ONLINE ISSN 2069-7430
ISSN-L 1841-4737

PRO LIGNO
www.proligno.ro

Vol. 9 N° 4 2013
pp. 498-503

FORMALDEHYDE EMISSION FROM WOOD BASED PANELS. AN ENVIRONMENTAL ISSUE

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Abstract:

Many companies provide well-designed furniture, at a low price and in almost all cases this means wood particle boards or fibreboards. Solid wood furniture has become a luxury, thus the market has oriented to the cheaper materials (wood based panels) for furniture manufacturing, so as to broaden the population segment that addresses. These materials, such as, particle board (PB), medium-density fibreboard, (MDF) and plywood contain formaldehyde, which is released in our living spaces in some amount. The acceptable level of formaldehyde emission has decreased dramatically and regulations have been established by some institutions to set emission limits for all products manufacturers. This study aims to analyse the formaldehyde emission from wood based panels found on the Romanian market and its integration in the standard limits. Panels like particle board, fibreboard and plywood were tested in order to evaluate the formaldehyde emission by the gas analyse method at a temperature of 60^0C and a constant air flow. It was found that formaldehyde emissions from plywood and PB samples are in the limit permitted by EN 13986:2005 standard, for E1- class. In contrast with these results, emissions from MDF samples were higher, exceeding the standard limits. The issue of formaldehyde emission from these MDF panels is probably related to the bonding adhesives used in the production. Furniture made of these boards could be dangerous for people health, and producers should be aware about the E2 class panels' uses indoor and severe measures of control should be taken into consideration.

Key words: *wood-based panels; furniture; formaldehyde emission; environment.*

INTRODUCTION

Particleboard 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 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) (Eastin *et al.* 2012). 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 (Döry 2004). 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 (Döry 2004). As can be seen wood based panels are widely used to manufacture furniture, home constructions (for wall partitioning ceiling, flooring, and furnishing). Great attention has been given to the issue of formaldehyde released from these boards due to its possible negative effects on human health. Concerns on this issue started early in the 1970s with increased use of wood panels in homes. It is well known that formaldehyde issue is related to urea-formaldehyde resin (UF) as traditional bonding adhesive used for the production of wood based panels like particleboard, fibreboard and plywood. 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. Wood-based products bonded with PF adhesives show low formaldehyde emission potentials because the cross-linking is more stable, compared to UF- bonded products which emit formaldehyde due to the presence of small amounts of free formaldehyde in the resin and to the reversibility of the urea−formaldehyde reaction (Salthammer 2010).

Studies have done to reduce the formaldehyde emission levels from products bonded with urea-formaldehyde adhesive (Myers 1984, 1989, Lorenz *et al.* 1999, Zeli *et al.* 2007). Even so, the debates continue on this subject and in 2004, formaldehyde was reclassified from ‘‘probably carcinogenic to humans (Group 2A)’’ to ‘‘carcinogenic to humans (Group 1)’’ by the International Agency for Research on Cancer (IARC), part of the World Health Organization (WHO) [IARC 2004]. Reactions to this Report came from all over the world and in 2007 at International Formaldehyde Science Conference organized in Barcelona, Spain, specialists and researchers debated the formaldehyde issues and concluded that “the common use of formaldehyde in consumer products and other applications does not pose a risk to human health”. The toxicology and epidemiology of formaldehyde were discussed on the 2nd International Formaldehyde Science Conference in Madrid, April 2012. It was noted that a substantial amount of new scientific data has appeared within the last years since the 1st conference in 2007 (Bolt and Morfeld 2013). On 7 December 2012, the European Chemical Agency (ECHA) announced the adoption of a scientific opinion of the Committee for Risk Assessment (RAC), proposing that formaldehyde be classified as carcinogen category 1B (presumed human carcinogen) and germ cell mutagen category 2 under the EU Harmonised Classification, Labelling and Packaging (CLP) Regulation. Formaldehyde is currently classified as category 3 under the Dangerous Substances Directive. In due course the European Commission will evaluate the proposal with Member State experts and could adopt the new classification in 2015.

