

## COMPOSITES OF HYDROPHILIC AND HYDROPHOBIC POLYMERS AS WICKING AGENTS

**Ibe, Kenneth Abara**

Department of Chemistry College of Science  
Federal University of Petroleum Resources  
Effurun, P.M.B.1221 Effurun, Delta State  
**NIGERIA**

**Otanocha, Benedict Omonigho**

Department of Mechanical Engineering  
College of Technology, Federal University of  
Petroleum Resources, Effurun P.M.B.1221  
Effurun, Delta State, **NIGERIA**

### ABSTRACT

Wicking action of hydrophilic polymers (different wood species)- Iroko, Melicia excels; Lagos Mahogany, Khayaspp; Afara, Terminaliasuperb; Malina, Gmelinaarborea and hydrophobic polymers(polythene) composites were explored in this investigation. The prepared wicking agents were tested for their wicking capacities with water and crude oil. The results showed that almost all the wicking agents had higher percentage of oil absorption than water. The range of oil absorption was 1.32 - 13.05% in Afara/Talc/polythene (5:1:4w/w) and Iroko/Talc/polythene (4:1:5w/w) respectively while the range for water absorption was 0.017%- 6.79% in Malina/Talc/ Polythene (5:1:4w/w) and Iroko/Talc/Polythene (4:1:5w/w) respectively. Since most of the matrices absorbed more oil than water, it suggests that the composites could be used as effective media for addressing challenges posed by clean- up of crude oil spills.

**Keywords:** Composites, wicking, waste polymer, hydrophilic, hydrophobic.

### INTRODUCTION

The study of polymer composites has continued to generate research interest in the century due to an upsurge in the production and use of polymers leading to increased waste generation. The ability to obtain useful products like polymer composites from wastes such as sawdust and discarded polythene bags which are polymeric in nature have numerous advantages [1]. A more up to date growth process in composite technologies is in the use of polymer composites. These are created by small and medium scale enterprises and many oil companies globally, with the various polymer materials, trying to benefit from the properties of both materials [2].

In this investigation, the application of wicking agent made from waste polymer composite (waste polythene bags and wood saw dust) in the relative absorption of water and crude oil, a first step appraisal for use in crude oil cleanup was explored.

### LITERATURE REVIEW

Thermoplastics are usually reinforced by means of cellulosic fibres such as wood and this improves stiffness and strength of the composite compared to the 'uncontaminated' polymer, at the cost of ductility and strength impact [3]. Composites can be defined as a system consisting of two or more materials having chemically and physically different phases separated by a different interface [4]. The different materials are combined sagaciously to obtain a material with more useful structural and functional properties which cannot be achieved by constituents alone. These constituents work together to give mechanical support to the composite material.

Wicking is one of such properties that results from such combinations of materials. Wicking is the spontaneous imbibition of a liquid into a porous substance due to the action of capillary pressure

[5]. Wicking may also occur from a combination of capillary pressure and an external pressure [5]. It is a function of the microstructure found inside porous media, the characteristics of the liquid involved, and time [6]. Wicking plays an important role in many phenomena observed in science, industry, and everyday life. In nature; for example, in green plants, both capillary and osmotic pressures are responsible for drawing water and minerals from the roots up to the leaves[7].Capillarity (another name for wicking) is considered a major performance index for industrial absorbing materials, such as wipes, diapers and commercial wicks[8]; [6]&[9]. An example of wicking due to the combination of an external pressure and capillary pressure occurs during the wiping of a surface by a wipe, paper, napkin, or sponge [10][11]; [12]; [13] &[5].

## METHODOLOGY

### Materials sampling

The sawdust samples (hydrophilic polymer) used in this work was sourced from saw mills in Effurun and Sapele, Delta State, Nigeria. They were put into polythene bags and properly labeled for easy identification.

The waste polythene bags (hydrophobic polymer) were collected randomly from different locations within Federal University of Petroleum Resources, Effurun, Nigeria by handpicking into calico bags.

