Some Properties of Thermoplastic Composites Filled with Fire Retardants and Sanddust from Medium Density Fiberboard

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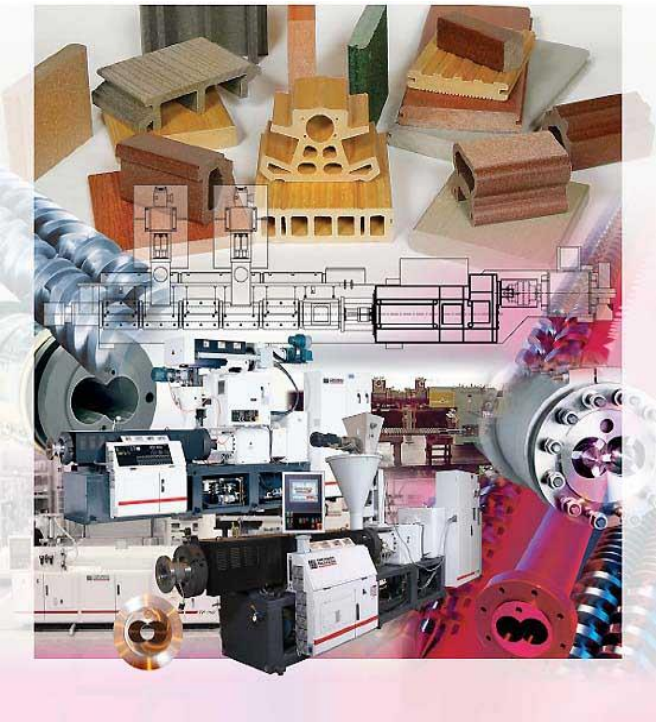
Wood plastic composites

Wood-plastic composites (WPC) are manufactured with the incorporation of wood fibers or flours into the thermoplastic matrix as filler or reinforcer.



WPC has lower cost and environmental advantages over plastic and good resistance against moisture, decay and termites, lower repair and renew costs, etc. over wood and wood based panels.

Wood plastic composites application

WPCs have wide application areas (decks, walkways, automobile industry, house hold applications, fence, door and window frames, music and sports materials, etc.) due to the their advantages over both the plastic and wood material

Wood and lignocellulosic materials in WPC

- Wood fiber and flour
- Agricultural wastes
  - **wheat straw,**
  - **corn stalks,**
  - **flax straw,**
  - **corn cob,**
  - **rice husk,**
  - **bagasse,**
  - **cotton husk,**
  - **kenaf,**
  - **hazelnut shell,**
  - **tea leaves,**
  - **banana stalk**
- Wood based Industrial wastes
  - **Sand dust**
  - **Lumber waste**
  - **Saw dust**

A potential wood materials as filler wood plastic composites: Residue of wood based industry **"Sand Dusts of MDF"**

Sand Dust Amounts after Sanding in a MDF plant (Turkey)

MDF thickness (mm)	MDF density (kg / m^3)	MDF production (m^3 / year)	Sand dust amount (kg / year)	Percentage of sand dust (% /year)
4>	840	1291.75	133925.4	12.12
6	840	3955.83	229438.6	7.28
8	820	9189.82	529049.1	7.01
	870 (HDF)	79426.39	3586753.0	5.21
10-12	820	6667.32	295822.7	5.52
14	760	165.81	6194.0	5.12
16-18	740	213229.74	7695568.0	4.80
30	710	13.58	400.4	4.15
TOTAL		313940.2	12477151.0	

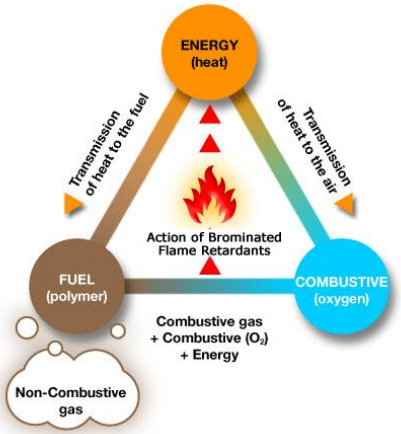
A MDF plant of capacity 314000 m^3 per year ⇒ 12.500 tons of sand dusts

nearly 5 million m^3 of MDF production per year in Turkey ⇒ 390000 tons sand dusts

