

# A Review of Wood Plastic Composites effect on the Environment

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## Abstract

Wood Plastic Composites (WPCs) are environmentally friend materials with a wide range of applications in the field of constructions, comprising high mechanical and physical properties with low cost raw materials as plastic wastes and different carpentry process wood reminder. The effects of wood, plastic waste and additives on various properties of the material such as mechanical (modulus of elasticity and modulus of rupture), physical (moisture absorption) and fire retardancy have been investigated in order to push the output functions of the products to the limits of work conditions requirements. This study, overviews the importance of Wood Plastic Composites in conserving the environment by depletion post consume plastics from landfills, and the impact of these composites in developing the economic via opening new flourished markets for modern products. Both the ecological and economical requirements oblige the Iraqi government to replace the negatively healthy effects formaldehyde wood composites (medium density fiberboard MDF) which are widely consumed in Iraqi markets with Wood Plastic Composites. a long-term strategy plan in which the researchers and the capitals meet under supervision of the government is very necessary and recommended in this paper to establish and develop WPCs industry in Iraq.

**Keywords:** Wood Plastic Composites WPCs, Plastic recycling, formaldehyde- wood composites.

## الخلاصة:

ان المواد المركبة بالخشب والبلاستيك هي مواد صديقة للبيئة و على مدى واسع من التطبيقات في مجال البناء و تضم خواصا ميكانيكية و فيزيائية عالية مع مواد اولية واطئة التكلفة مثل النفايات البلاستيكية وكذلك الخشب المتبقي من الاعمال المختلفة في النجارة. ان تأثيرات كل من الخشب، والنفايات البلاستيكية وكذلك الاضافات على الخواص المختلفة للمادة كالميكانيكية منها (معامل المرونة ومعامل التمزق)، والفيزيائية (امتصاص الرطوبة) وكذلك تثبيط النار قد تم البحث عنها والهدف هو الدفع بالوظائف الناجمة من المنتجات الى اقصى الحدود وحسبما تتطلبه ظروف العمل. ان هذه الدراسة، تستعرض اهمية المواد المركبة بالخشب والبلاستيك في حماية البيئة من خلال استنزاف البلاستيك المتبقي من ما بعد الاستهلاك من مكبات النفايات، وكذلك تأثير هذه المتراكبات في تطوير الاقتصاد من خلال فتح اسواق جديدة ومزدهرة لمنتجات حديثة. ان كلا من المتطلبات البيئية والاقتصادية تحتم على الحكومة العراقية ان تستبدل المواد المركبة بالخشب والفورمالديهايد (الواح متوسطة الكثافة MDF) ذات التأثيرات الصحية السلبية والواسعة الاستهلاك في الاسواق العراقية مع المواد المركبة بالخشب والبلاستيك. ان وضع خطة استراتيجية طويلة الامد و التي تلتقي فيها الباحثين ورؤوس الاموال وتحت اشراف الحكومة من اجل انشاء وتطوير صناعة المواد المركبة بالخشب والبلاستيك في العراق هي ضرورة ملحة وموصى بها في هذا البحث.

**الكلمات المفتاحية:** المواد المركبة بالخشب والبلاستيك، اعادة تدوير البلاستيك، المواد المركبة بالخشب والفورمالديهايد.

## 1. Introduction

Plastics are synthetic organic polymers, the enjoyed properties of plastics (lightweight, strong, and cheap) make them industrially desirable and the daily life demand to plastics persist in increasing (Derraik, 2002). But the disposal of plastic is a producing concern and the drivers behind it looks set to continue. Ecological pollution by plastic either in micro or macro plastic form has sparked an uproar among researchers and the general public. Organisms can ingest the plastic or become implicated in it; plastic waste, therefore, has catastrophic effects on the entire ecosystem (Li, Tse, and Fok, 2016). In Iraq, US military had burned 147 tons of waste per day in 2008 and abundant pollutants emitted in the air as combustion results