The mineral Talcum [ $Mg_3Si_4O_{10}(OH)_2$ ] purchased from the Federal Institute of Industrial Research, Ceramic Division, Oshodi, Lagos, Nigeria was used as an additive for proper blending of the mix and for creation of pores in the composite matrix. It could also help in enhancing the compatibility between hydrophilic wood and hydrophobic plastic; allowing the formation of single-phase composites [14]. The physical and mechanical properties of the composite may also depend on the interaction developed between the wood sawdust and waste polythene bags

The Crude oils used in this work were obtained from the National Petroleum Development Company, Nig

**Table 1: Common and Scientific names of wood samples**

Common Name	Scientific Name
Iroko	Melicia excels
Lagos Mahogany	Khayaspp
Afara	Terminaliasuperb
Malina	Gmelinaarborea

### Methods

Shown in Figure 1 is an illustration of the production process of composite materials used as wicking agents in this research.

### Pre-treatment

Before compounding and production of the composites, the following pre-treatments were carried out:

- i. Dirt particles were carefully removed from the waste saw dust samples by selective handpicking. The dirt-free wood saw dust samples were oven dried at 100°C.
- ii. The waste polythene bags and water used sachets were washed with distilled water to remove dirty particles and sun dried.

**Size reduction**

The sizes of the pre-treated samples and the talcum mineral were reduced as follows:

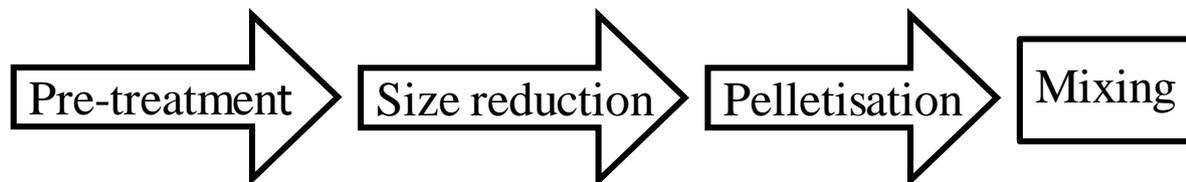
- i. The dried waste sawdust samples were milled in a jar mill for 1hour and sieved through a 100µm mesh sieve.
- ii. The Talcum mineral was milled in a ball mill for 45minutes and sieved through a 100µm mesh sieve.

**Pelletisation**

The waste polythene materials were fed into the waste treatment machine set to a temperature of about 200oC to produce the intermediate nodules which were subsequently channeled to the cutter segment of the waste treatment machine that ultimately churned out the pellets.

**Mixing**

The pellets were mixed with the talcum mineral and the wood saw dust in different ratios by weight of saw dust, talcum mineral and polythene pellets before been fed into an extruding machine, set at 3000C and pressure of 2bar (pre-determined after over ten trials). The hot mixed composite was collected in 5×3×3 cm cylindrical metallic molds. On setting and cooling, they were carefully scaled out of the molds.



**Figure 1: Illustration of compounding and production of composite wicking agents.**

**Wicking Test**

The prepared wicking materials were tested for water absorption and crude oil absorption as described below

**Water absorption test**

- The 11 different wicking agents prepared were weighed in a digital weighing balance (Adam PW Model) to determine the initial mass of each.
- They were immersed in separate beakers containing 100ml of distilled water.
- The time of immersion noted; the samples were retained in the beakers for 18hours at 6hours intervals.
- At the end of every 6hours, the samples were removed from the beakers with a tong, allowed to dry at ambient temperature and the weight of the samples obtained using a digital weighing balance (Adam PW Model).
- The water absorbed was obtained by difference.
- The water absorption test was done in triplicate to obtain a mean value and error estimate.
- The percentage of water absorption was calculated as shown below:

$$WA (\%) = \frac{M_a - M_b}{M_b} \times 100 \quad \text{eq (1)}$$

Where:  $M_a$  is the mass of sample after immersion (g).

$M_b$  is the mass of sample before immersion (g).

WA (%) is the percentage of water absorption.

