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Identification and Performance Analysis of Eco-friendly Fire Retardant on Wood Surface Specimen with Water-based Paint

Jayandran Mohan[1], **J.Aravind Kumar**[2*]
[1]Ph d Student, Sathyabama Institute of Science & Technology Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai - 600 119. Tamil Nadu, India, Email: Jayndranhse@gmail.com Orcid
[2*]Professor, Department of Energy and Environmental Engineering, Saveetha School of Engineering, SIMATS, Saveetha University, Thandalam, Kanchipuram - Chennai -602105 Tamilnadu, India, Email: aravindkumarj.sse@saveetha.com

***Corresponding Author:** Dr. J. Aravind Kumar
Professor, Department of Energy and Environmental Engineering, Saveetha Nagar, Saveetha School of Engineering, SIMATS, Saveetha University, Thandalam, Kanchipuram - Chennai -602105 Tamilnadu, India, Email: aravindkumarj.sse@saveetha.com

ABSTRACT
Fire Retardant are the effective passive controls which have the efficiency to control the spread of fire also it is an important control aspect in Fire Safety. But when they exposed to fire some of the Fire retardant release smoke which may not be eco-friendly. So, eco-friendly fire retardant additives have been studied and their fire resisting performance has been analyzed. The fire-retardant material has been mixed with Water based paint separately. This substrate has been applied on the Wood testing surface and the Do It Yourself (DIY) experiment has been carried out. The five performance criteria have been identified and the eco friendly fire retardant performance have been determined.

Keywords: Eco friendly , Water based paint, Fire retardant additive, DIY

1. INTRODUCTION

A fire retardant is a substance that slows down or stops the spread of fire, or reduces its intensity. Fire retardants can be used in a variety of ways, including: (I) Applied to surfaces Fire retardants can be applied as a coating; (ii) Spray to prevent fires from starting. The Fire Retardant will work in three phases [(1)] like Decomposition, Gas Phase Mechanism and Condensed p h a s e mechanism. While the Fire Retardant has be exposed to fire, it will go through the above-mentioned phases that it releases smokes which may cause environment impact. Currently, the following Fire Retardants have been used in the industry like Poly brominated Di phenyl Ethers (PBDEs), Hexabromocyclododecane (HBCD)* and Chlorinated Paraffin. Apart from Ammonium Poly phosphate most of the above-mentioned fire retardants have been banned in many countries because of their anticipated environmental impacts. These impacts includes Persistence in environment, Bio accumulation in wildlife and humans , Toxicity to aquatic and terrestrial life, Endocrine disruption and Cancer & reproductive issues.

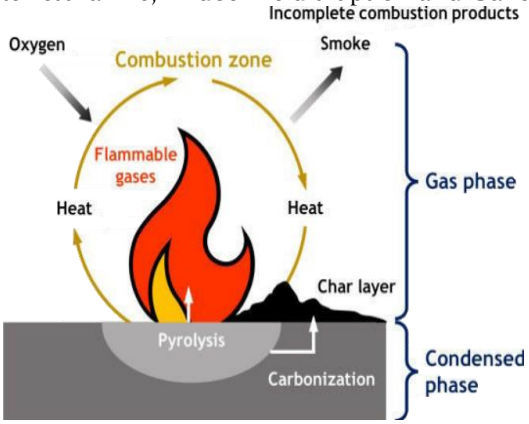

Fig 1.1 Fire Retardant Mechanism

So eventually research has been initiated to find out the effective eco friendly fire retardant (FR) which includes Halogen-free phosphorus-based FRs , Nitrogen-based FRs (e.g., melamine), Inorganic FRs (e.g., Aluminum Hydroxide), Bio-based FRs (e.g., derived from plants) and Nano material-based FRs. This research focuses on identifying the effective eco friendly fire retardant coating along with the water based paint near and in around LPG storage area as well as on the LPG bullet.

