Research Article
Araştırma Makalesi
DOI: 10.24011/barofd.425409

Bartın Orman Fakultesi Dergisi,
20 (2): 382-387,
15 Ağustos/August, 2018

Journal of Bartin Faculty of Forestry
p-ISSN :1302-0943
e-ISSN :1308-5875

Formaldehyde Emission Problems and Solution Recommendations on Wood-Based Boards: A review

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Abstract

Wood composite panels are widely used in building, decoration, bridge, pier construction, transportation sectors and furniture production in the world. Formaldehyde which is found from formaldehyde containing adhesive bonded wood composite panels and the wood products above the standard amounts released has a negative impact on the environment and human health. Formaldehyde emission; Depending on the concentration in the environment, exposure time and shape, causes severe allergic reactions in the skin, eye and respiratory system, weakens the immune system, and causes cancer like health problems. In this context, it is concluded that legal arrangements should be prepared for formaldehyde usage, which is used in the production of formaldehyde-containing adhesives, especially wood composite panels, and necessary controls should be made if the adhesives are prepared within the standard limits.

Keywords: Wood based panels, wood composite, formaldehyde, emission

Ahşap Esaslı Levhalarda Formaldehit Emisyon Problemleri ve Çözüm Önerileri

Öz

Ahşap kompozit levhalar dünyada yapı malzemesi olarak inşaat ve dekorasyonda, köprü ve iskele yapımında, taşımacılık sektörü ve mobilya üretiminde yaygın şekilde kullanılmaktadır. Formaldehit içerikli tutkallarla üretilen ahşap kompozit paneller ve bunlardan üretilen malzemelerden salınan formaldehit standartların üzerinde olması çevre ve insan sağlığını olumsuz etkilemektedir. Formaldehit emisyonu; ortamdaki konsantrasyona, maruz kalma süresi ve şekline bağlı olarak deri, göz ve solunum sisteminde ciddi alerjik reaksiyonlara, bağışıklık sistemini zayıflatıcı, kanseri tetikleyici sağlık sorunlarına neden olmaktadır. Bu bağlamda ahşap kompozit panellerin üretimi başta olmak üzere formaldehit içerikli tutkalların üretiminde kullanılan formaldehitin standart sınırlar içerisinde olması konusunda yasal düzenlemeler yapılarak uygulamaya konulmalı ve gerekli denetimler yapılmalıdır.

Anahtar Kelimeler: Ahşap esaslı levhalar, odun kompozitler, formaldehit, emisyon.

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Geliş (Received) : 21.05.2018
Kabul (Accepted) : 04.07.2018
Basım (Published) : 15.08.2018

1. Introduction

Demand for building materials with more positive characteristics in terms of human and environmental health is increasing and these products are preferred more. In addition to being able to produce the wood materials cheap, light, desired colors and designs, they have many positive features in terms of ease of processing, cleaning and maintenance, meeting high demands in terms of physical and mechanical properties, aesthetics, environment and health (Bilgin,2016; Baumann, et. al. 2000; Maloney, 1993; İstek, et. al. 2017a). Wooden materials are widely used in construction, decoration as building materials, in interior spaces, in the construction of bridges, scaffolding in transport sector and in furniture production in the world. When they are evaluated in terms of economy and sustainability among wooden materials, wood composite panels are used more frequently than others (Hematabadi, et. al. 2012; Eroğlu and Usta, 2000; Boran and Usta, 2010).

The disadvantages of wood-based materials include dimensional change under various humidity conditions, coloration, decay, structural deterioration, resistance loss due to biotic and abiotic factors (İstek, et. al. 2017b; Roffael, 2016). Moreover, emissions from synthetic adhesives and chemicals used in the production of wood materials cause significant problems in terms of environmental and human health, depending on the conditions of use. Board products produced with formaldehyde-containing synthetic adhesives cause a variety of diseases, particularly with the release of formaldehyde from indoor use (İstek, et. al. 2017a). During the production of formaldehyde-containing glues, free formaldehyde, which does not form bonds with glue, and formal glue condensation reaction formaldehyde, which comes to the hot press in the board production, is formed. In addition, the results of exposure of the boards to moisture during use, in particular the resultant degradation of formaldehyde in the bonds polymerized by the OH group of the cellulose C6 is the issue. Such kind of disruption causes formaldehyde emission. Emission values on wood-based boards are called E0, E1, E2 and E3 in order to indicate the free formaldehyde content of the glue used in production. According to the EN 120 perforator test that takes place EN 13986 standard, the wood composite sheets have a maximum of 2mg/100g in the E0 glues, 2-8mg/100g in the E1 class, 8-30mg/100g in the E2 class and 30-150mg/100g in the E3 class (Boran and Usta, 2010). Today, most of the board products are produced according to E1 and E2 class, they are required to use of glues such as E0 and E1 plus, we can say without emission (Özlüsoylu and İstek, 2015).