### Crude oil absorption test

After the water absorption test, the 11 samples were air dried for twenty four (24) hours to remove surface water and oven dried at 100°C to remove water in the wicking agent matrix. The complete removal of the entrained water was ascertained by repeated oven drying and weighing to constant mass.

The oil absorption test was carried out thus;

- The labeled 11 different wicking agents were weighed with the digital scale (Adam PW Model) to ascertain the actual mass of each wicking agent.
- They were immersed in separate beakers containing 100ml of Crude oil.
- The samples were retained in the beakers for 18hours at 6hours intervals.
- At the end of every 6hours, the samples were removed from the beakers with a tong, allowed to dry at ambient temperature and the weight of the samples were obtained by measuring with a digital weighing balance( Adam PW Model).
- The crude oil absorbed was obtained by difference
- The crude oil absorption test was done in triplicate to obtain a mean value and error estimate
- The percentage of oil absorption was calculated as shown below:

$$OA (\%) = \frac{M_{Oa} - M_{Ob}}{M_{Ob}} \times 100 \quad \text{eq (2)}$$

Where:  $M_{Oa}$  is the mass of sample after immersion in crude oil (g).

$M_{Ob}$  is the mass of sample before immersion in oil (g).

OA (%) is the percentage of oil absorbed.

### Desorption of absorbed crude oil

The oil absorbed by these wicking agents was desorbed using n-hexane and the process was carried out as follows:

- 30ml each of hexane was placed in 11 beakers containing the wicking agent only.
- The beakers were tightly covered with aluminium foil and allowed to stand for 1hr.
- The wicking agents were removed from the beakers using a tong and allowed to dry at ambient temperature.
- However, the desorbed oil quantities were not quantified. This is because absorption was the main focus while desorbed crude oil is considered in another work by the authors.

**RESULTS****Table 3: Effect of time of immersion in water on mass of different ratios of the composite wicking agents**

Wicking Agent Sample	Ratios	Initial Mass (g)	Mean Increase in Mass(g) at time (t)		
			6hrs	12hrs	18hr
1.Mahogany/Talc/Polythene	1:1:1	40.83	0.80± 0.05	1.46±0.03	2.0±03
2.Mahogany/Talc/Polythene	4:1:5	24.29	0.09± 0.03	0.23±0.02	0.35±0.01
3.Mahogany/Talc/Polythene	5:1:4	7.40	0.06 ±0.01	0.20±0.01	0.30±0.01
4.Iroko/Talc/Polythene	1:1:1	40.60	0.64±0.05	1.76±0.03	2.64±0.02
5.Iroko/Talc/Polythene	4:1:5	18.51	0.10±0.02	0.71±0.04	1.26±0.03
6.Iroko/Talc/Polythene	5:1:4	13.58	0.03±0.00	0.13±0.03	0.19±0.00
7.Afara/Talc/Polythene	1:1:1	38.60	0.10±0.01	0.30±0.00	0.45±0.01
8.Afara/Talc/Polythene	4:1:5	23.41	0.11±0.03	0.29±0.00	0.29±0.01
9.Afara/Talc/Polythene	5:1:4	20.47	0.03±0.00	0.17±0.02	0.23±0.01
10.Malina/Talc/Polythene	4:1:5	26.12	0.87±0.02	1.18±0.02	1.36±0.03
11.Malina/Talc/Polythene	5:1:4	14.47	0.0003±0.00	0.0017±00	0.0024±0.01

**Table 4: Effect of time of immersion of the composites on % water absorption**

Wicking Agent Sample	Ratios	Water absorption (%) at time (t)		
		6hrs	12hrs	18hr
1 Mahogany/Talc/Polythene	1:1:1	1.97	3.57	4.80
2 Mahogany/Talc/Polythene	4:1:5	0.39	0.96	1.43
3 Mahogany/Talc/Polythene	5:1:4	0.76	2.70	4.04
4 Iroko/Talc/Polythene	1:1:1	1.58	4.33	6.50
5 Iroko/Talc/Polythene	4:1:5	0.54	3.85	6.79
6 Iroko/Talc/Polythene	5:1:4	0.22	0.94	1.41
7 Afara/Talc/Polythene	1:1:1	0.26	0.78	1.17
8 Afara/Talc/Polythene	4:1:5	0.46	1.25	1.26
9 Afara/Talc/Polythene	5:1:4	0.13	0.85	1.14
10 Malina/Talc/Polythene	4:1:5	3.32	4.52	5.22
11 Malina/Talc/Polythene	5:1:4	0.002	0.012	0.017

