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An assessment of formaldehyde emissions from laminate flooring manufactured in China

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ABSTRACT

Formaldehyde emissions from two laminate flooring products, labeled as California Air Resources Board (CARB) compliant, were evaluated. Passive 24-hr samples (n = 79) and real-time measurements were collected following installation and removal of the products in two rooms of similar size. Mean formaldehyde concentrations following installation were 0.038 and 0.022 ppm for Products 1 and 2 respectively, and 7 days after flooring removal the concentrations returned to background pre-installation levels. Both products were also evaluated in a small chamber (ASTM D6007) using Deconstructive (de-laminated product) and Non-Deconstructive (intact product) methods. Deconstructive testing showed that Product 1 exceeded the applicable CARB emission standard by 4-fold, while Product 2 was equivalent to the standard. Non-Deconstructive measurements were far below the Deconstructive results and were used to predict 24-hr steady-state room air concentrations. Based on the products that we tested (one of which was found to not be compliant with the CARB standard), the airborne formaldehyde concentrations measured following installation in a real-world setting would not be expected to elicit adverse acute health effects.

1. Introduction

Formaldehyde is a colorless, reactive, volatile organic compound that is ubiquitous in the environment (ATSDR, 1999). Common emission sources of formaldehyde (i.e., contributors to exposures in the general population) include fossil fuel combustion, tobacco smoke, and the use of certain building materials. The most sensitive acute non-cancer health endpoint associated with exposure to airborne formaldehyde is eye irritation; at higher exposures, respiratory irritation and immunological and neurological effects may occur. Formaldehyde is also considered by various agencies to be a known (IARC, 2006; NTP, 2014), suspected (IARC, 2006), probable (USEPA, 2010), or potential (NIOSH, 1988) human carcinogen.

It has long been understood that composite wood products bonded with urea-formaldehyde (UF) and phenol-formaldehyde (PF) resins may release formaldehyde (USDA, 1986). The synthesis of a UF resin takes place in two stages. In the first stage, urea is hydroxymethylated by the addition of formaldehyde to the amino groups, forming mono-, di-, and trimethylolureas (Conner, 1996). In the second stage, the methylolureas are condensed to low molecular weight polymers (Conner, 1996). UF resins are primarily used in the manufacture of products, such as hardwood and softwood plywood, oriented strandboard, medium- and high-density fiberboard (MDF and HDF), and waferboard for indoor applications (e.g., laminate flooring, wall paneling). Overall, UF is the most commonly used thermosetting resin for composite wood products, primarily due to its low cost, resistance to microorganisms, hardiness, excellent thermal properties, and lack of color (Conner, 1996; Meyer and Hermanns, 1985; USDA, 1986). PF, on the other hand, is the most commonly used binder in products used for exterior or moist environment applications due to its water resistance, though the cost of this resin is significantly greater than that of UF resins (Conner, 1996). The vast majority of formaldehyde in PF resins is consumed during the curing process, and the release of formaldehyde from PF products is typically considered to be negligible (Dunky, 1998; USDA, 1999). Any health concerns related to formaldehyde release from wood composites have, therefore, been

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primarily limited to UF products.

Extensive research related to indoor air formaldehyde concentrations began in the mid-to-late-1980s following proposed or anticipated regulatory actions regarding residential exposures and associated health effects. As a result, over the past few decades numerous studies in the U.S. have reported indoor air formaldehyde levels in buildings and homes with laminate floors, cabinets, and furniture. For example, the U.S. Environmental Protection Agency (EPA) reported formaldehyde concentrations ranging from 0.004 ppm (5th percentile) to 0.026 ppm (95th percentile) in 100 office buildings between 1994 and 1998 (USEPA, 2015c, 2015a); concentrations up to 1.01 ppm have been measured in offices with inadequate ventilation (ATSDR, 1999). Studies have also shown that formaldehyde in tobacco smoke may contribute significantly to indoor air concentrations (ATSDR, 1999). Although residual formaldehyde levels in the resins used in older composite wood products were generally higher than in modern versions, airborne formaldehyde concentrations in older structures tend to be lower due to depletion of the formaldehyde source over time. For example, recent studies have reported indoor formaldehyde concentrations ranging from 0.014 ppm to 0.45 ppm in newly constructed homes and from 0.03 ppm to 0.05 ppm in older homes (ATSDR, 1999, 2010).

Currently, there are no federal regulations governing residual formaldehyde levels in composite wood products. In 2010, the United States Congress signed into law the Formaldehyde Emissions Standards for Composite Wood Products as Title VI of the Toxic Substances Control Act (TSCA) (USEPA, 2015b). According to the U.S. EPA, the final rule was expected to be released in late 2015; however, an updated completion date has not been provided (USEPA, 2015b). The proposed rules, as they apply to laminate wood products, are similar to the California Air Toxic Control Measure (ATCM) regulation (CARB, 2008). This regulation, which was adopted in 2007, established two phases of emissions standards that were intended to result in "a reduction in formaldehyde emissions, total public exposure, and excess cancer risk in California" (CARB, 2007): an initial Phase 1, and later, a more stringent Phase 2, required all finished goods, such as flooring, destined for sale or use in California to be comprised of only compliant composite wood products (CARB, 2015a). As of January 2014, only Phase 2 compliant products are legal for sale in California.