It is stated that as the molar ratio of formaldehyde used in the production of formaldehyde-containing glues increases, the amount of emission increases, especially in the production of UF glue (Que, et. al. 2007). It is emphasized that the formaldehyde emission concentration changes in a wide range (6.5-540 μg/m^3) in living houses and that the emission amount depends on the age of the house, the ambient temperature, the relative humidity, smoking cigarette and the density of wood products (Menteşe and Güllü, 2005). It is stated in previous studies that the formaldehyde emission in wood composite boards is inversely proportional to the material density (Çolak, 2002) the increase of formaldehyde emission output increases with temperature (Kim and Kim, 2005; Wiglusz, et. al., 2002), and the surface and the edges of the coatings reduces formaldehyde emission (Keskin and Tekin, 2015). It is also stated that the formaldehyde emission from timber composite materials decreases in time (Roffael, 2006; Özlüsoylu and İstek, 2015). In this study, the problems related to formaldehyde emissions caused by the use of wood composite panels and the methods applied to solve these problems were investigated.

2. Formaldehyde Emission

Volatile organic compounds (VOCs) occur in living spaces and affect the environment and human health negatively, and free formaldehyde is one of them. After flue gases, the other significant formaldehyde emission sources are furniture and decoration materials produced from wood composite boards, as well as paints, varnishes and polish materials. It is stated in our country that E1 certification system as a formaldehyde emission class in furniture production has started to be applied but it is not a legal obligation (URL-1). In this context, the problems caused by formaldehyde emission and the researches on the prevention of these problems are briefly summarized.

2.1. Problems Relating to Formaldehyde Emission

Formaldehyde is the simplest member of aldehydes that is a colorless, odoriferous, toxic chemical and is transported and stored in a 37% aqueous solution, usually called formalin (URL-2). Formaldehyde; It is used in construction materials, insulation materials, paper coating materials, textile fabric products, especially in the production of glues, paints, varnishes, cosmetics, disinfectants, cleaning materials and wood composite boards (Boran and Usta, 2010; URL-3; URL-4). Formaldehyde has negative effects on humans that can cause serious allergic reactions in the immune system, weakening of the immune system, trigger of cancer, skin, eye and respiratory system diseases. The World Health Organization has incorporated formaldehyde into the class of carcinogenic substances from the class of substances that can cause cancer. Formaldehyde emission has negative

effects on human health due to factors such as concentration in the environment, exposure duration and types (URL-5). Emission of formaldehyde from wood based composites is the most important source of formaldehyde that threatens human health in living spaces. Formaldehyde release continues for a long time after board production, especially at variable temperature and relative humidity conditions. Formaldehyde emission quantities in wood composite panels are classified as E0, E1, E2, E3. Particle boards and fiber boards, which are widely used in the production of furniture and office supplies, are products that emit most formaldehyde. In experiments, emission of formaldehyde and volatile organic compounds has been found after months on new office furniture (Aksakal, et. al., 2005).

Formaldehyde emissions cause respiratory irritation, cough, throat instability, headache, redness in the eyes and burning and heart problems, depending on the amount in the environment. For example, concentrations may range from 0.1-5 ppm in eyes, nose and throat irritation, severe tears over 10 ppm, burning in the nose and throat, difficulty in breathing, and serious illnesses involving lethal pulmonary edema over 25 ppm (URL-6). Studies on humans have emphasized formaldehyde to cause nasopharyngeal cancer, sino-nasal cancer and myeloid leukemia (URL-7). The study conducted by the American National Cancer Institute has shown that there may be a relationship between exposure to formaldehyde and mortality in the blood and lymph system, particularly myeloid leukemia cancer cases (URL-8).

2.2. Formaldehyde Emission Reduction Methods

Over the last decade, due to increased environmental pressures and consumer awareness, legal regulations have been made on formaldehyde emissions in wood composite boards, emission classes have been identified and put into practice. The free formaldehyde in wood composite boards comes out in two ways. One is the free formaldehyde that board production, which does not react with urea in a hot press and is present during the production, or is present in the board structure. The other is free formaldehyde which is released at the place of use by the breakdown of the methyl-ether bonds (decondensation) resulting from temperature and humidity effects (Eroğlu and Usta, 2000). The gas causing formaldehyde emission can be trapped in the board or dissolved in the water in the board (Zhang, et. al. 2013). Studies to reduce formaldehyde emission in wood composite board production can be grouped into three groups. Modification of board production conditions, reduction of formaldehyde content in the glues and the use of formaldehyde-retaining chemicals (Roffael, 2006). The proposed formaldehyde emission reduction solution is summarized below.

- To change the molar ratio of U/F in glue production,
- Chemical formaldehyde bonding materials (urea, tannic acid, amine, ammonia, melamine and cyanoguinidin)
- Development of new glue formulations,
- The usage of alternative adhesives (phenol formaldehyde, isocyanate) to urea formaldehyde adhesives,
- The usage of plant and animal-based glues,
- Nanotechnology and plasma applications,
- Changing production conditions (such as press temperature and pressure).