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 most significant source of formaldehyde in homes is wood based panels made with urea-formaldehyde resins. These include particle board, fibreboard and plywood most of them used for furniture pieces and home decorations. In the indoor environment, formaldehyde concentrations of interest range between 0.001 and 1ppm so, different methods for formaldehyde evaluations have been developed. Since 1970s, Perforator method (SR EN 120 1998), developed by the European particleboard association (EPA), is used for formaldehyde content determination. The desiccator method (JIS A 1460 2001) is used mostly in North America, Australia and Asia. Then for formaldehyde emission, more common for Europe are chamber method (SR EN 717-1 2004), gas analysis method (SR EN 717–2 1994) and flask method (SR EN 717–3 1996). The main objective of the paper was to evaluate the emissions released from the main wood based panels found on the market and their integration in the standard limits. These panels, like PB, MDF, plywood, are sold to different small manufacturers and arrive in the living places especially as different pieces of furniture, flooring, doors or decorative panels. Their emissions should be within the limits stipulated by the product standards in order to lower the indoor pollutants and avoid any health risk of people.

MATERIALS AND METHODS

The wood–based composites covered by this research are: particle board (PB), medium density fibre board (MDF) and beech plywood (PLY), used for non–structural and interior application as furniture materials. These are extensively used in furniture decorating apartments or others places like schools, pharmacies, hotels, public places etc.

The samples (the number and thickness are shown in Table 1), were obtained from boards available on the market, from a Romanian manufacturer and were conditioned one week at 20°C, 65% RH according to SR EN 717–2: 1995/AC:2004.

Gas analysis method was used in determination of formaldehyde emission. A sample with known area and edges sealed with self-adhesive aluminium tape was placed in the closed chamber in which parameters (temperature, humidity and air flow) are controlled to defined values. Air was continuously passed through the chamber over the sample.

The formaldehyde from the sample is released in the chamber air and is collected in the wash bottles containing water (which absorbs the released formaldehyde), at every one hour during the four hours testing.

Next, the formaldehyde content is spectrophotometrically determined by means of the acetyl acetone method at a wave length of 412nm. The formaldehyde release is calculated from this concentration, the sampling time and the exposed area of the test piece and is expressed in mg/m^{2}h.

The tests were made in duplicate for each sample using two different pieces and the formaldehyde value was the average of these two pieces after 4 hours, expressed in mg HCHO/m^{2}h. For each samples was determined the moisture content according to SR EN 322 (1993). In Table 2 are presented the test characteristics.

Table 1

Samples dimensions used in the experiments

Board type	PB	MDF	PLY	
Thickness, mm	18	18	4	10
No. of samples	8	8	5	5
Area, m^2	0.400	0.400	0.400	

Table 2

Test characteristics

Test standard	EN 717-2
Material	wood based panels
Test sample	400 mm x 50 mm x panel thickness
Edge sealing	Yes
Test duration	4 hours
Air flow rate	(60 ± 3) l/h
Temperature	(60 ± 0.5) °C
Humidity	≤ 3%
Pressure	(1000 Pa – 1200 Pa) ± 30 Pa
Emission class according to standard	E1 ≤ 3.5 mg HCHO/ m^{2}h

RESULTS AND DISCUSSIONS

The panels are produced from softwood and/or hardwood particles and fibres bonded with UF resin. UF-resins are fast curing resins recognised for their good performance. However, boards bonded with UF-resins are, in general, of limited moisture resistance and emit detectable amounts of formaldehyde (Roffael *et al.* 2010). Fig. 1 presents the variation of formaldehyde emission (FE) values from PB and MDF panels and from PLY is shown in Fig. 2. The values of formaldehyde emission (FE) from MDF samples (ranging from 3.89 to 6.63mg/m^{2}h) were higher than those from PB and PLY the values exceeding the limit specified in standard 13986 (2005) for E1 class (≤3.5) as is shown in Fig. 1.

MDF samples were classified in E2 class emission (>3.5mg/m^{2}h÷≤8.0mg/m^{2}h). PB and PLY samples had the lowest amount of FE, the values variation between samples is presented in Fig.1.

