Reuse of hazardous waste in plastic wood composite production.

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Abstract

The reuse of materials is a topic of great interest due to the high amount of waste generated in many different activities. Wastes of wood poles treated with chromated copper arsenate (CCA) and the ceramic electrical insulators (RIP) are reusable materials that can be applied in the wood plastic manufacturing. Such wastes are generated in the maintenance of electricity distribution networks. In this work the capability of of reuse these wastes as reinforcements in composite materials containing a matrix high density polyethylene (HDPE) was analyzed. It was added coupling agent for improved adhesion between the phases. The wood was milled in mill knives and the RIP was ground in ball mills. It was tested several formulations for the composite, totaling 30% of reinforcement. The materials were processed on a double threaded extruder and injected for obtaining the test samples. It was analyzed the flexural strength ,tensile strength and the leaching test, according to NBR 10,005/04 to evaluate the classification and possible application for this material. In the flexural and tensile strength tests the addition of 50% of each reinforcement increasesthese properties compared to pure HDPE, indicating effort transfer between matrix and reinforcement.. The concentration of copper, chromium and arsenic in the leachate was lower than allowed by law. Thus, developing composites with hazardous waste as a reinforcing agent presents itself as an alternative for recycling this waste and contribute to reducing the environmental impact.

Key words: Hazardous waste. Reuse. Composites.

Theme Area: Solid waste

1 Introduction

The waste is produced in carrying out several activities such as industrial, home, search or rural activities, among these there are hazardous waste that represent about 40% of solid waste and which requires specific treatment due to its high degree of impact on the environment and health (TOCCHETTO, 2009; IPEA, 2011) .

In the electricity distribution sector several kinds of waste from logistics and maintenance of electrical networks and poles are generated. they can be grouped into four categories in accord with the type of residue produced: metal, lignocellulosic, ceramic and polymeric (GERD, 2014). Metallic materials are generated in larger volumes and have well-developed disposal logistics. Polymeric materials present ample opportunity for recycling; the reuse and recycling potential of ceramic materials is expanding and lignocellulosic materials have wide application in the co-processing sector although some limitations (JANIN *et al.*, 2011).

Among the lignocellulosic materials, wooden poles, crossarms, reels for wire and tree pruning can be cited the. The posts and crosspieces wood undergo a chemical preservation treatment under vacuum with chromated copper arsenate (CCA). After treatment, the durability of the wood increases, and it may take up 25 years to start the deterioration process. Due to that, they are a good alternative to be used as reinforcement in other materials, although its use can be related to health and the environment hazards, and that can be argued (FERRARINI *et al.*, 2012; GRESS *et al.*, 2014.).

The components on CCA have high toxicity and there are limitations related to leaching and volatilization process the treated wood may undergo, which may infect man and nature. In addition, there are environmental and occupational hazards during the production process (SILVA, 2008; FERRARINI *et al.*, 2012.).

The arsenic acts as an insecticide while copper acts as a fungicide. According to the Anuário Estatístico da ABRAF - 2012 (Associação Brasileira de Produtores de Florestas Plantadas) there are about 300 wood preservative reserves distributed mainly in south and southeastern regions. Such industries presents capability of treat 2.0 million m³ of wood for year although the annual production of the sector corresponds to 1.5 million m³.

It is a big challenge to dispose waste wood treated with CCA, after its useful life (JANIN *et al.*, 2011; VIDOR; 2011; FERRARINI *et al.*, 2012). In Brazil, the NBR 10.004/04 classifies this waste as Class I - Hazardous but in other countries they can be classified in several other categories (FERRARINI *et al.*, 2012.).

For over twenty years, policies for waste management have been discussed at national and international level. By this kind of waste presents a complex environmental demand, there was necessary the involvement of government, organized civil society and the private sector, to present action to reduce environmental degradation caused by human activity (FREIRE and LOPES, 2013; MOREIRA, 2013).

With the promulgation of the Política Nacional dos Resíduos Sólidos – PNRS, the business sector adopted in its strategic planning actions for promote the correct disposal for the waste generated in production process. The possibility of employing new technologies for the reuse of waste seeking financial returns combined with environmental and social responsibility showed opportunities develop projects to reuse this waste or that provides it a clean disposal (MOHEE *et al.*, 2015;. RONG *et al.*, 2015). .

One way to reuse the wood treated with CCA and the ceramic insulators waste (RIC) is incorporating them as reinforcement in polymer composites. The wooden poles and crossarms, provided from electricity distribution networks, has excellent properties, even after its useful life. They belong to lignocellulosic waste group, and can be incorporated in composites providing improvement in its mechanical properties and resistance to biological degradation (FREITAS, 2002; VIDOR, 2011; ABRUZZI *et al.*, 2012; BORGES and MORESCHI, 2013).