1.1 Do It Yourself (DIY) Experiment

The ultimate idea of research is to identify solution either for the existing technical issues or to enhance the existing controls/solutions so as to improve the process. In Process Safety, researches are going to find the solutions for the unexpected process incidents or to improve the controls so that the process oriented incidents can be controlled effectively. The Do It Yourself (DIY)[2] experiments are the type of methods where the pilot laboratory or experimental set up conducted by individuals or like minded people based on self built equipment/methods in the optimal cost with innovative ideas. The primary advantages are the creativity and methodology can be developed on own which is an important aspect required for a researcher. It will improve the practical skill and the rapid prototyping so that the experiments can be carried out fastly. If the researcher is unable to access the lab facilities or if the equipment is not available or unable to procure in the research institution, DIY experiment will be the best option. The disadvantages of DIY experiments are lack of precision, limited equipment, likelihood of more errors. The above-mentioned Eco-friendly fire-retardant experiment has been carried out as DIY category. Based on the going fire retardant studies relevant equipment and lab set up has been done. This DIY experimental results should be considered as suggestive input and further elaborative formal experiments are recommended

1.2 Eco friendly Fire Retardants

The following Fire retardants have been used in the industry like., Polybrominated Diphenyl Ethers (PBDEs), Hexabromocyclododecane (HBCD), Chlorinated Paraffins. Most of these fire retardants have the following environmental concern like Persistence in environment, Accumulation in wildlife and humans, Toxicity to aquatic and terrestrial life and Endocrine disruption. To overcome these environmental impacts, eco friendly fire retardant research is in progress. In this research the following fire retardant additive like Tartaric Acid, Ammonium Phosphate and Nano Silica have been considered. Tartaric Acid ($C_4H_6O_6$)[3] can be derived from natural sources like grapes also from other citrus fruits like orange, lemon with the process of fermentation, extraction and purification. Tartaric Acid is biodegradable, non toxic and they cause low environmental impact. It is slightly skin and eye irritant. As a Fire Retardant it is a moderate flame inhibition and thermal stability in nature. Ammonium Phopshate $(NH_4)_3PO_4$ can be synthesized through the reaction of ammonia (NH_3) and phosporic acid (H_3PO_4) also It can be derived either from organic waste or from bio based phosphorus sources like fish bone etc. The ammonium phosphate is a non toxic bio degradable fire retardant[4] having excellent flame inhibition and thermal stability which potential release of ammonia. Nano Silica (SiO_2) can be derived naturally from silica sand or by the chemical synthesis like Sol-gel process or Precipitation method. The rice husk ash, fly ash and bio based silica sources are the alternate sources for Nano Silica. It is a biodegradable, non toxic, low environmental impact fire retardant[5] with excellent thermal insulation and flame inhibition properties. The paint based used in this experiment is Acrylic water based paint which is environmentally friendly and Low odor in nature.

2. MATERIALS AND METHODS

The following materials and DIY laboratory set up have been arranged to carry out the fire retardant performance analysis experiment.

2.1 Materials

(I) Jenson & Nicholson Universal Primer (Composition) : Epoxy Resin (40-60%), Poly amide Resin (20-40%), Solvents (10-30%):, Additives (5-10%), UV stabilizers, anti-settling agents, and wetting agents; Pigments (5-10%):

Titanium dioxide (white),*Film Thickness 40 micron thickness/coat,*
Drying time 30 mins- 01 Hour
(ii) Shine Ultra Water based paint (Composition): *Water (50-80%), Pigments (10-30%) , Binder (acrylic) and Additives (thickeners, surfactants, UV stabilizers); Film*
Thickness 40 micron thickness/coat,

Fig 1.2 DIY Experiment Resources

Drying time 24 hrs
(iii) Flame Torch: *Maximum Temperature: 60 deg Centigrade; Torch distance between the testing surface & flame torch: 6.5 cm; Flame length from the torch towards testing surface : 4.5 cm; Volume of Torch (propane container volume) 215 cubic centimeter.*
(iv) (IR) thermometer – Max Range 110 degree centigrade
(v) Pine Wood substrate Dimension: 7.5 cm x 7.5 cm x 1 cm and to measure the smoke spread vertical traveling time, vertical measurement of 3.75 cm has been marked from the center point.

2.2 Methods

The DIY experiment setup and the research execution methods are based on the following standards: ***(9,10,11)***
Based on the literature study, the following procedure has been followed and the experiment has been carried out:
a) In the wood specimen, from the center vertical distance (Vertical Traveling -VT) has been marked so as to determine the smoke spread for a specific distance in a given time
b) The proposed eco-friendly fire retardants (10%) have been mixed with Water paint to form a Fire-Retardant Coating blend
c) Wood specimen has been double coated with the above blend
d) The wood specimen has been allowed to dry for 24 hours
e) The Wood specimen has been aligned on the heat-resistant stand
f) Flame torch has been exposed on the specimen for 5 minutes

