# ENVIRONMENTAL PROBLEMS IN THE PRODUCTION OF GYPSUM ENCOURAGE ITS RECYCLING AND REUSE FOR THE PRODUCTION OF NEW COMPOSITES

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## ABSTRACT

*In Brazil, plaster recycling has been growing since the change in resolution 307 of the National Council of the Environment (Conama), which since 2011 classifies plaster as a recyclable product. Thus, the industries generating this type of waste are responsible for properly targeting them. The main ways to recycle plaster are: reuse for soil repair in the agricultural industry and calcination, therefor, the waste can be reused again in the civil industry. This work studied the temperature for calcination and the contamination of the residues of the production of plaster angles, to verify the feasibility of recycling with a lower possible energy consumption and, also for the use of these particles as dispersed phase in new composites. For this, XRD, FTIR tests were carried out and the grain size obtained after the plaster recycling was determined.*

*Keywords: Environmental problems, recycling, gypsum, plaster, composite*

## INTRODUCTION

One of the biggest gypsum production of South America is Brazil, that produced 3300 tons in 2016, representing a drop of 22 % in its production, compared to data from 2013, when 3750 tons were produced, a number that is falling every year. The largest producer of gypsum in the world is China, which produces 130000 tons per year, out of a total of 265,000 tons produced worldwide [1–3].

The large-scale production of gypsum around the world boosts civil construction, its main consumer and also seeks sustainability by reducing the use of natural resources, the use of energy resources and waste generation, as well as increased reuse and recycling of waste. Therefore, this area is an eminent consumer of recycled products and also, the main generator of gypsum waste. However, the production of plaster causes many environmental impacts, such as groundwater contamination, desertification of the region due to deforestation, discarded ores and suspended particulate matter and pollutants. Another big problem, for Brazil, a country with continental dimensions, is logistics. The plaster produced in the northern and northeastern regions is often transported to the southern region, about 3000 km away, increasing the cost due to transport and, again, generating pollutants due to the burning of fuels used in the supply of trucks, the main means of industrial transportation in Brazil [4–6].

All these factors encourage the recycling of plaster in Brazil, mainly after the change in resolution 307 of the National Council of the Environment (Conama), which since 2011 classifies plaster as a recyclable product. Thus, the industries generating this type of waste are responsible for properly targeting them by increasing the amount of waste plaster recycled in the country ever since. The main ways to recycle plaster are: reuse for soil repair in the agricultural industry and calcination, therefor, the waste can be reused again in the civil industry [1, 7].

Besides other applications, gypsum can be used as a wall coating and ceilings coverings, headliner and retardant of the cement setting time. It is also used in the medical area in surgeries and traumatology, in agriculture as soil conditioning, in the ceramic, metallurgical and plastic industry for making mold, and other applications [4]. Considering the great applicability of gypsum, mainly in civil construction, this material was chosen to be reused and used as dispersed phase in a composite.

However, during the manufacture of commercial plaster, the hydrated calcium sulfate ($CaSO_42H_2O$), known as gypsum, is heated between 140 °C and 180 °C for removing water from crystallization. This process, called calcination, dehydrates the gypsum by changing the chemical formula to calcium sulfate hemihydrate ($CaSO_40,5H_2O$) or commercial plaster. This process is reversible; therefore, during the hydration of the commercial plaster for application, the structure turns into gypsum again, as shown in Equation A [8, 9].

$$CaSO42H2O + 23.81\ cal/g \rightleftarrows CaSO40.5H2O + 2.5H2O \quad (A)$$

In order to allow plaster reuse after consumption and its reproducibility, it is necessary to study the dehydration process of the material seeing that the type of calcium sulphate obtained will depend on the temperature used [8, 9].

This work studied the temperature for calcination and the contamination of the residues of the production of plaster, to verify the feasibility of recycling with a lower possible energy consumption and, also for the use of these particles as dispersed phase in new composites.