The formaldehyde emission ranged from 0.38 to 3.48mg/m^{2}h for PB samples and from 2.1 to 2.88mg/^{m2}h, for PLY samples, with an average value of 2.4mg/m2h for both products (Fig. 3). All boards were tested at the same thickness 18mm excepting PLY samples. Therefore, no significant difference between plywood thicknesses was observed as is shown in Figure 2 (PLY 4mm thickness included 3 veneer sheets and PLY 10mm thickness had 7 veneer sheets). Additionally, moisture content values of each sample tested, was included in graphics. The average values of MC for PB, MDF were 6.8%, 6.63% and 8.76% for PLY (Fig. 3). Some research mentioned that poplar plywood formaldehyde emissions decreased with increasing veneer moisture content (Aydin *et al.* 2006). As can be seen in Fig. 1 and 2 no major influence of MC on formaldehyde emission was observed.

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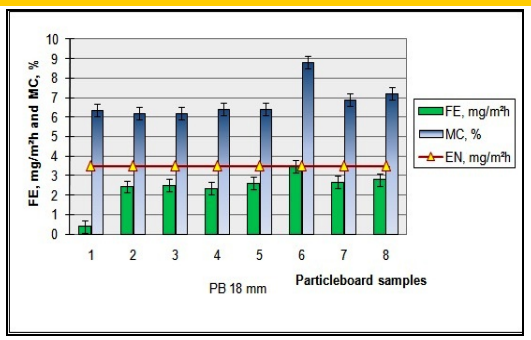

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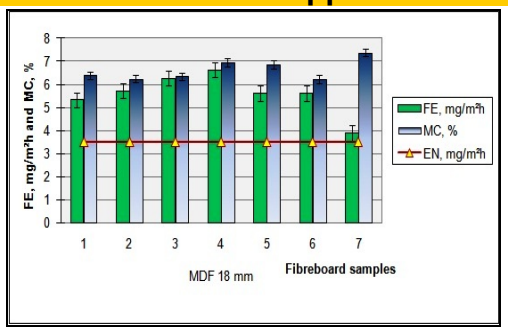

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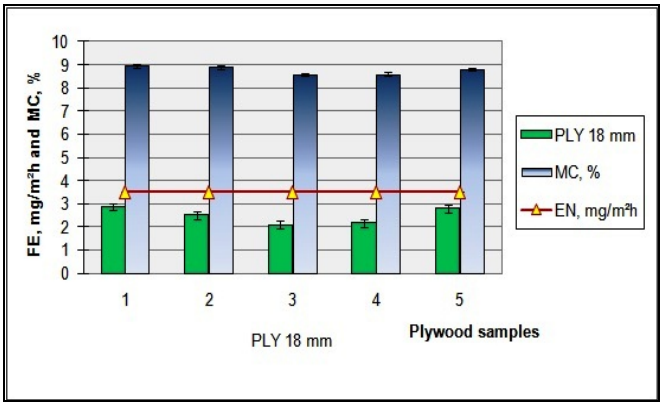
Fig. 1
Formaldehyde emission and MC from PB and MDF compared to EN limit: a - PB 18mm; b - MDF 18mm.



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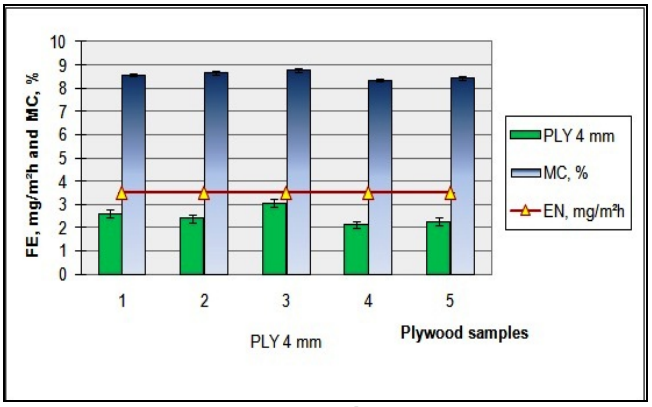

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Fig. 2
Formaldehyde emission and MC from plywood compared to EN limit: a - PLY 18 mm; b - PLY 4 mm.