causing long- term hygienic impacts. The most dangerous pollutant was Highly toxic dioxins related to burning of plastic waste as rejected water bottled (burn pit, 2016). For these reasons, and from the ecological point of view, humans need to develop new ideas and philosophy about the materials that are producing for different applications. The development means that we need environmentally friend materials which can be used and we are secure that they will not cause a disaster damage to the planet after disposal. This can be achieved in one of two ways, either by producing materials which are biodegradable or by using recyclable materials that when they expired in one form can be re-lived in another form. Polymeric materials because of chemical and biological inertness will not degrade after disposal so they may form high percent of landfills disposal (Callister and Rethwisch, 2007). According to these frighten data about plastic waste and its disaster effect on the planet over the last few years and since humans civilization fast growth depends on the natural resource availability, the available raw is at risk especially the requirement to it persists. if human beings want to sustain the modern life on the planet and protect the share of next generation from the resources, they have to develop new criteria to manage the resource. One of most powerful criteria to protect our resources from diminishing is by treating wastes as a raw material instead of disposal in landfills. The recycling process is an effective tool to balance economic growth and natural resource (Huysman *et.al.*, 2015). Wood Plastic Composites, which are considered as modern composite materials and widely used in many construction applications such as decking, roofing, furniture and house decorations is a powerful instrument to recycle post-consume plastics. In addition to that, WPCs have priority over detrimental content wood composites. Formaldehyde based particleboard has many healthy side effects, Upper respiratory tract irritation, combustion of eyes, and cancer are all formaldehyde caused diseases and need to be replaced with no healthy consequences green materials as WPCs (Aras *et.al.*, 2015) . In the 1970s, the modern concept of WPCs was developed in Italy and then impact other parts of the world. Wood in the form of flour/particles/fibers is combined with the thermoplastic materials under specific heat and pressure for producing WPCs where additives may be added for improving the quality. The ability of fabrication a composite from sawdust (SD) and recycled polyethylene terephthalate (PET) with a different ratio (w/w) by the flat-pressed method has been studied. The effect of sawdust on various physical and mechanical properties of the composite was estimated (Rehmani *et.al.*, 2013). The development and production of fiber composites using agricultural and plastic wastes are economically and environmentally hopeful solutions for benefit from both domestic and agriculture waste. Date palm leave with domestic plastic waste have been used to produce WPCs, the raw materials were pretreated with a different coupling agent. The produced composite properties lead to the conclusion that date palm leaves and plastic waste can be recycled to produce WPCs with characteristics similar or close to commercial wood that was innovative, clean, cheap, and effective. The mechanical and physical properties proved an acceptable final and promising WPCs products (Binhussian, and EL-Tonsy, 2013). The effect of different chemicals on the WPCs flame retardancy has been investigated. The best results were achieved by the flame retardants ammonium polyphosphate, Paxymer, and expandable graphite. Especially in combination with red phosphorus (Seefeldt, 2012). This paper overviews Wood Plastic Composites properties, manufacturing processes and the ability to be replaced with formaldehyde- based composites to attain economic and environmental goals. At the end of this paper, a recommendation is proposed to the Iraqi government to

develop the economy and protect Iraqi environment through a comprehensive plan intend to stimulate new and modern industries in Iraq as Wood Plastic Composites.

## **2. Manufacturing of Wood Plastic Composites**

### **2.1 Raw material preparation and mixing**

Wood Plastic Composites (WPCs) are materials that consist of two phases polymeric matrix either thermoplastic or thermoset reinforced with the second phase which is wood. The reinforced wood may be in any form (fibers, particles, sawdust or flakes of wood) depending on the availability and the required properties of the final products (Javier *et.al.*, 2015). Even palm leave (Bin Hussain, and EL-Tonsy. 2013), and agriculture waste are used to manufacture WPCs (Ghasem, 2013). Depending on the type of the polymer used to compound wood, WPCs may or may not be environmentally desired. Thermosets polymers are not widely used in WPCs this makes thermoplastic and due to recyclability more promising ecologically, added to this that the second phase which is wood is also recyclable (Javier *et.al.*, 2015). The compounding of wood with thermoplastic required the application of heat to ensure wetting of wood with plastic to enhance bonding. Thermally compounding process has criteria which are strongly recommended, the melting or softening temperature of used plastic must not exceed the wood degradation temperature ( $\approx 210\text{C}^{\circ}$ ). The types of thermoplastics that meet the above criteria restricted in a class of polymer known as polyolefins such as polystyrene, low and high polyethylene, polypropylene and polyvinyl chloride. On the other hand, and away from criteria of temperature, the second challenge in compounding process is a homogenous dispersion of polymer melt throughout the wood particles. The mixing quality reflects the properties of the final products such as finishing and appearance quality. The degree of mixing is a very sensitive parameter especially in preparing composites with short fiber reinforcement, insufficient or over mixing may cause a detrimental effect on the mechanical properties of the products. Insufficient mixing results in a poor bonding between wood and plastic, whereas overmixing leads to fibers damage severely. WPCs production process primary based on thermoplastics techniques such as single-screw extrusion, twin- screw extrusion, injection molding, ... etc. The products include solid or hollow bodies sections, coverings, films, and foams (Wolcott and Englund, 1999).