We should also take into account this residue!!!

wooden materials and plastics are in flammable material group

Wood & Plastic

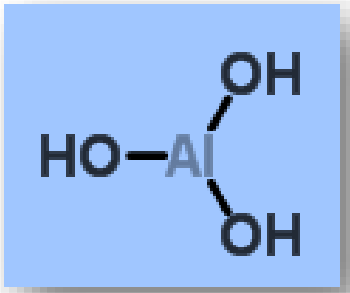


Danger for multi dwelling areas; hospital, schools, subway etc.

We should use fire retardants to improve fire performance of composite materials!!!

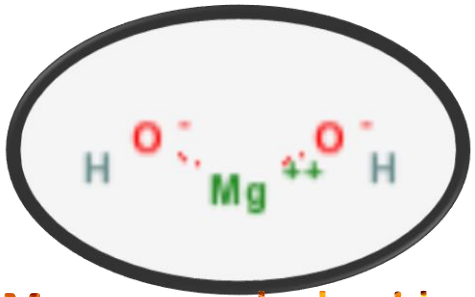
Environmentally friendly FRs : Metal hiydroxides and boron compounds

- ✓Easy to process
- ✓Low toxity
- ✓Low cost
- ✓Non volatile



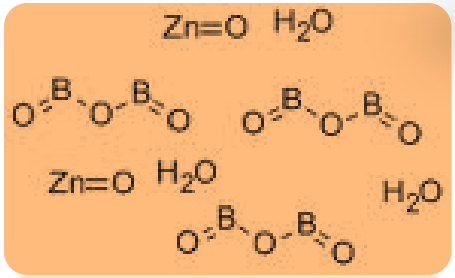
Aluminium tri hydrate

During combustion;
- ✓Releasing water to stage
- ✓not occuring toxic gas
- ✓İncreasing charring



Magnezyum hydroxide

Boron compounds also;
- ✓High resistance against fungi and termite besides having high fire resistance



Zinc borate

The aim of this study

To determine the effects of halogen free and environmental friendly fire retardants, which are zinc borate and ATH, on the properties of sand dust of MDF filled thermoplastic composites

- mechanical properties
  - tensile properties(ASTM D 638)
  - flexural properties (ASTM D 790)
  - impact properties (ASTM D 256)

- thermal properties (TGA), (DSC)
- fire performance (LOI) (ASTM 2863)
- decay test (EN113) (*C. Puteana)*

- Physical properties (WA- ASTM D 1037and TS- EN317 for 6months)

Parameters of manufacturing wood plastic composites

Composite panel type	Plastic type	Coupling agent	FRs	Composite formulations (%)				
				FRs (phr)	SD_MDF Loading	Plastic	Coupling agent	Wax
Control_HDPE	HDPE	MAPE	-	-	40	54	3	3
Control-PP	PP	MAPP	-	-	40	54	3	3
A1	HDPE	MAPE	ATH	20	40	54	3	3
B1	HDPE	MAPE	ATH	40	40	54	3	3
C1	PP	MAPP	ATH	20	40	54	3	3
D1	PP	MAPP	ATH	40	40	54	3	3
A2	HDPE	MAPE	ZB	3	40	54	3	3
B2	HDPE	MAPE	ZB	6	40	54	3	3
C2	PP	MAPP	ZB	3	40	54	3	3
D2	PP	MAPP	ZB	6	40	54	3	3

WPC Manufacturing Process

granulated polymer, rMDF and FRs

Mixed (5 minutes)

scale single-screw extruder
speed 40 rpm, heating zones
170, 180, 185, 190 and 200 °C