## MATERIALS AND METHODS

The post-consumption gypsum was obtained from burrs of the production process of plaster frames in a manufacturer located in Barueri, São Paulo. Samples of the virgin plaster used for manufacturing the same frames were collected from the same manufacturer.

Samples of plaster residue was taken to a drying oven for 3 hours at 100 °C. Then, the samples were milled in a ball mill at room temperature until a fine and homogeneous powder was formed. The samples of recycled gypsum was again dried in a drying oven at 100 °C for 2 hours. Thus, 3 types of samples were obtained, virgin plaster and used gypsum without thermic treatment and recycled plaster treated at 100 °C.

To verify the efficiency of the heat treatment, Fourier transform infrared spectroscopy (FTIR) and X-ray diffraction (XRD) tests were performed. In order to size the obtained particles, the Malvern test was performed.

FTIR was employed in a NICOLET-ID5-ATR Spectrometer, in the transmission mode. The working wavenumber range of the spectrometer was from 4000 to 500 $cm^{-1}$. The FTIR spectra were recorded in all samples and the transmittance (u.a.) was plotted as a function of the wavenumber ($cm^{-1}$).

The XRD analyses were performed with a diffractometer Rigaku Miniflex 300 using Cu Kβ radiation with wavelength of 0.154 nm, generated with 30KV voltage and 10mA current , at room temperature, in the range of 2Θ from 5 to 120 ° and at a scanning rate of 0.02 °/min.

An equipment of the brand Malvern Mastersizer 2000, version 5.154, was used to determine the particle size distribution by laser granulometry, using ethanol as a dispersion medium.

## RESULTS AND DISCUSSION

*Fourier transform infrared spectroscopy (FTIR)*:

Figure 1 shows the spectrum obtained for samples Virgin Plaster, Used Gypsum and Recycled Plaster. By the analysis of the functional groups present in Virgin Plaster and Recycled Plaster it can be seen that these samples are composed by calcium sulfate hemihydrate ($CaSO_4 0,5H_2O$-plaster). The bands appearing at 3606 and 3550 $cm^{-1}$ are related to the stretching of the O-H bond. At 1620 $cm^{-1}$ is attributed to the bending of the H-O-H bond from water molecules of crystallization, present in the calcium sulfate hemihydrate and not present in the hydrated calcium sulfate ($CaSO_4 2H_2O$-gypsum) [8, 10–12]. The sulfate groups ($SO_4^{-2}$) were identified by bands 1120, 1080 and 1010 $cm^{-1}$ for asymmetric stretching and the band 660 $cm^{-1}$ for asymmetric bending of the sulfate ion [8, 11].

However, in the spectra of the sample Used Gypsum, as shown in Figure 1, calcium sulfate hemihydrate and hydrate are present, by onset of bands 1680 and 3403 $cm^{-1}$. The first is attributed to the bending of the H-O-H bond of the water molecules and is present only in $CaSO_4 2H_2O$. The second is attributed to the stretching of the O-H bond [8, 10–12]. The sulfate groups ($SO_4^{-2}$) were identified by bands 1120, 1080 and 1010 $cm^{-1}$ for asymmetric stretching and by the band 660 $cm^{-1}$ for asymmetric bending of the sulfate ion [8, 11].