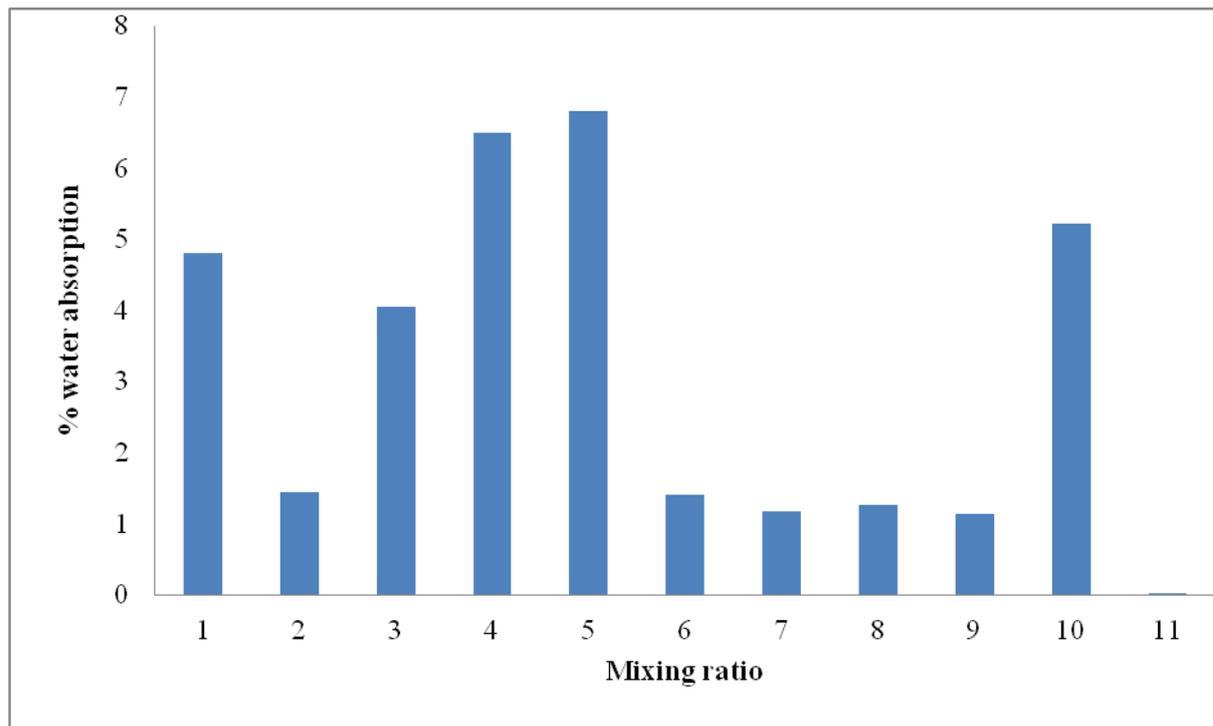


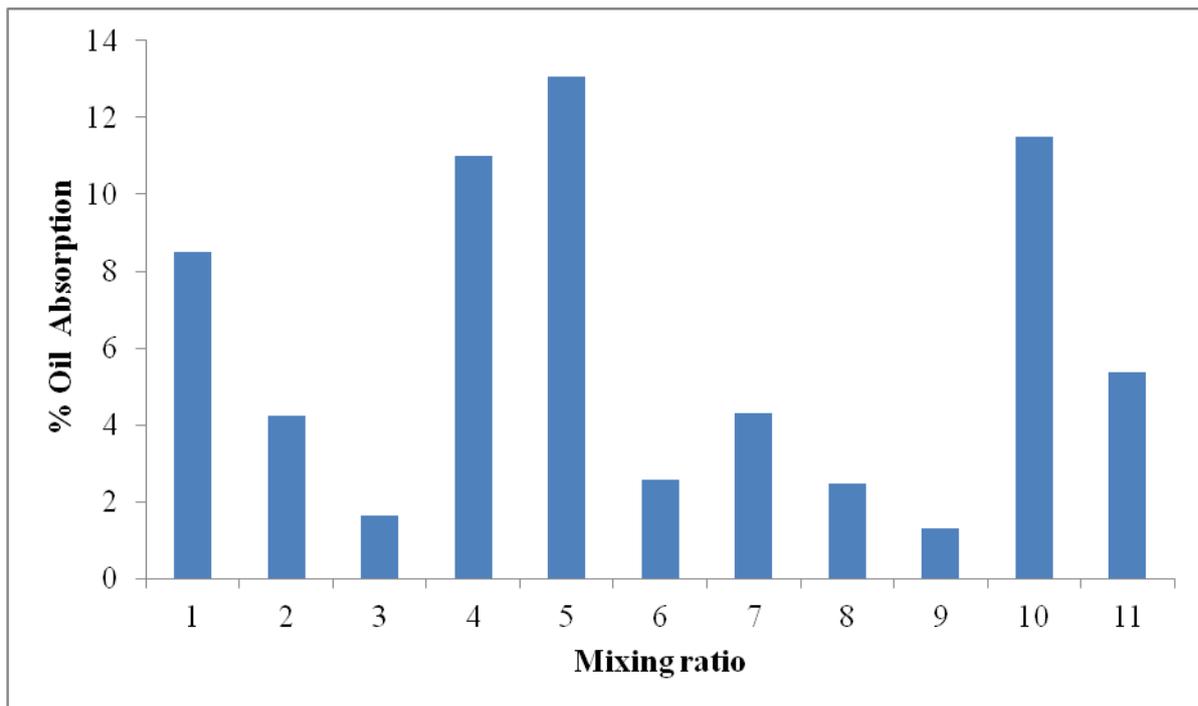
Figure 2: Chart of % water absorption after 18hours

Table 5: Effect of time of immersion in crude oil on the masses of different ratios of Sawdust/Polythene wicking agents

Wicking Agent Sample	Ratios	Initial Mass (g)	Mean increase in Mass(g) at time (t)		
			6hrs	12hrs	18hrs
1.Mahogany/Talc/Polythene	1:1:1	40.83	0.60±0.01	2.43±0.02	3.47±0.03
2.Mahogany/Talc/Polythene	4:1:5	24.29	0.42±0.03	0.74±0.02	0.74±0.02
3.Mahogany/Talc/Polythene	5:1:4	7.40	0.36±0.02	0.40±0.01	0.43±0.01
4.Iroko/Talc/Polythene	1:1:1	40.60	1.05±0.03	3.40±0.03	4.47±0.05
5.Iroko/Talc/Polythene	4:1:5	18.51	0.44±0.01	1.27±0.05	2.42±0.01
6.Iroko/Talc/Polythene	5:1:4	13.58	0.02±0.02	0.26±0.01	0.35±0.00
7.Afara/Talc/Polythene	1:1:1	38.60	0.39±0.15	1.35±0.02	1.66±0.02
8.Afara/Talc/Polythene	4:1:5	23.41	0.22±0.02	0.48±0.01	0.58±0.02
9.Afara/Talc/Polythene	5:1:4	20.47	0.02±0.00	0.17±0.02	0.27±0.00
10.Malina/Talc/Polythene	4:1:5	26.12	0.93±0.03	2.77±0.05	3.00±0.05
11.Malina/Talc/Polythene	5:1:4	14.47	0.35±0.01	0.63±0.01	0.78±0.02