Extrudates pellet

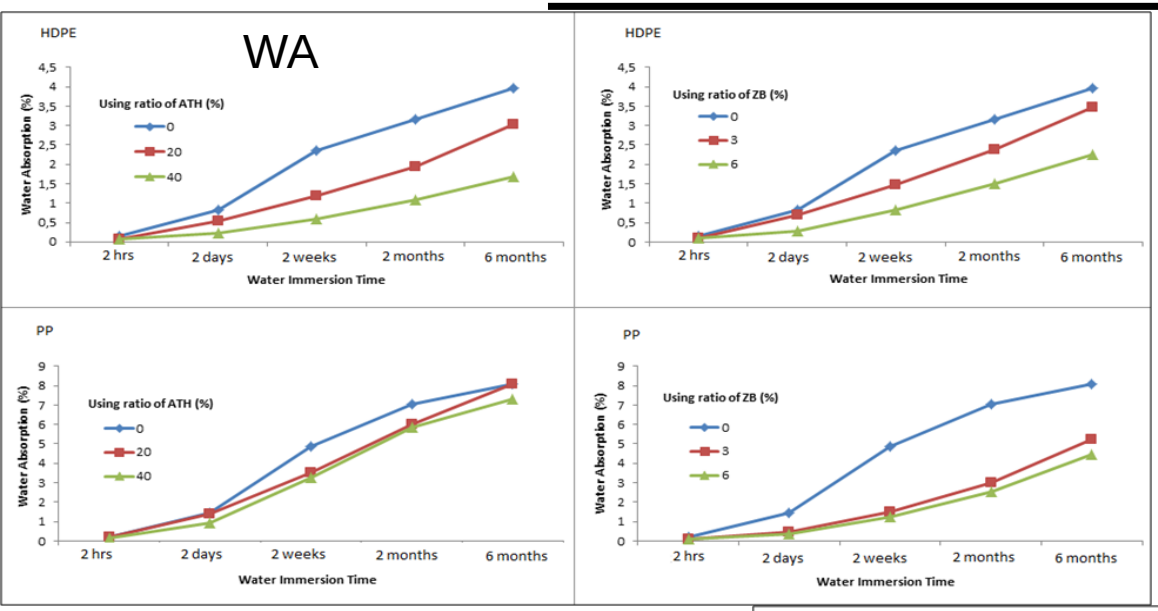
granulating

Granulated pellets

size of 5x150x200 mm

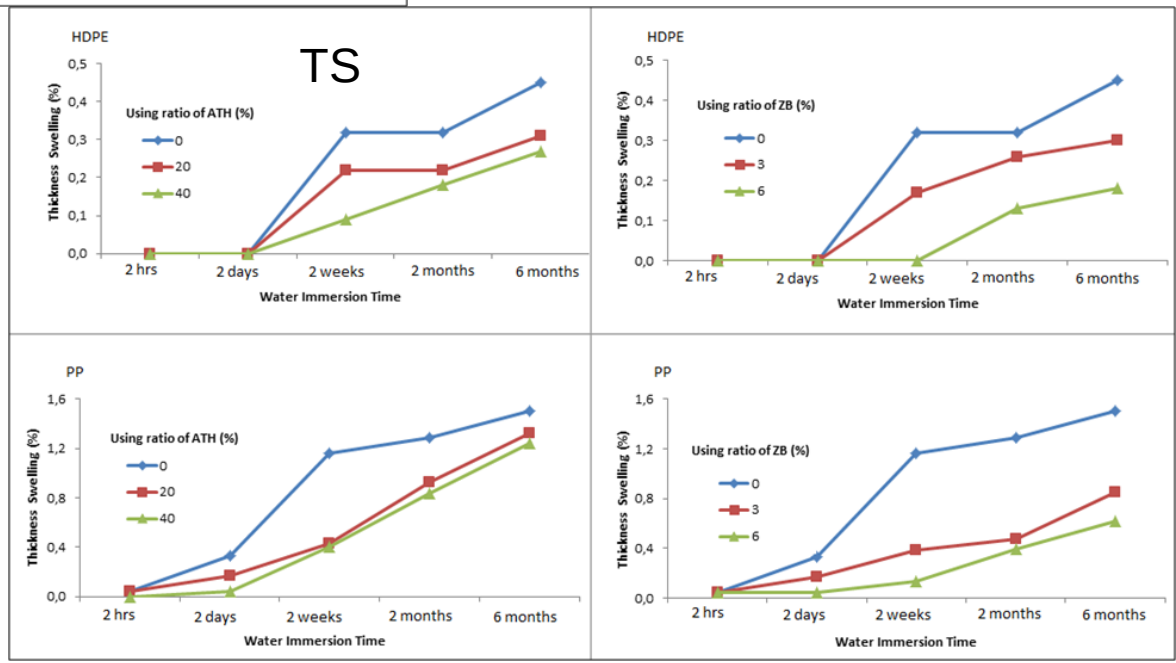
compression molded in the hot
press 200 °C, 5 minutes