It is emphasized that these methods have some disadvantages although the alternative methods mentioned reduce the formaldehyde emission to a certain extent. Chemical formaldehyde scavengers, one of the methods used to reduce formaldehyde content, have additional investment cost and price disadvantage due to the necessary equipment of the chemicals to be added to the system (Boran and Usta, 2000). Chemical formaldehyde bonding materials have been shown to adversely affect the curing mechanism of the glue (Puttasukkha, 2015). Lowering the urea / formaldehyde (UF) molar ratio of the UF glue negatively affects the physical and mechanical properties of composite board (Özlusoylu and İstek, 2015). It is emphasized that the formaldehyde and VOC emissions of MDF boards are primarily bonded by UF glue, and that there is a linear relationship between the emission rate and the formaldehyde content of the glue. It is stated that hot press conditions in plate production change formaldehyde and VOC emissions (He, et. al., 2012). It is reported that formaldehyde emissions caused by wood composite boards decreased with the addition of urea to the glue solution, and the physical and mechanical properties were improved (Hematabadi, et. al. 2012). Researchers developed plywood for use in formaldehyde-free indoor environment containing soy flour and hardener, and evaluated three different plywood panels with different tree species and resistance to water (Jang, et. al. 2011). It is indicated that in terms of emission values and board properties, low formaldehyde emission chipboards are found suitable for indoor use by applying methyl-diphenol-diisocyanate (PMDI) adhesive (Wang, et. al. 2007).

Tannin is used as a formaldehyde scavenger in MDF sheets and is stated to reduce emissions. In addition, it is explained that formaldehyde release in wood composite boards is affected by external factors such as moisture, air exchange and temperature, and by internal factors such as raw material type, resin type and production conditions (Boran, et. al., 2011). Different studies have indicated that natural and bio-based formaldehyde bonding materials with different properties can be successfully used to reduce the emission of formaldehyde from wood-based composite materials (Eom, et. al., 2006; Kim, 2009; Kim, et. al., 2006; Boran, et. al., 2011; Costa, et. al., 2012; Park, et. al., 2008; Costa, et. al., 2013). The effect of propylamine as a formaldehyde scavenger in particleboard production was investigated and has been reported that the use of 1% propylamine has successfully reduced formaldehyde emission levels (Ghani, et. al., 2017). Melamine urea formaldehyde has been reported to have a linear decrease in the amount of formaldehyde in plywood panels produced with different press durations due to the increase in press time (Aydın, et. al., 2011).

It is understood that wood composite boards cause different emissions in different places of use. It was also found that the properties of the glue used in the board production and the board type affected the amount of emission. If the current limit values of formaldehyde emission are thought to be further reduced in the future, it is obvious that further studies on this subject are needed. It is seen that positive results are obtained when studies related to reducing the emission of formaldehyde from past to present are examined. However, in many studies it has been pointed out that the properties of wood composite panels produced from low-emission glues are reduced, costs are increased, their use is not sustainable, or there are different problems in practice or afterwards.

3. Conclusions and Recommendations

Formaldehyde emissions from building materials produced from wood composite panels present some risks to human health, especially in enclosed environments. Formaldehyde emissions can cause diseases ranging from severe allergic reactions in the skin, eyes and respiratory tract to cancer, depending on the concentration to which they are exposed. Formaldehyde emission classes have been identified in wood composite board production. After the formaldehyde content of the panel products has been measured by the methods specified in the standards, it must be specified which emission class it belongs to. Usage areas of panels should be evaluated according to these classes. As health concerns have increased, producers and consumers have become more conscious and emission values for wood composite board products have been decreased year by year. However, final users and workers in the production of formaldehyde-based products still face with some disease risks. Today, as the methods that can be used to solve this problem; options such as using low-emission glue prescriptions, adding formaldehyde-retaining chemicals to formaldehyde-containing adhesives, using different glue mixtures, or choosing alternative bio-based glues are recommended. Glues with lower formaldehyde content (E0, E1) has lower bonding capacity than those with higher formaldehyde (E2, E3) glues. Therefore, gluing performance of low formaldehyde-containing glues is poor, and they must be used in larger amounts for board production. And these increases the costs, decrease board properties and adversely affect the potential of commercial competition. Disruption of glue bonding in formaldehyde-containing binders is due to temperature and relative humidity in the application areas. Board products to be used in areas with high temperature must be produced using lower formaldehyde-containing binders or formaldehyde-retaining chemicals. Also, keeping the panels for long periods in storage before the lamination will reduce emissions. However, consumers should also ventilate the rooms frequently in the winter months, especially in the indoor environment, to reduce VOC and other emissions that accumulate in the environment. In addition, it is recommended that when consumers buy products manufactured from wood based panels, they should request at least an E1 certification document. It is concluded that, for Turkey, legal regulations and standards must be made on the application of VOCs and free formaldehyde emission for materials produced, as in many developed countries.

Acknowledge

This work was presented as oral presentation at International Conference on Engineering Technologies (ICENTE'17).

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