Through this allocation is possible to change the way this waste is viewed which cease to be residue and become raw material for other products, thus, in addition to provide for the society new products it is in accordance with Law 12,305/10 which provides for the PNRS (BRAZIL, 2010; SONG *et al.*, 2015).

In this study was analysed the effect of wood flour, provide from poles treated with CCA, and milled RIC, after use, incorporated in the high density polyethylene matrix (HDPE), using maleic anhydride as the coupling agent. The mechanical properties of flexural and tensile strength were evaluated and leaching test, according to NBR 10,004/04, of the wood plastic composite produced.

2 Experimental

Materials

The HDPE, brand HC LS 7260-L Brasken, with melt index of 7.2 g.10 mim^{-1} and density of 0.959 g.cm-3, was used as polymeric matrix. As coupling agent was used Polybond 3009® produced by Crompton Co., which is composed of HDPE graphitized with 1% in mass of maleic anhydride, recommended for composite with natural fibers. The reinforcements wood post (outside) and RIC were supplied by Companhia Paulista de Forca e Luz - CPFL/RGE unit Caxias do Sul / RS.

Methods

The wood posts (outside) were milled in mill knives, brand Primotécnica - P1001, and the RIC were milled in ball mill, brand SP100 - 312. Both were dried in oven, brand Quimis Scientific Instruments - B252, at 105 ° C for 24h. It was analyzed different composite formulations with 30% reinforcing, 2% coupling agent, on total weight, resulting in five formulations proposed as shown in Table 1.

Tabela 1 – Composition of the samples

Sample	Composition	
	Wood	**RIC**
MA100IS0	30	0
MA75IS25	22,5	7,5
MA50IS50	15	15
MA25IS75	7,5	22,5
MA0IS100	0	30
HDPE	0	0

Note: In the codification the acronyme MA is related to the wood fraction and IS to RIC fraction in each sample

The materials were processed in a twin screw extruder, model COR 20-32-LAB, brand MH equipment, with the following temperature profile 150, 160, 175, 180, 180, 185, 190, 190 ° C, with screw rotation speed of 200 rpm. The test samples were produced in a Injector, model 150-80 LHS brand Himaco, with three heating zones, 160, 170 and 180 °C, mold with 40 °C and screw speed of 60 rpm.

Characterization

The flexural strength test was performed according to ASTM D790-10 at a speed of 1.5 mm / min. The tensile strength test was performed according to ASTM D638-10 at a speed of 5 mm / min. Both tests were conducted in a universal machine EMIC DL 2000 in the Polymer Laboratory - LPOL, University of Caxias do Sul. The leaching test in the composite MA50IS50 was performed in according to NBR 10.005/04.

3 Resultados e Discussão

Flexural strength

The composite properties were compared to those of pure HDPE. That passed for the same process than the composite sample to undergo the same mechanical and thermal degradation process which the composite material was submitted. Figure 1 presents the flexural strength of samples.

Figura 1- Flexural strenght of composites.