Results: WA and TS



Using FRs into the polymer matrix decreased their WA and TS values

WA and TS values of all samples increased with increment of water immersion time



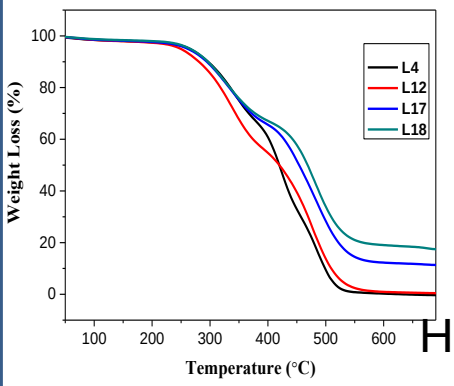
Results: Mechanical Properties

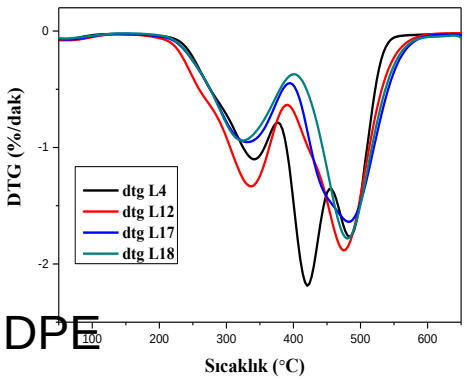
ID	Flexural Properties		Tensile Properties			IS (J/m)
	FS (MPa)	FM (MPa)	TS (MPa)	TM (MPa)	EB (%)	
Control_HDPE	24.68[1]	1692.57	12.82	598.38	2.71	21.68
	1.72[2]	34.91	0.14	9.90	0.18	3.60
Control_PP	32.01	1803.72	16.43	695.97	3.07	20.22
	0.50	80.61	0.95	22.60	0.09	0.56
A1	23.45	1269.99	14.04	586.25	2.86	19.10
	0.52	27.62	0.69	14.73	0.07	0.67
B1	23.38	1275.59	13.48	627.67	2.57	19.02
	0.79	75.54	0.80	20.61	0.07	1.60
C1	30.68	1549.64	16.43	721.73	2.58	18.94
	1.46	31.64	1.27	27.89	0.23	1.50
D1	30.05	1568.11	16.43	831.78	2.51	18.46
	1.00	25.55	0.35	9.15	0.05	1.33
A2	23.88	1134.26	15.01	586.99	3.08	19.28
	0.46	26.49	0.31	10.63	0.15	0.72
B2	22.54	1135.24	14.97	587.37	3.09	20.25
	0.76	46.51	0.93	24.25	0.28	0.62
C2	29.67	1156.00	15.64	607.47	3.11	20.24
	0.81	58.62	3.00	34.93	0.48	0.73
D2	29.17	1166.69	15.22	648.78	3.08	28.53
	1.50	25.70	1.00	32.36	0.30	0.48

- Usage of FRs caused a small reduction on flexural properties of the samples
- this reduction is mainly due to agglomeration of FRs and phase separation between FRs and thermoplastics
- Tensile modulus of the composites improved with addition of ATH into polymer matrix by 5-20 %. When increase filler loading into polymer matrix, the elasticity of material decrease and it gets rigidity

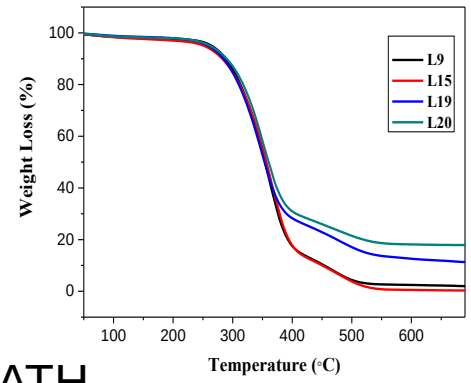
- IS values increased by a 41% with increment of ZB in PP-matrix. This may be related to shape and grain size of FRs . Some filler which has smaller grain size positively affects IS of the thermoplastic composites