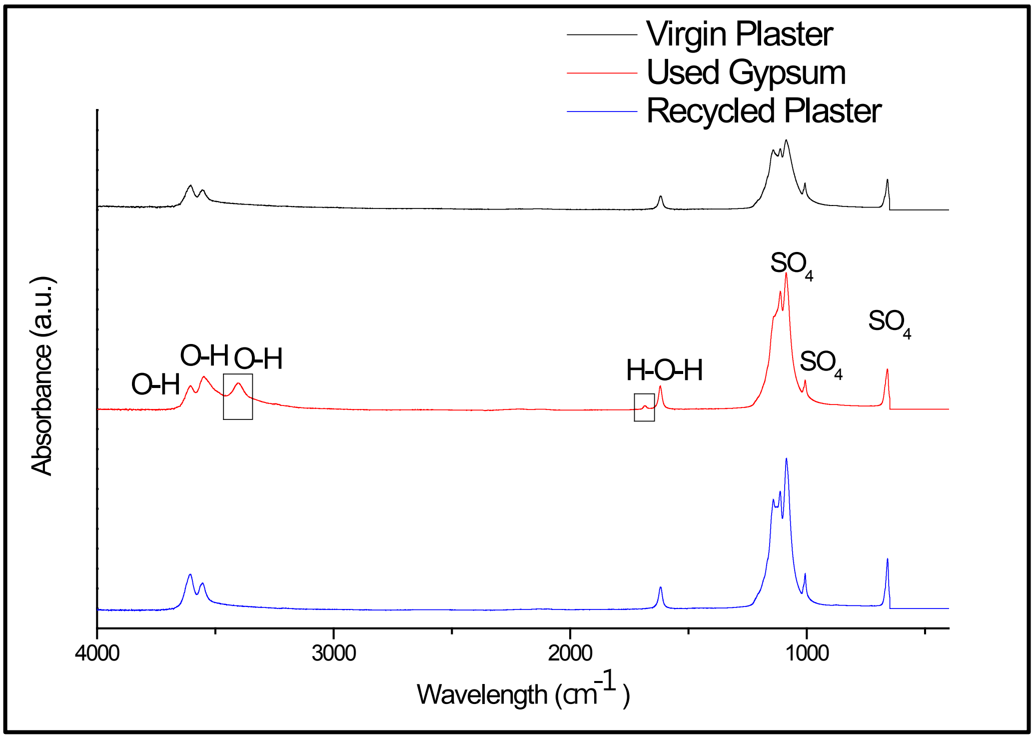


Figure 1: FTIR spectra for Virgin Plaster (room temperature), Used Gypsum (room temperature) and Reclycled Plaster (100 °C).

*X-ray diffraction (XRD):*

Figure 2 shows the X-ray diffractogram obtained for the samples. The peaks identified with the letter C are characteristic of the calcium sulphate hemihydrate ($CaSO_40.5H_2O$-plaster) and were found in the three samples. The peaks identified with the letter H are characteristic of hydrated calcium sulfate ($CaSO_42H_2O$-gypsum) and were found only in the sample Used Gypsum, as expected, due to due to the presence of water from the process of wetting the plaster for modeling. The peaks of bassanite (β-$CaSO_40,5H_2O$) and anhydrite ($CaSO_4$), by-products of gypsum calcination, were also foundin all samples [8, 12].

XRD analyses corroborate the FTIR spectra and confirm that samples Virgin Plaster and Recycled Plaster are formed by calcium sulphate hemihydrate ($CaSO_40.5H_2O$)

and the sample Used Gypsum is formed by the mixture of calcium sulphate hemihydrate and hydrate.