The California regulation specifically applies to formaldehyde emissions from UF-containing products, such as hardwood plywood (HWPW), particleboard, and MDF, as well as furniture and other finished goods made with composite wood products (CARB, 2015b). HDF products may be labeled as compliant if they (1) meet the MDF emission standard and (2) "are marketed for use in typical MDF applications[,] such as furniture manufacturing, shelving, molding, and kitchen cabinets" (CARB, 2015b). The California regulations, promulgated by the California Air Resources Board (CARB) and typically referred to as "CARB Phase 2", specify the "maximum concentration" of formaldehyde allowed in a testing chamber after the UF-containing wood composite sample has been present in the test chamber for a specified period of time, using testing protocols such ASTM E1333-96 (ASTM International, 2002a) or ASTM D6007-02 (ASTM International, 2002b). Labels are used to signify compliance with the CARB emission standards and are mandatory for products sold in California.

Recently, some health concerns have been raised regarding formaldehyde emissions from laminate flooring products that are manufactured in China and sold in the U.S. Initial complaints lodged by consumers included foul odor, development of headaches, and skin, eye and throat irritation. Elevated levels of formaldehyde, based on indoor air testing after installation of the flooring products, were also reported (Zhou, 2013). Subsequently, emission testing results for a limited number of flooring samples were posted online and submitted in a letter to the Chairman of CARB (Zhou, 2013). Although the tested products were labeled as CARB Phase 2 compliant, emission results for one of the HWPW products exceeded the applicable CARB limit by over 3-fold. Concerns increased with the airing of a national news special on formaldehyde emissions from Chinese laminate flooring products, wherein it was reported that, of 31 MDF and HDF products purchased nationwide, 30 exceeded the applicable CARB Phase 2 limit, in some cases by up to 13-fold (BMH, 2014a, 2014b, 2014c, 2014d, 2014e, 2014f, 2014g, 2014h, 2014i, 2014j, 2014k, 2014l, 2014m, 2014n, 2014o, 2014p; HPVA, 2014a, 2014b, 2014c, 2014d, 2014e, 2014f, 2014g, 2014h, 2014i, 2014j, 2014k, 2014l, 2014m, 2014n, 2014o; 60 Minutes 2015). The U.S. Consumer Product Safety Commission (CPSC) and the Agency for Toxic Substances and Disease Registry (ATSDR) have since released the results of their investigation into the safety of laminate flooring (ATSDR, 2016), and several class-action lawsuits have been filed.

At the same time, some scientists have questioned the relevance of emission test results with respect to actual exposure conditions and potential health risks. In general, chamber test results do not reflect "real-world" exposures that might occur with much larger room dimensions and higher air exchange rates. As noted in a formaldehyde technical guide and consumer fact sheet recently released by the American Industrial Hygiene Association (AIHA), "[c]hamber tests of flooring samples can produce accurate formaldehyde emissions, but they do not necessarily represent in-home conditions" (AIHA, 2015). Also, it is important to note that the CARB formaldehyde standards are not specifically health-based. They are instead "control measures" intended to "limit formaldehyde emissions … to the maximum amount feasible" (CARB, 2007).

We are unaware of published chamber emission tests involving Chinese wood composite products and the aforementioned CARB compliance testing method, nor do there appear to be any published comparative studies in which a specific laminate flooring product was tested in both a chamber study and in a controlled, room-scale environment. In this analysis, we evaluated formaldehyde emissions from two different Chinese HDF laminate flooring products, both of which were evaluated in the aforementioned study (HPVA, 2014b, 2014n; BMH, 2014e), using small chamber testing of both the delaminated (Deconstructive Testing) and intact (Non-Deconstructive Testing) products. Deconstructive Testing results were compared to the applicable CARB Phase 2 standard and the findings previously reported for these products (BMH, 2014e; HPVA, 2014b, 2014n). Using standard modeling techniques and the results of the Non-Deconstructive Testing, the steady-state concentrations resulting from real world use of the two products were predicted and compared to actual measured levels under simulated consumer use conditions in which the intact laminate products were used as flooring. We conclude with a discussion of the various formaldehyde exposure standards, the potential health effects associated with the use of these particular products, and areas for future research.

2. Methods

This study took place over the course of 63 days from April to June of 2015 in an office building in Chicago, IL.

2.1. Study materials

Six packages each of two types of HDF laminate flooring products were purchased on March 31, 2015, from a single manufacturer. The materials were selected because (1) HDF products are widely used by U.S. consumers, and (2) these particular products