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Flame Retardants For Wood And Combustion Characteristics Of Flame Retardant Treated Wood – A Short Review

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Abstract:
This paper reviewed how to apply flame retardants to wood and improve the flame retardant performance of wood, and the need to improve wood as a sustainable building material. Wood has been a basic building material for thousands of years, and offers advantages such as renewability. However, its natural vulnerability to fire raises safety concerns. Meeting fire safety standards is essential for its use as a construction material, and this study explores various methods to improve the flame retardancy of wood, particularly vacuum pressure impregnation. Previous papers reviewed various flame retardants, including inorganic compounds such as silica nanosols, ammonium polyphosphate, sodium silicate, and ammonium borate. They evaluated their efficacy in improving fire safety by reducing heat release rate, total heat release, and smoke production. These studies show that treated wood exhibits significantly improved flame retardant properties while reducing flammability and smoke emissions. This paper highlights the potential of using treated wood in construction to meet environmental and safety standards. We also identified the need for continued research and development on efficient and environmentally friendly flame retardants and flame retardant treatment methods for wood.

Keywords: *Wood material, Flame retardant, Vacuum pressure impregnation, Building material, Combustion properties of wood.*

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I. INTRODUCTION

In addressing the serious issue of climate change, reducing energy use and greenhouse gas emissions, particularly carbon dioxide emissions, has become a global concern [1]. The construction sector, in particular, faces significant challenges in conserving natural resources and reducing carbon emissions [2].

For thousands of years, wood has been used as a primary building material and a major source of furniture in the construction industry [3,4]. Wood offers environmental benefits such as renewability, sustainability, and minimal energy loss through production and disposal. Therefore, increasing the use of wood in construction can be a strategy to reduce carbon emissions [5,6].

However, wood as a building material has natural disadvantages, one of which is its susceptibility to fire. This poses a concern related to human safety and life. Standards for fire safety of building materials are set by countries around the world. To use wood as a building material, it needs to meet these fire safety standards, necessitating fire retardant treatments, for which various methods have been proposed [7,8].

There are two primary methods for applying fire retardant treatments to wood: coating with fire retardant substances and impregnating the pores of wood under vacuum pressure [9,10]. Generally, impregnation is a more advantageous method than coating for introducing fire retardant properties to wood [11].

The significance of fire retardant impregnation of wood lies in its accompanying enhancement of fire retardancy. Therefore, investigating the fire retardancy of wood after treatment is essential. In the case of intumescent flame retardants mainly treated on wood[13] that is heated, the carbonizing catalyst causes the carbonizing agent to dehydrate into carbon, and the carbides form a carbon layer with a fluffy porous closed structure under the influence of the gas produced when the intumescent agent is broken down. Once created, it is not flammable in and of itself and reduces heat transfer from the heat source to the wood, which stops the gas from spreading. The wood will self-extinguish if there is insufficient oxygen and fuel for burning[14]. Adding intumescent biomass flame-retardant is one of the easiest, most economical, and most effective ways to improve the flame retardancy of wood surfaces [15].

In this paper, previous studies were reviewed to investigate the resulting flame retardant performance of wood with wood flame retardants applied.

II. LITERATURE REVIEW AND DISCUSSION

*FPI: fire performance index; pHRR: peak of heat release rate; THR: total heat release; TSR: total smoke release; pSPR: peak of smoke production rate.

In a paper published by Luming Li et al. (2021), a water-soluble flame retardant consisting of bio-resourced phytic acid (PA), hydrolyzed collagen (HC), and glycerol (GL), was used to improve the flame retardancy of wood ("PHG/wood"). PHG-C30/wood samples have significantly higher fire safety compared to pure wood. The fire performance index (FPI) for PHG-C30/wood (concentration of the flame retardant solution = 30%) was 75% higher, indicating a lower combustion risk. The peak of heat release rate (pHRR) and total heat release (THR) for PHG-C30/wood was 178.5 kW/m² and 28.2 MJ/m², respectively, which are 47.7% and 54.7% lower than those of pure wood. Smoke emissions were also substantially reduced in the PHG/wood samples. The total smoke release (TSR) of the PHG-C20/wood (concentration of the flame retardant solution = 20%) sample was the lowest at 40 m²/m², 15.75% lower than pure wood. Additionally, at the end of the experiment, the final char residue of PHG-C30/wood was 22.1%, about six times higher than that of pure wood. These results indicate that PHG/wood offers a higher standard of fire safety compared to pure wood.[16]

This paper enhances the flame retardancy of wood using a phytic acid (PA) and silica nanosol hybrid system. Poplar wood from Liaoning, China, was treated with PA and silica nanosol through vacuum-pressure impregnation. Pristine Wood (the control group) was impregnated with deionized water. PA/Wood was impregnated with a solution of PA (phytic acid [PA, 70%, aqueous solution]); and PS/Wood was impregnated with the PA–silica nanosol (SiO_2 content = 30%, pH = 10.46, Na_2O < 0.1%). The treated wood, particularly the PS/Wood group, showed significantly higher flame retardancy, evidenced by a higher limited oxygen index (LOI) and reduced peak heat release rates (PHRR) in combustion tests. Additionally, the treatment resulted in lower smoke production and increased char residue, indicating improved thermal stability. Importantly, these enhancements in fire safety properties did not adversely affect the wood's mechanical strength. The study demonstrates an effective method to increase the fire safety of wood materials without compromising their structural integrity.[17]