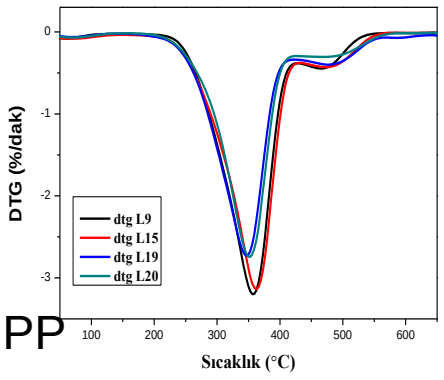
Thermal PropertiesTGA-DTG (SD MDF)





HDPE

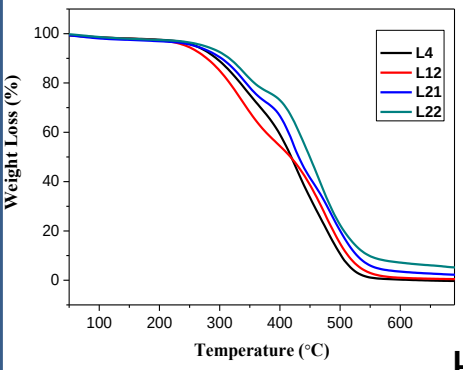


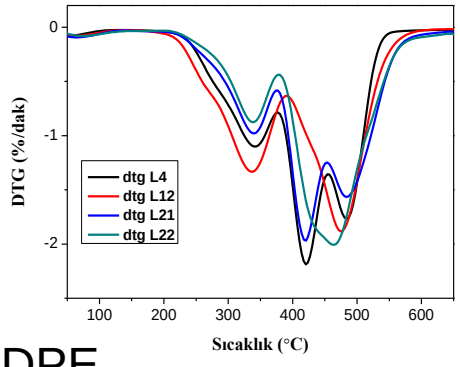


PP

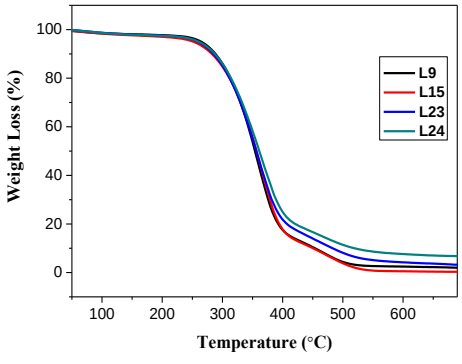
ATH

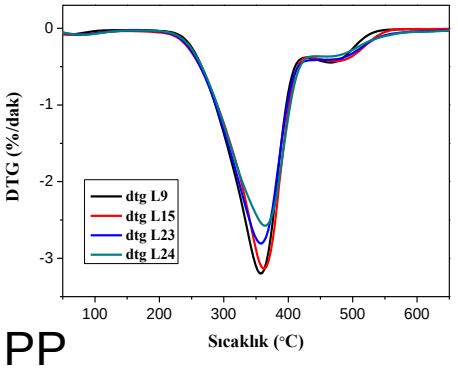
❖ The curves of TG gave similar peaks to the control samples ❖ increase of the residue char thanks to FRs