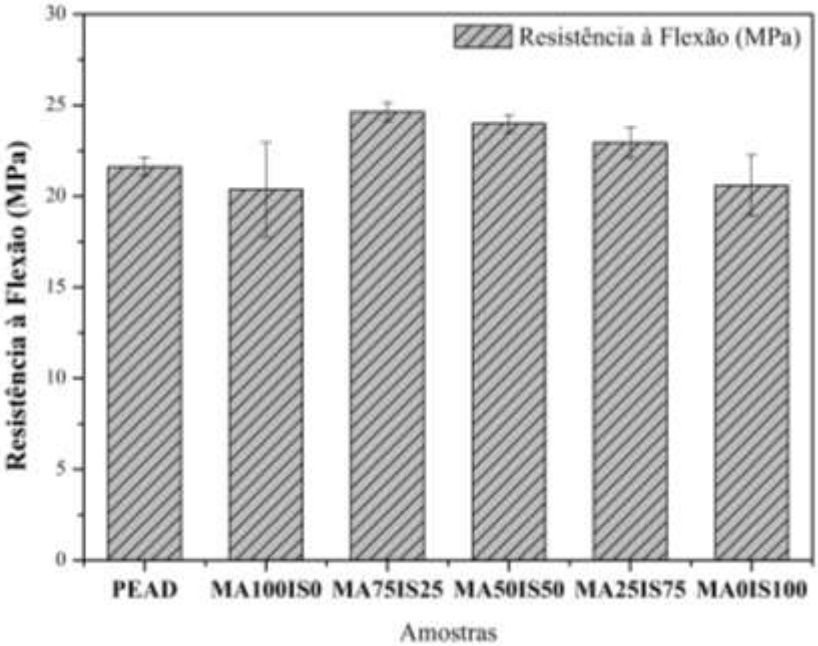


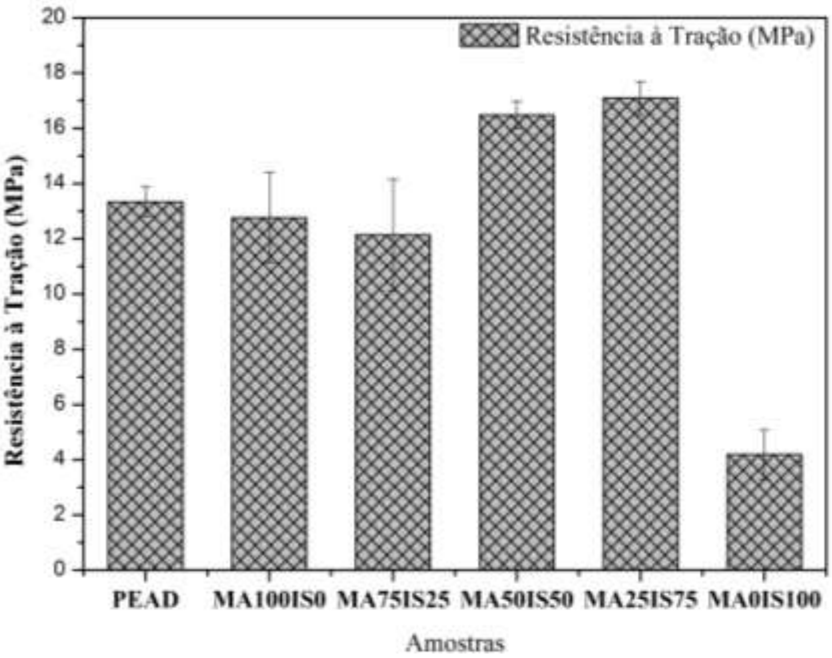
Figure 1 shows that reinforcements addition increased the flexural strength in MA75IS25 and MA50IS50 MA25IS75 samples, compared to HDPE. This result is associated with the restriction in the polymeric mobility promoted by the presence of particulates. The fillers geometry contributes for a its homogeneous distribution in the polymeric matrix beyond the shear forces in the extrusion process that favor the reinforce distribution, lastly a possible orientation of fellers in a preferential direction during the injection process (ANTICH *et al*., 2006; KUO *et al.*, 2009; SOCCALINGAME *et al.*, 2015).

The flexural strength increase can be related to the structural wood composition that is formed by cellulose, hemicellulose and lignin, which is considered a natural polymer with intrinsic property of flexibility. The mineral filler, on the other hand, provides greater surface hardness and increased the composite stiffness. The fillers properties combination and its concentration in the composite contributed to obtain considerable increase in the flexural strength property.

Tensile strength

The results for the tensile strength test of composites are shown in Figure 2. It is possible to observe that the tensile strength increase in MA50IS50 and MA25IS75 samples. This result is related to the effect promoted by the reinforcement with wood and RIP powder and its distribution inside the composite, this particulate fillers, when homogeneous disperse, results in a more effective load transfer, improves the stiffness and strength properties of the composites obtained by injection process. Another relevant factor is the wood composition which favors the increase of this property (ANTICH *et al*., 2006; BORSOI, *et al*., 2011; JAWAID *et al.*, 2011; ALBINANTE, *et al.*, 2013).

Figure 2 – Tensile strength of composites.



Leaching Test

The composite was subjected to the leaching test, the leachate was analyzed the chemicals elements present in the wood. The Table 2 shows the concentration of chemical elements in the leachate and the maximum concentration of it allowed by legislation.

Table 2 - Leaching test results and maximum concentration of chemical elements alloed by conforme NBR 10.005/04.

Chemical elements	Leaching concentration ($mg.L^{-1}$)	Maximum leaching concentration allowed byNBR 10.004/04 ($mg.L^{-1}$)
Copper	0,626	-
Chrome	0,225	5,00
Arsenic	0,101	1,00

The concentration of metals in the leachate is very low compared with the Law limit, related to maximum leaching concentration only 4.5% of chrome and 10.1% for arsenic leached from the composite. The Copper concentration was not compared because there is no limit established in legislation. Thus, the composites produced can be considered non dangerous, according to the classification presented by NBR 10,004/04, enabling the application of these materials.

4 Conclusion

It was possible to produce composites from waste, and the sample with 50% wood threated with CCA and 50% of RIC powder (MA50IS50) presented the best mechanical properties compared to pure polymer.

The obtained compound can be considered non-hazardous because it did not show leaching above the limits allowed for NBR 10.004/04, although it is necessary perform the solubilization test, according to NBR 10,006/04, to classify it as inert or not inert.

The production of wood plastic composites from wood waste with CCA and RIC particles proved to be a viable alternative as it allows the prime destination of waste, adding value to the material and promoting the reuse practice.

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