3 Theory/Calculation

The following performance criteria have been considered to determine the effectiveness of the fire retardant coating that has been applied on the wood specimen
Performance Criteria I : Smoke Spread (Vertical Traveling Time – VT in min:secs)
Time taken for the Smoke to Spread from center point to vertical distance of 3.75 cm . Longer time for the smoke spread is preferable which shows the effectiveness of the Smoke suppression property.
Performance Criteria II : Rear Surface Temperature in Deg Centigrade
Wood Specimen Rear side temperature has been measured for every 1 min to till 5 min to know the heat resistant ability of the fire retardant. Low back temperature is preferable which indicates higher thermal insulation property.
Performance Criteria III : Exposed Surface (front) in Deg Centigrade
Temperature will be measured @ 5^{th} minute to know the heat resistant ability of the fire retardant. Low front temperature is preferable.
Performance Criteria IV: Time for Initial Ignition in Minutes/Seconds
Time at which the first ignition starts . Longer time is preferable which shows the fire resistant nature.

Performance Criteria V: Visual Observation of Char on the sample . The more char formation is highly preferable which indicates the Fire Retardant effectiveness.

RESULTS

The experiment has been carried out as per the above mentioned procedure and the results have been tabulated as below with the required performance criteria so as to determine the effectiveness of Eco-friendly fire retardant with the water based paint.

Eco Friendly Fire Retardant & Water Based paint blend Performance Data									
Paint: Water Based	Time for initial ignition (TTI)	Rear Surface Temperature					Exposed Surface	Smoke spread @3.5 cm	Visual Observation
Fire Retardant (10% concentration)		1 min	2 min	3 min	4 min	5 min	Temp @ 5 min	(Vertical Travelling -VT)	(Char Formation)
Tartaric acid $C_4H_6O_6$	51 sec	29	29.3	29.4	35.8	43	66.3	3 min	Low-Moderate
Ammonium Phosphate $(NH_4)_3PO_4$	21 sec	30.4	31.6	38.6	39	39.3	60.1	2.1 min	High
Nano Silica SiO_2	2 min 42 sec	29.8	31.5	32.4	33	34.5	48	3.5 min	Moderate -High

Table 1.1 Eco friendly Fire Retardant Performance Data (Temp in Deg C)

To determine the level of char formation on the wood specimen, visual observation has been done.

10% Tartaric Acid 10% Ammonium Phosphate 10% Nano Silica

Fig 1.3 Char Formation

DISCUSSIONS

The following points can be inferred from the Table 1.1 & Fig 1.3

The *Time for Initial ignition (TTI)* for Nano-Silica based fire retardant coating has started around 2 minutes 42 seconds which indicates the higher fire resistant property. The *Rear Surface Temperature* at 5^{th} minute for Nano silica coating is 34.5 degree Centigrade which is much lower than Tartaric and Ammonium Phosphate fire retardant coating indicates that Nano-Silica coating has higher thermal insulation. The Exposed (front) Surface temperature at 5^{th} minute is 48 degree Centigrade for Nano Silica which is much lower than other two fire retardant coatings shows the higher heat resistant. The *Smoke spread (Vertical Traveling Time)* is 2 minutes & 1 seconds for Ammonium Phosphate which is lower than the Tartaric acid and Nano Silica. Also by visual observation it is very clear that the *Char formation* is moderate to high in both Ammonium Phosphate and Nano Silica fire retardant coating.

CONCLUSION

The DIY experiment is intended to identify the eco friendly fire retardant and to evaluate the effectiveness of them with Acrylic water based paint. After the literature study the characteristics and mechanism of fire retardants have been understood. The eco friendly fire retardant and the standards for evaluating the fire retardant effectiveness have been analyzed. Based on these findings, the DIY experimental set up and the performance criteria have been identified. After this process, the identified eco friendly additives like Tartaric acid, Ammonium Phosphate and Nano Silica have been mixed separately with Water based paint and the fire retardant coating has been formulated.The coating has been applied on the pine wood and the experiment has been carried. By analyzing the experimental results the Nano Silica Fire retardant performed well in initial ignition temperature

(higher fire resistant property), rear surface temperature (higher thermal insulation), Exposed (front) surface temperature (higher heat resistant) aspects. But, Ammonium Phosphate Fire retardant performance is slightly higher than Nano Silica in smoke spread vertical travel time (smoke suppression efficiency) and Char formation. So, overall in this experiment, Nano Silica can be considered as a higher performing Fire retardant and it has been recommended to attempt for hybrid fire retardant of Ammonium Phosphate and Nano Silica for further research progression.

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