Table 6: Effect of time of immersion of the composites on the % oil absorption

Wicking Agent Sample	Ratios	Oil absorption (%) at time (t)		
		6hrs	12hrs	18hr
1 Mahogany/Talc/Polythene	1:1:1	1.47	5.95	8.51
2 Mahogany/Talc/Polythene	4:1:5	1.71	3.05	4.22
3 Mahogany/Talc/Polythene	5:1:4	0.74	1.33	1.65
4 Iroko/Talc/Polythene	1:1:1	2.58	8.38	11.00
5 Iroko/Talc/Polythene	4:1:5	2.35	6.88	13.05
6 Iroko/Talc/Polythene	5:1:4	0.12	1.92	2.57
7 Afara/Talc/Polythene	1:1:1	1.001	3.58	4.30
8 Afara/Talc/Polythene	4:1:5	0.94	2.05	2.48
9 Afara/Talc/Polythene	5:1:4	0.12	0.84	1.32
10 Malina/Talc/Polythene	4:1:5	3.54	10.62	11.50
11 Malina/Talc/Polythene	5:1:4	2.44	4.36	5.37



**Figure 3: Chart of % oil absorption after 18hours**

## DISCUSSION

### EFFECTS OF MIXING RATIOS OF THE COMPOSITES ON WATER ABSORPTION

Each of the wicking agents was observed to be effective in absorbing water as there was an increase in the mass of the wicking agents.

The wicking of water by the composites at different periods of immersion is shown on tables 3 & 4. The values showed that irrespective of wood sawdust type, the water absorption of the wood sawdust/polythene wicking agent increased with increasing sawdust content to some extent. This behavior was anticipated since the water absorption of these wicking agents may be chiefly due to the presence of numerous hydroxyl groups (-OH) in sawdust, which are available for interaction with water molecules by hydrogen bonding and also the infilling which created pores in the matrix. The wood sawdust interacted with water not only at the surfaces, but also in the bulk material composite. There are three main regions in the composite where the adsorbed water could reside: the lumen, the cell wall and the gaps between the wood sawdust and polythene in the case of weak interface adhesion [15].

From Table 4, the wicking agent prepared with Iroko, 4:1:5 exhibited the highest absorption rate of water (6.794%). This can be attributed to the compatibility of the polythene with the sawdust and the increase in the micro pores of the composite with Iroko sawdust. The wicking agent prepared with Malina, 5:1:4 exhibited the minimum value of absorption (0.017%) and this may be attributed to the low compatibility of the polythene with the wood sawdust as well as reduced micro pores of the composite. It could be deduced here that the wood sawdust component in the wicking agent matrix facilitated water absorption maximally at 4:1:5 w/w mixing ratio, after which further increase led to attenuation in water absorption. Hence, the compatibility of the composite constituents and micropores which facilitate optimal absorption were attained at 4:1:5 ratios (Fig. 2).

## EFFECTS OF MIXING RATIOS OF COMPOSITES ON CRUDE OIL ABSORPTION

The wicking agents showed various absorption amounts for crude oil; with the highest amount of absorption in the 4:1:5 composite made with Iroko saw dust (13.054%); and the least amount of absorption in the 5:1:4 wicking agent made with Afara saw dust (1.316%). This can be seen in the masses of oil absorbed in 18hrs as shown on Tables 5 and 6.

From Table 6, the wicking agents with the composite ratio, 5:1:4 exhibited the least absorption in the different composites while the ratios, 1:1:1 and 4:1:5 exhibited the highest values. This could be attributed to the quantity of wood sawdust in the wicking agent matrix. It could be deduced that the wood saw dust component in the wicking agent matrix facilitated oil absorption maximally at 4:1:5, after which further increase led to attenuation in oil absorption (Figure 4). Hence, the compatibility of the composite constituents and micro pores which facilitate optimal absorption were attained at 1:1:1 and 4:1:5 ratios.

This phenomenon is slightly different from the trend in water absorption which optimized only with ratio, 4:1:5. Tables 4 and 6 show that the same compositional matrix of 4:1:5 exhibited higher levels of crude oil absorption than water absorption. This is a fundamental characteristic of good oil sorbent; as a good crude oil sorbent is supposed to pick up oil strongly and pick up water weakly [16]. It was however paradoxical that a continuous increase in the composition of the hydrophilic polymer, wood saw dust did not result to a corresponding continuous increase in water absorption.