HDPE

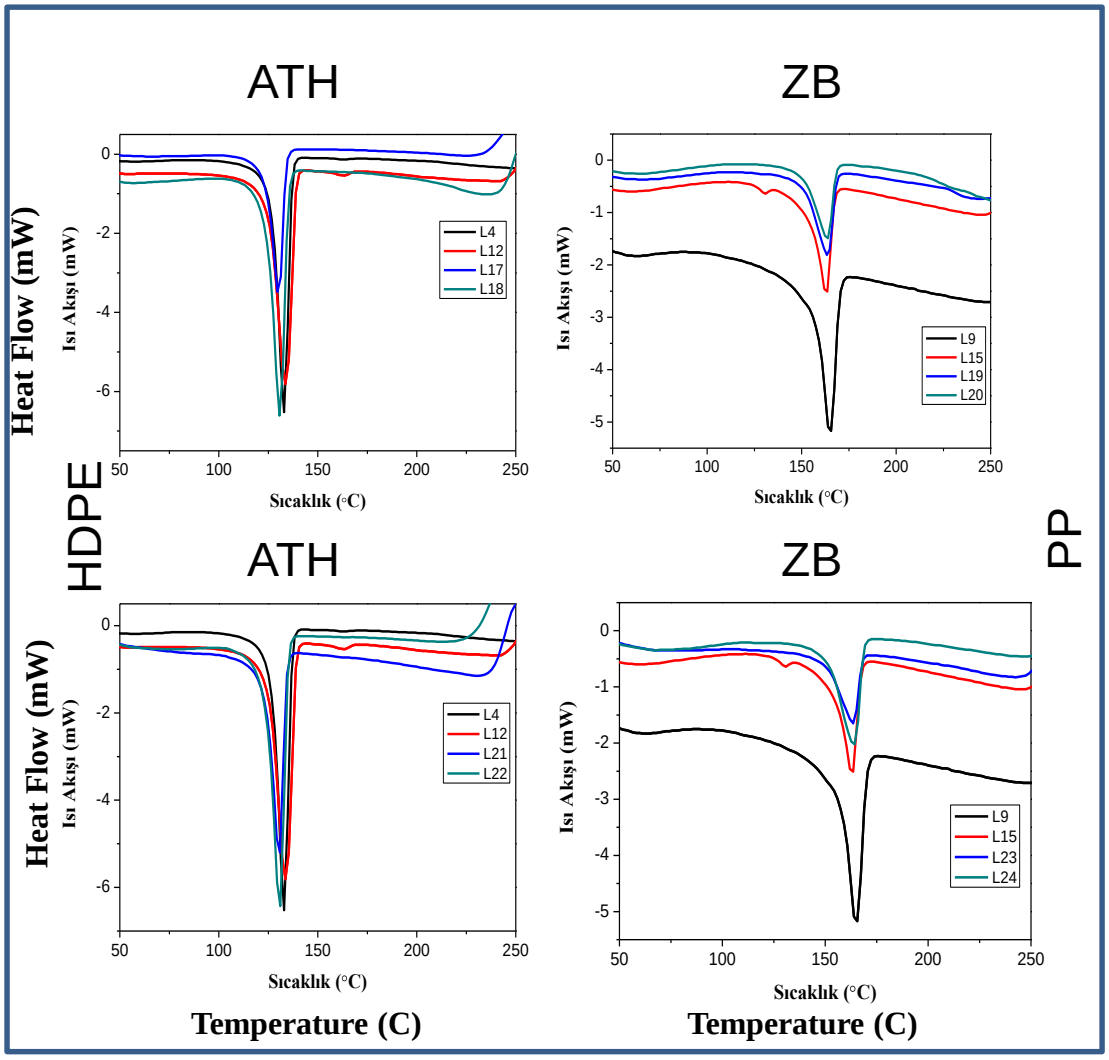




PP

ZB

Thermal Properties ofDSC (SD_MDF)



