratio adhesive, a plant can achieve better results by using a system of an equivalent F:U ratio, which is a combination of a higher F:U ratio UF, and a formaldehyde scavenger. Further developments to address these problems included the addition of a small quantity of melamine (usually 1–4%). Although the addition of melamine increases the production cost, it results in quite successful. Another approach to overcome the negative side effects of the low-emission UF adhesives is the addition of small amounts of PMDI (polymeric diphenylmethane diisocyanate) in the UF binder, in the core layer of particleboards [9].

Table 2. *Standards for determining formaldehyde emission from wood-based panels in China, USA, Europe, and Japan.*

Standard	Limit value	Grade	Testing method	Application scope
EN13986:2005	≤3.5 mg/(m²·h) ≤8 mg/(m²·h)	E_1 E_2	Gas analysis	Plywood
	≤8 mg/100 g ≤30 mg/100 g	E_1 E_2	Perforation	MDF PB
Formaldehyde Emission Standards for Composite Wood Act (S.1660, H.R.4805)	≤0.05 ppm ≤0.09 ppm ≤0.11 ppm ≤0.13 ppm		Chamber	Plywood PB MDF ≤8 mm MDF
JIS A 1460-2001	≤0.3/0.4 mg/L ≤0.5/0.7 mg/L ≤1.5/2.1 mg/L	F☆☆☆☆ F☆☆☆ F☆☆	Desiccator	Plywood MDF PB
GB/T9846.3-2004	≤0.5 mg/L	E_0	Desiccator	Plywood
GB18580-2001	≤1.5 mg/L ≤5.0 mg/L	E_1 E_2	Desiccator	Plywood
	≤9 mg/100 g ≤30 mg/100 g	E_1 E_2	Perforation	MDF PB

Some regulations in Europe is given in Table 3. As the French labeling system Decree 2011-321 used as construction material. volatile organic compound of many materials used keeps its emissions at a certain standard.

Table 3. *VOC regulations used in Europe*

EU	Construction Product Regulation (CPR)	CEN/TS 16516:2013 ISO 16000-9
FR	Decree 2011-321 French labelling	ISO 16000-9 ISO 16000-3, 6
DE	Health-related Evaluation of Emissions of Volatile Organic Compounds (VVOC, VOC and SVOC) from Building Products	AgBB ISO 16000-9
BE	Royal Decree establishing the threshold levels of emissions to the indoor building products for specific intended use	CEN/TS 16516:2013 ISO 16000-9

3. *Formaldehyde scavengers*

Main parameters affecting formaldehyde emission from wood-based panels produced using UF resin are as follows:

1. Tree species and wood acidity
2. F/U molar ratio of UF resin
3. The amount of resin used
4. Density and thickness of of fiberboard
5. Hardener type and content
6. Free-formaldehyde content in the UF resin
7. Moisture content of mat
8. Moisture content of finished panel
9. Hot pressing parameters (temperature, time, and pressure)
10. Environmental conditions (humidity and temperature) for finished of fiberboard
11. Overlaying of fiberboard

Formaldehyde scavengers, capable of capturing formaldehyde either physically or chemically and forming stable products, are added to UF resins or to wood particles before pressing. These additives should provide long-term FE reduction, in principle along the panel's service life. Examples used in industry include addition of urea in aqueous solution or powder form, organic amines, scavenger resins such as UF resins with F/U well below 1.0), sulfites, and functionalized paraffin waxes In the last decades, F/U values in resins for WBP production have decreased from about 1.6 to a range between 0.9 and 1.1. In addition to the F/U ratio, the synthesis process has a relevant role in the final resin properties, including formaldehyde emissions. One strategy to counteract the negative effects of decreasing F/U ratio is resin modification with co-monomers, like melamine or phenol [10].

Industrial use of wood adhesives obtainable from natural resources (also called bioadhesives or bioresins) has been researched since 1970's, but industrial implementation is still restricted due to the production costs, limited availability and consistency of raw materials, and land use issues. Some significant advantages of bio-based adhesives are lower toxicity, renewability, sustainability, and biodegradability, biodegradability. Three materials, tannins, lignins, and vegetable proteins, have found commercial success in the industrial applications.

4. Conclusions

The legal regulations on the formaldehyde emission from wood-based panels will help to increase awareness for the consumers and panel manufacturers. Although the legal regulations can be different in different regions on the world, recently most of them have been updated. Especially, furniture industry is strictly affected by the formaldehyde emission issue due to panel-type furniture has been widely used in the market. It is important for customers to know the meaning of the formaldehyde emission class label from panel type furniture.

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