Production of WPCs with variety shapes other than continuous profiles required two stages process the first stage starts with the compounding of ingredients (wood/thermoplastic) and then the compounds will be conveyed into the second stage which is forming process via different techniques. Relating to the final properties of the products each technique has a privacy depending on the parameters of the technique used. The extrusion process shows an advantage over injection molding in the protection of wood fibers during production of one-piece pallet since injection molding burns wood fiber by unnecessary heat generates from high shear rate during high-speed injection. In Contrast, the extrusion process generates lower heat due to lower shear. In term of final products shapes extrusion process is familiar with wide range of die design (El-Haggar *et.al.*, 2011).

### **2.2 Additives**

Although wood and thermoplastic form the bulk of a WPCs many other additives are added to the composites in small quantity. The main aim of the additives is to enhance the final products property via different purpose of these additives and different effects that will result from. The additives are

- **Coupling agents:** the crucial in manufacturing WPCs is the interfacial bonding between two widely separate materials in chemical properties, hydrophobic polymers versus hydrophilic woods. The intact mechanical properties of the composites rely on the interfacial bonding since stress is transferred between matrix and fibers across the interface. One method to improve the bonding is chemical treatment, alkali, acetyl, and silane are widely used as coupling agents. Silanes used for the treatment of fibers due to differences in chemical trends at either end, while one end tends to react with a hydrophilic group of fibers the other prefers to react with hydrophobic polymers forming a bridge between them. Initially, silane treatment of natural fibers involves hydrolysis of alkoxy groups on silane with water to form silanol (Si–OH) groups which can then react with hydroxyl groups on the fiber surface hydrogen or covalent bonding can occur. The most widely investigated silanes used are amino, methacryl, glycidoxyl and alkyl silanes. Silanes have been found to increase the hydrophobicity of natural fibers and strength of WPCs with larger increases occurring when covalent bonding occurs between silane and the matrix (Pickering, Efendy, and Le 2016).
- **Lubricants** since WPCs production require melting of the plastic which is well known with its high viscosity, the addition of lubricant to the mixture of WPCs during the process is one of many requirements to ensure a homogenous flow of the melt through the machine and mold. The criterion is that the lubrication must be within the allowable amount in engineer to avoid the lack of wood/ plastic interface linkage due to excess lubrication and to select a proper type for processing of wood fiber composites to lower the viscosity of melted polymer. In many polymer systems, the oxidized polyethylene lubricant noticeably satisfies the lubricant criteria. (Hatch, 2008).

### 3. Properties of Wood- Plastic Composite

#### 3.1 Moisture absorption

Wood Plastic Composite is classified as a type of green materials by its great contribution in consumption the wastes from landfills and protection of atmosphere through saved energy via recycling process, but the environment harshly attacks WPCs causing severe damage to the properties and the output functions. WPCs in order to work in an open-air ambient with minimum maintenance cost and highest durability, improvement of the products must be kept at the top level of the concerns especially from moisture which has a detrimental effect on the appearance, dimensional stability and the bonds of the composite components. Biologically, the moisture content of WPCs needs to be in the lowest level otherwise WPCs undergo biodegradation by micro-organism attack as fungi. Moisture absorption of WPCs in a first grade returns to the hydrophilic part (wood) other than hydrophobic part (polymer) thus, the enhancement against moisture may be achieved by developing high-performance wood through a chemical modification (chemical modification means treatment of the wood with chemicals such as Acetylation in which acetyl group replaces one hydroxyl group in the cell wall polymers of the wood). In the result the moisture absorption of modified Wood Plastic Composites can be reduced 50% of that with unmodified wood, hence higher dimensional stability and outdoor durability (Segerholm, 2012). A research has been implemented to investigate moisture resistance of WPCs and MDF manufactured from palm leave and randomly