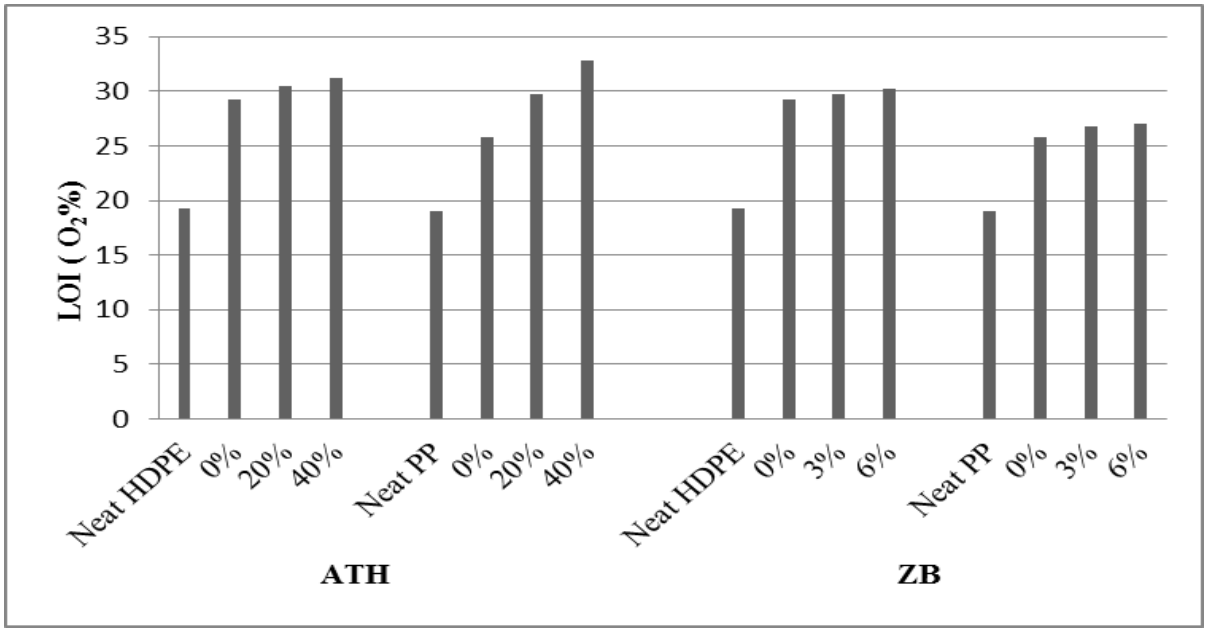
- the curves of melting temperature for all samples gave one similar peak

The melting temperatures;

- 130 to 134 °C for HDPE
- 163 to 165 °C for PP

- FRs and SD_MDF didn't affect the melting temperature of polymer matrix

Fire Performance: LOI Levels



classification of all composite samples in this study according to ISO 4589

LOI level	Classification of Fire	Composite Type
≤ 23	Combustible or Flammable Material	Neat HDPE, Neat PP
24–28	Limited Fire Retardant or Fire Resistance Material	Control PP, 3%ZB/PP, 6%ZB/PP
29–35	Fire Retardant or Fire Resistance Material	Control HDPE, A1, B1, C1, D1, A2, B2

- LOI levels of the samples were significantly increased to neat HDPE/PP
- ATH and ZB act as heat sinks and prevent oxygen to set fire to flammable compounds by releasing water, or by forming a protective layer as a coating

Biological Properties: Decay Test

. Weight losses of the thermoplastic composites after decay test.

FRs Type	ATH							ZB					
Polymer Type	HDPE			PP				HDPE			PP		
Usage of FRs (phr)	0	20	40	0	20	40		0	3	6	0	3	6
Mean (%)	**0.37**	**0.35**	**0.09**	**0.54**	**0.28**	**0.20**		**0.37**	**0.19**	**0.06**	**0.54**	**0.21**	**0.08**
S.D.	0.12	0.16	0.1	0.28	0.22	0.08		0.12	0.08	0.02	0.28	0.14	0.05
Reference	**Scotch pine 41.38** (8.64)							**Beech wood 15.4**1(3.40)					

The WA values of all composites were found less than 20 % even after 6months in this study, therefore weight losses weren't seen remarkably after decay test.

According to CEN/TC38/WG23 N34
5 durability classses ;
very durable ≤ 5: All composites samples
durable > 5 to ≤10
moderately durable > 10 to ≤ 15
>15 to ≤ 30
not durable >30

This is related directly to moisture content of materials since fungi need a minimum 18-20 % of moisture content to attack wood or wooden materials before decay begins

Conclusions

- This research was investigated whether FRs affect the properties of the filled thermoplastic composites
- FRs improves dimensional stability by decreasing WA and TS values and thermal stability of the composites
- Mechanical properties of the samples slightly reduced with increment of the FRs while tensile modulus of those increased with increment of ATH
- FRs also increased the residue charring and LOI levels of the samples. Fire retardant performance of samples increased with the high loadings of ATH
- FRs also improved resistance against decay fungi by decreasing the weight losses of the samples and the lowest weight losses were obtained from ZB (6phr) filled composites

In the light of obtained results, it was specified that use of FRs enhanced physical, biological, thermal and fire properties of SD_MDF filled thermoplastic composites.

THANK YOU FOR YOUR ATTENTION