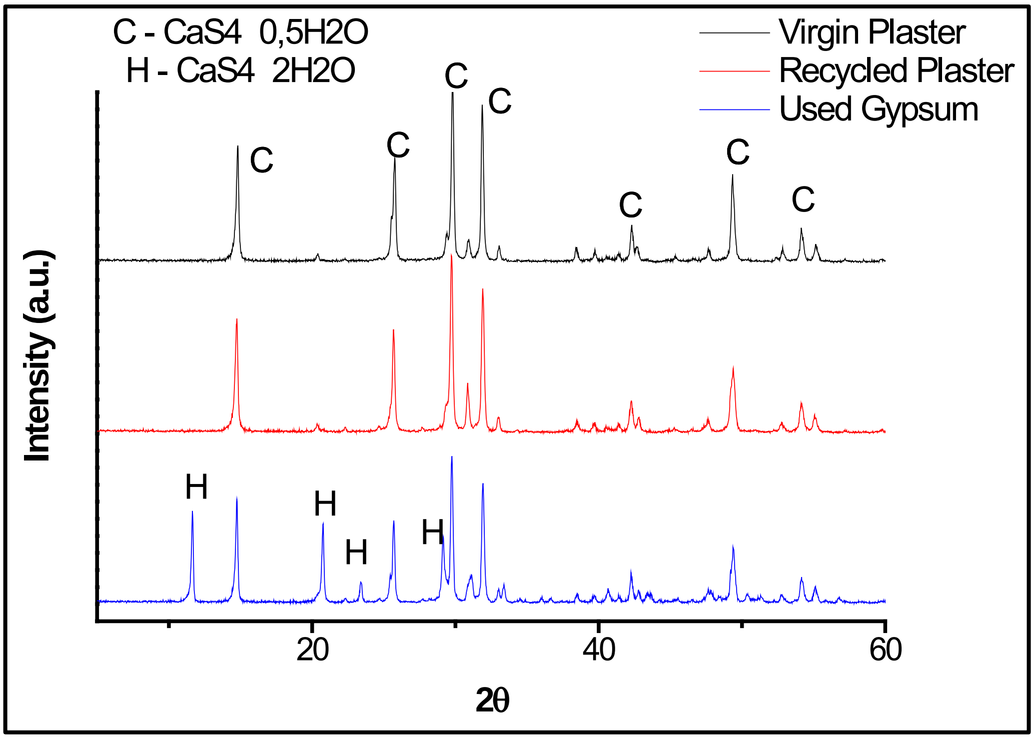


Figure 2: XRD diffraction patterns for Virgin Plaster (room temperature), Used Gypsum (room temperature) and Reclycled Plaster (100 °C).

*Particle size distribution:*

The sizes and distributions of recycled plaster particles have been investigated by Malvern. Figure 3 shows that particles possess a distribution ranged from 0,3 to 200 µm with one intensive peak at 3 µm.

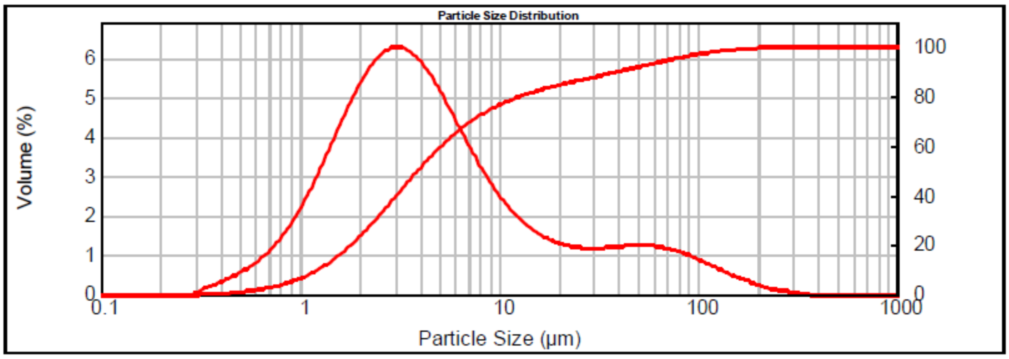


Figure 3: Particle size distribuition of recycled plaster particles by Malvern.

## CONCLUSIONS

The FTIR and XRD analyses performed in the samples show that the material studied has high purity; it is basically formed by calcium sulphate, which was confirmed by the analysis of the functional groups related in the results of these tests. The results confirmed that the process of hydration and dehydration of the commercial plaster are reversible. Because a virgin plaster sample had a dehydrated structure, a sample of gypsum recycled at room temperature presented a hydrated structure. When the recycled gypsum was dried in an oven, it was again dehydrated as virgin plaster. The drying process proposed is shown to be efficient for gypsum dehydration. The grinding resulted in particles with dispersion of homogeneous granulometry. This recycling process may be used in future work to control the moisture and size of gypsum particles and then insert them into a polymer matrix

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