In this study, furfurylated wood (FW) treated with ammonium polyphosphate (APP) and FW/APP/SiO_2 showed significantly lower heat release rates (HRR) compared to original wood (OW) and untreated FW. The total heat release (THR) was reduced by 46.7% and 50.0% for FW/APP and FW/APP/SiO_2, respectively. The addition of APP enhanced char formation, creating a dense, stable protective layer during combustion that isolates heat and blocks combustible gases. APP also acts as a gas source, with generated NH_3 diluting flammable gases, and produces reactive P-containing radicals that capture radicals in the air, contributing to its flame-retardant properties.[18]

The fire retardant performance of inorganic fire retardant-treated wood was investigated. Sodium silicate, ammonium phosphate, and ammonium borate were effective in the fire retardance of the wood. The effective chemical combination, 50% sodium silicate and 3% ammonium borate, accounts for grade 3 of the KS F ISO 5660-1 standards (Reaction to fire tests — Heat release, smoke production and mass loss rate — Part 1: Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement). Also, the retardant-treated wood could reduce CO_2 gas emissions [19].

In this study, pine wood (*Pinus densiflora*) was treated with fire-retardant chemicals using pressure impregnation to enhance its fire resistance. The treatment effectively delayed the heat release time and significantly reduced the total heat release (THR) value from 84.68 MJ/m² for untreated wood to 14.34 MJ/m², indicating improved fire retardancy. The lower slope of THR curves in burning tests further confirmed this enhancement. The use of boric acid and cyanide ions contributed to a lower thermal decomposition temperature and higher char yield. A specific specimen, the FRTW-pressure, showed a THR of less than 8 MJ/m² within 5 minutes, meeting the standards for fire-retardant materials. These results demonstrate that fire-retardant-treated wood is a safer material for building interiors than natural wood, underscoring the importance of fire-retardant chemicals and their treatment process for effective fire safety.[20]

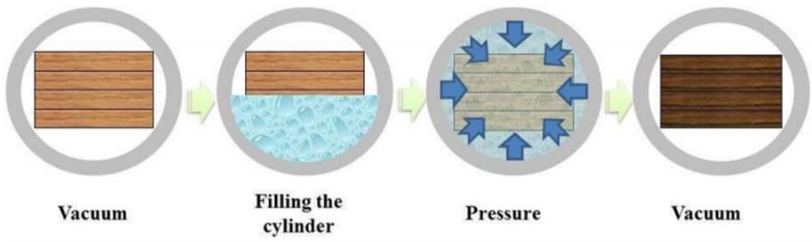

Fig. 1. Vacuum and pressure processing to treat flame retardants.[20]

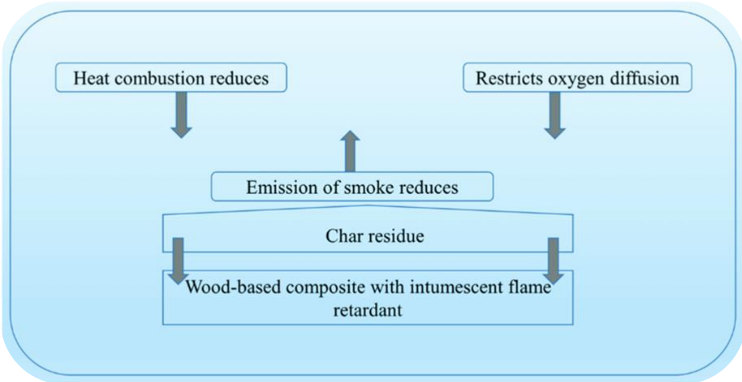

Fig. 2. Intumescent flame retardant mechanism [21]

III. CONCLUSION

In this study, flame retardants and the flame retardancy of treated wood are summarized. According to previous research, the vacuum pressure impregnation method shown in Figure 1 was mainly selected for treating wood with flame retardants. As a result, it was confirmed that the flame retardant was impregnated into the wood and improved its performance.

The application of wood has grown along with human society, and research on the quality of wood that has been given flame retardancy for fire safety as a building material will continue.

Previous research investigated in this study mainly confirmed the improvement of the flame retardant performance of wood through the formation of charcoal and heat blocking during combustion by impregnating wood with intumescent flame retardants.

It is known that methods for improving the flame retardant performance of wood include surface coating with flame-retardant materials and special treatment of wood. However, this study focused on improving the flame retardant performance of wood treated with flame retardants.

As a result of continued concerns about human development and environmental issues, research to overcome the flammability of wood will continue, and we hope this short review paper can be used for future research and reference. In the future, new and better technologies are expected to be developed to ensure the economic viability of flame-retardant-treated wood.

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