## CONCLUSIONS

All the wicking agents had higher percentages of oil absorption than water absorption, except for the 5:1:4 wicking agent prepared with Mahogany sawdust which absorbed more water than crude oil. It was expected that as wood sawdust in each wicking agent increased, there would be a corresponding increase in percentage water absorption than crude oil absorption but this was not the case as the wicking agents made with Iroko, Afara and Malina showed increase in percentage oil absorption than water absorption. Thus, the wicking of crude oil by the wicking agents may not wholly depend on the chemical composition of the composite materials but on the nature of the composite material, arrangement and compatibility of the matrix. Since most of the composites absorbed more oil than water, it suggests that the composites could be used as effective media for combating oil spill in a marine environment hosting crude oil.

## ACKNOWLEDGEMENTS

Our appreciation goes to the Management of Federal University of Petroleum Resources, Effurun(FUPRE), Delta State, Nigeria for the use the facilities in the Department of Chemistry for this investigation. Our profound gratitude goes to Federal Institute of Industrial Research, Oshodi, Lagos, Nigeria for her support during this research work. We also appreciate the wood sellers in Effurun and Sapele, Delta State, Nigeria for their assistance in getting the wood sawdust samples and their promptness in volunteering the common names of the wood samples.

## REFERENCES

1. Kamel, M. (2010) Investigating the mechanical and physical properties of wood plastic composites Doctoral dissertation, University of Cairo, Egypt.
2. Morrell, J.J. (2002). Wood-based building components: what have we learned? International biodeterioration & biodegradation, 49(4), 253-258.

3. Nygard, P., Tanem, B.S., Karlsen, T., Brachet, P. and Leinsvang, B. (2008) Composite science technology, 68(15/16): 3418-3424.
4. Sabu, T., Kuruvilla, J., Sant, K.M., Koichi, G., and Mammarrappallil, S. S.( 2012) Polymer Composites (1st ed.), Vol 1, -VCH Verlag GmbH & Co. KGaA, p400-450
5. Masoodi, R., Pillai, K.M. and Varansi, P.P.( 2010) The effect of hydraulic pressure on the wicking rate into the wiper. Journal of engineered fibers and fabrics, 5(3):49-66.
6. Masoodi, R., Pillai, K.M. and Varansi, P.P.( 2007) Darcy's law based models for liquid absorption in polymer wicks. AIChE Journal, 53(11), 2769-2782.
7. Ksenzhek, O.S. and Volkov, A.G.(1998) Plant energetics,1st ed., Academic Press, San Diego, p20-30
8. Chatterjee, P.K. and Gupta, B.S.( 2002) Absorbent Technology: Porous structure and liquid flow models. Amsterdam, Elsevier, Amsterdam, p1-57.
9. Masoodi, R.,Tan, H. and Pillai, K.M.(2011) Numerical simulation of liquid absorption in paper-like swelling porous media. AIChE Journal, 57 (5), 1132 -1143.
10. Mao, N. and Rusell, S.J. (2002) Prediction of liquid absorption in homogenous three dimensional non-woven structures. International non-woven technological conference, Atlanta; p 60 -70
11. Mao, N. and Rusell, S.J.( 2003) Anisotropic liquid absorption in homogenous two dimensional non-woven structures. Journal of applied physics, 94(6), 4135-4138.
12. Lockington, D.A. and Parlange, J.Y.(2003) Anomalous water absorption in porous materials. Journal of applied physics, 36,760-767.
13. Gane, P.A.C., Ridgway, C.J. and Schoelkopf, J. (1992) Absorption rate and volume dependency on the complexity of porous network structures. Transport in porous media, 54, 79-106.
14. Wechslera, A. and Salim, H.(2009) Some of the properties of wood-plastic composites. Materials and design, no. 30, 4183-4191.
15. Bledzki, A.K. and Gassan, J. (1999) Composites reinforced with cellulose based fibres. Progress in polymer science, 24(2), 221-274.
16. Doerffer, J.W. (1992) Oil Spill Response in the Marine Environment, 1st ed., Pergamon Press Ltd Oxford, England, p 88-93.