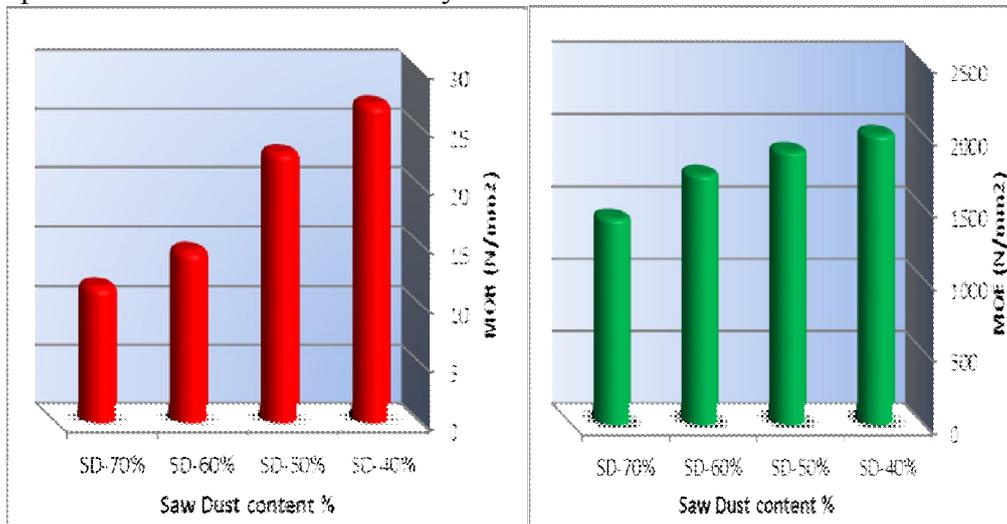
collections of home disposal plastic following ASTM-D-570-95. The samples immersed 24hr in water for water absorption test and the change in mass before and after soaking was the criteria to determine the results. WPCs with only 8.7% water absorption showed a great priority over 31.9% absorption for Medium Density Fiber Board. The resistance of WPCs returns to the hydrophobic nature of waste plastic which foliates wood fiber and prevents moisture from absorption (Bin Hussain, and EL-Tonsy. 2013).

### 3.2 Mechanical properties of Wood Plastic Composites

The sensitive in the mechanical properties of a composite material is the cohesion strength of the components. The higher the bounds of the components the better the distribution of the stress throughout the composite and force transformation from the matrix to the reinforcements hence, higher work performance. In manufacturing Wood Plastic Composites from recycled plastic and output of the wood process wastes, the criteria to achieve the desired properties are a homogenous mixture and well wetting of the reinforced particles by melted plastic. Since the mean applications of Wood Plastic Composites are in the field of constructions and buildings the mechanical properties of the product have a major role. the properties of the WPCs as a function of the ingredients percent have been tested. The work starts first by paneling Wood Plastic Composites via flat press method, the panels made up of different ratios saw dust (40, 50, 60 and 70%) with dimensions (240 mm× 50 mm× 6 mm), both moduli of elasticity (MOE) and modulus of rupture (MOR) have been evaluated using three points bending test with IMAL-IB600 universal machine and according to ASTM-D-1037-93 standard. The highest values of MOE and MOR were 2008.34 and 27.08  $N/mm^2$  respectively with 40% (the minimum addition of sawdust). The investigations showed a continuous decrement in the properties of the WPCs as the sawdust content increased from 40% to 70% (figure 3). Such behavior might result from poor texture formed during the process of production and the process temperature seems to be the control parameter. The melting temperature of PET is 260°C whereas the temperature that uses to press the components was 190°C this might cause insufficient wetting of the sawdust due to poor flow of the melted PET and inadequate mixing. The inhomogeneous texture and collection of the sawdust without wetting with melted plastic effects inversely on the efficiency of stress transformation from the matrix to reinforcements and finally weakness of the mechanical properties of the products (Rehmani *et.al.*,2013).

The properties of WPCs made from green raw materials as wood and plastic waste could be analogous to that of commercial wood and other environmentally undesired formaldehyde-based wood composites. The MOE and MOR values of formaldehyde resin particleboard panels necessity to be applicable as construction materials are 11.5, 13, and 1600  $N/mm^2$  according to EN- standards (Aras *et.al.*, 2015) which correspond to the minimum values obtained in WPCs (figure 3). With comparable properties and as a requirement to fulfill the ecological advantages, Wood Plastic Composites can be replaced for other formaldehyde- wood composites. (Bin Hussain, and EL-Tonsy. 2013) have tested the hardness of WPCs made from palm leaf and plastic waste. The mixture treated with saturated solutions of polycarbonate, PVC, and polystyrene separately in three batches (PC-mix, PVC-mix, and PS-mix). The Rockwell hardness recorded for (PC-mix, PVC-mix, and PS-mix) where 54.82, 57.05, and 52.65 respectively which are comparable to the nature hardwood hardness 85.46, softwood hardness 56.1, and MDF hardness 64.2. It is clear that the hardness of the

three mixed forms was all within the range of nature softwood. Away from mechanical properties that can be achieved by controlling different parameters WPCs have preference over wood and other wood composites in that they are cheap, clean, high performance and environmentally intimated materials.