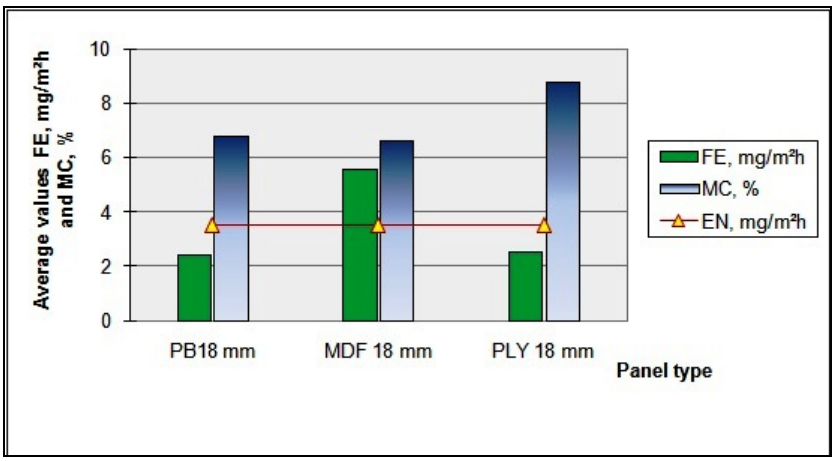

Fig. 3
Formaldehyde emission on different wood–based panels and associated MC.

Obvious variations in formaldehyde emission are found within wood panels and among them due to different factors such as: raw materials, adhesive and additive formulations, synthesis parameters. Basically urea-formaldehyde is the most used resin for wood based composites. Medium density fibreboard contains a higher resin-to-wood ratio than any other UF pressed wood product thus UF could be the responsible for the high formaldehyde emission in MDF samples. It is well known that the reactions leading to the formation of the urea-formaldehyde products are catalyzed by acid, the use of an acid catalyst to accelerate bond cure increases also the rate of hydrolysis and formaldehyde liberation (Conner 1996).

To evaluate the differences between boards an analysis of variance was used (ANOVA). Outputs of the statistical analyses are given in Table 3.

Table 3

ANOVA results for the effects of board type and moisture content on the overall formaldehyde emission values measured from PB, MDF and PLY panels

Source	Type III Sum of Squares	df	Mean Square	F-value	Sig. (P)	Partial Eta Squared
Corrected Model	45,705(a)	3	15,235	24,717	0,000	0,823
Intercept	0,144	1	0,144	,233	0,636	0,014
MC	0,710	1	0,710	1,152	0,299	0,067
Panel_type	40,674	2	20,337	32,995	0,000	0,805
Error	9,862	16	0,616			
Total	305,703	20				
Corrected Total	55,567	19				

a R Squared = 0,823 (Adjusted R Squared = 0,789)

ANOVA analysis was applied in order to evaluate the influence of MC and panel type on FE. The global effect of factors was significant, being expressed through Sig. 0.000<0.05 coefficient. It is noticed that the effect of the two factors is different, but is not significant in case of "MC" factor (Sig. 0.299>0.1).

The value of Sig. 0.000<0.05 coefficient indicates the main significant effect of "panel type" on FE and η^2=0.805>0.50 shows the relation intensity. Thus, the effect of panel type on FE is more important than the one of MC.

CONCLUSIONS

Formaldehyde emission (FE) represents the key issues for wood-based composites sector, therefore only those panels that fulfil the requirements stipulated in regulations and standards at international level are accepted on the market. In this study, the formaldehyde emission from different wood composite, such as, PB, MDF and plywood found on the Romanian market, was measured using gas analysis method. The values measured at the same thickness varied from 0.38 to 6.63mg/m^{2}h depending on the panel type. The lowest emission was measured for PLY samples (2.1 - 2.88mg/m^{2}h) and PB samples (0.38 to 3.48mg/m^{2}h) while MDF samples showed the highest values (3.89 to 6.63mg/m^{2}h). The formaldehyde release level for BP and PLY was in E1 class. The analysis of variance showed that was a significant effect of board type (Sig. = 0.000) on the FE. Generally all panels are manufactured to satisfy the E1 grade in Europe, less than 3.5mg/m^{2}h as indicated in EN 13986 (2005). There are still on the market wood panels which are classified in E2 class as is revealed in this study i.e. MDF panels, which exceeded with about 60% the limit for E1 class. Even most of producers are conscious of necessity to control the quality of their production further changes should make on the concept of products certification and life quality. Furniture made of these boards could be dangerous for people health. Based on the findings, manufacturers and suppliers should raise awareness on the impact that high-emission panels could have on people's health and make efforts to improve the quality of their products in order to meet the new demands for very low formaldehyde emission.

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