**Figure 3: MOE and MOR of sawdust- PET as a function of sawdust content adapted from (Rehmani, *et.al.*, 2013)**

### 3.3 Fire retardancy of WPCs

In the engineer when treating with WPCs as a construction material protection from fire is a top concern. Since the incorporations wood and polymers are both combustibles and the WPCs constructions will be always under hazard of fire. To face such hazardous in construction, flame-retardancy of WPCs is extremely recommended. Flame-retardancy can be achieved either through prevention of fire ignition or via retardancy of fire propagation. The mechanism of flame retardancy basically built on the concept of barrier formation. The aim of the barrier is protection the beneath material from fire by insulation the underlies from heat transfer. Fireproof of WPCs have been investigated by addition of different flame-retardant materials, such as Expandable Graphite (EG) and Pax (red phosphorus (RP), polydimethylsiloxane, magnesium hydroxide and calcium hydroxide) all investigation showed acceptable results. Expandable graphite has lowest retardancy of fire by creating graphite worms on the top of the material. The graphite worms which are formed by degassing a blowing agent incorporated in the layers of graphite such as sulfuric acid using heat, the output from blowing process is expanded graphite layer which forms a thermal barrier. Expandable graphite is a good fire retardant, but the destruction of the thermal barrier (graphite worm) as fire proceeds reflects on its ability to resist fire. proceed investigations showed cross-linking of wood cellulose is a key to retard fire. Based on this mechanism the highest influence of fire-retardant is achieved by chemicals that contain phosphorus in the composition such as Pax and combination of red phosphorus and expandable graphite. The major condition to activate the fire retardancy is presences of oxygen to form phosphate, in Pax the ingredients are considered to be oxygen source. in the red phosphor, the oxygen comes to contact from surrounding atmosphere when EG reduce the flame as a result of the thermal barrier formed by EG. So both Pax and a red phosphor with expandable graphite achieved the best results as fire retard (Seefeldt, 2012).

#### 4. Preference of WCPs over formaldehyde-based wood composites

Based on its chemical composition and enjoyed properties, the Wood Plastic Composites have many advantages over other formaldehyde- wood composites in both ecological and economical system. Ecologically, WPCs play a crucial role in ecological preserving by reduction the accumulations of the plastic waste in landfills and marines eliminating the negative effects of these wastes. In economic terms, the industry of WPCs could be a powerful instrument to support the budgets of the countries. In the USA the industry of WPCs required 204 million Kilograms of plastic with 95% being plastic disposals. The produced WPCs used as fencing, decking and roofing of houses and the market of these composites exceeds all anticipates. The US houses roofing markets exceed 1.1\$ billion in 2007, fencing market in 2002 valued at 2.6\$ billion, whereas 65\$ million spent in 2000 for decking (Winandy *et.al.*,2004) which means that plastic disposal can be one of economic exhilaration reasons if it recycled into another form instead of being disposed of in landfills. In Iraq, the value of imported medium density fiberboard raised from 304  $m^3$  in 1999 to 99,827  $m^3$  in (factfish Fibreboard, medium density, import volume world statistics and data, 2016) costing thousands of dollars which could be saved if it is replaced with locally manufactured Wood Plastic Composites. It is recommended from the Iraqi government to pay a great attention to the issue of plastic waste and to follow the American course in dealing with recycled plastic as raw materials. Strategy plan must be draw up in order to encourage and support the researchers in the field of recycled plastic- wood composites and to direct the potentials of the country toward the investment in this field as a method to protect the environment and to develop the economy of the country.

#### 5. Conclusions

Wood Plastic Composites can be considered as a promised material from both the economic and the environmental points of view since Wood Plastic Composites have the potential to use wood waste and recycled plastic. The produced composites which are enjoyed with high-performance properties, high market potential, and low-cost maintenance compared to solid wood and other wood composites can be used as construction materials with a wide range of applications. The properties of the final products which are firmly related to the ingredients (wood/plastic) shape and type, can be improved by using additives and controlling both manufacturing condition and the combination of the raw materials.

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