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ANNALS OF THE UNIVERSITY OF ORADEA
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ESTIMATING mg CO_2 GENERATED FROM A COTTON FABRIC DEGRADATION

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Abstract: *Nowadays, concern about sustainability is a fact. Textile industry is considered as one of the most pollutants. There is an increase interest in quantifying the pollution generated by textiles. The chemicals and water used by textile industry are considerable. However, water consumption and wastewater are not the only drawback form textile sector. Greenhouse gases are important pollutants as well. It is necessary to measure pollution, in order to design and apply mecanisms to reduce the one generated from textiles, it is also important to improve product stewardship and control the value chain.*

This article establishes a method to evaluate the accelerated biodegradability by burial in compost of textile materials. In our experiment, a respirometric technique has been used to estimate the production of CO_2 through the comparison of results between the textiles to be analyzed against a reference product, which corresponded to a microcrystalline cellulose, and the ecosystem itself, without fibers. This test has allowed adjusting the reactions for reagent consumption volumes within an acceptable range. The results obtained have made it possible to validate the analysis method, since the process shows sufficient sensitivity to obtain significant differences between the analyzed samples which are microcrystalline cellulose and a sample from cotton fabric.

Key words: *Biodegradability, cellulose, greenhouse gas, sustainability, environment, fiber*

1. INTRODUCTION

The main environmental problems caused by the textile industry are usually related to high energy consumption, high amount of water consumption, the formation of wastewater, the use of chemical products, CO_2 emissions and solid waste. Textiles are responsible for 10% of global carbon emissions [1,2]

As for solid waste, it is the current model of textile production and preparation and its high consumption that leads to the formation of large quantities, since only 20% of textile waste, worldwide, is recycled or reused; while the remaining 80% is deposited in landfills or incinerated. This produces a great loss of energy and raw materials, as well as contamination of soils and marine ecosystems.

Solid waste can be generally classified according to its origin into three main types:

1. Post-industrial waste: those produced in manufacturing;
2. Pre-consumer waste: substandard or unsold items;
3. Post-consumer waste: generated by consumers.

But, in addition, they can be classified according to their raw material, in biodegradable waste (natural fibers or biopolymers) or non-biodegradable (synthetic polymers). Synthetic waste that is not recovered or recycled takes 100 to 1,000 years to degrade and ends up as microplastics, usually as a result of photodegradation, in small fragments. Microplastics, around five millimeters in size, accumulate above all in the sea, but also in the terrestrial environment [3].

This causes, therefore, contaminated farmland and, consequently, contamination of the food that is grown; as well as marine pollution, since agricultural products end up in local streams, rivers and groundwater, which will transport these residues to the sea.

With all this, some larger plastics cause death by suffocation or choking in marine animals that ingest them without realizing it. But the real problem is microplastics, which alter the quality of water, which are absorbed by plants and animals and, finally, reach the human food chain through the food that is consumed. [4,5]

The presence of these compounds continues to grow, affecting marine life, and therefore the entire planetary ecosystem, becoming a public health problem. [6]. For this reason, the textile sector is moving towards products that follow the bases of the circular economy in order to obtain products that are more durable, recyclable and easier to reuse or repair, as well as the greater use of biodegradable materials, in order to obtain greater sustainability in the sector.

Biodegradation occurs due to the action of enzymes from natural microbes (bacteria, fungi, and algae) resulting in a reduced molar mass of macromolecules that make up the biodegradable material. The biodegradation process can be divided into:

- 1) primary degradation
- 2) final degradation.

During primary degradation, the material undergoes weight loss, fragmentation, molecular weight reduction, and degrades into soluble, low molecular weight compounds. Final biodegradation or mineralization leads to the conversion of low molecular weight compounds (from primary degradation) into water (under aerobic conditions), CH_4 (under anaerobic conditions), CO_2 and/or cellular biomass, when it is a compostable material.

The degree of biodegradation or mineralization is defined as the conversion of organic carbon to CO_2. This depends on the properties of the polymer, as well as various abiotic and biotic factors.

For example, in compost and soil, where the higher temperature is available for degradation reactions, the rate of biodegradation is higher. Similarly, the concentration and diversity of microbial communities are higher in soil and compost that support higher rates of biodegradation. In aquatic systems, microenvironments have been shown to have a profound impact on the degradation of biodegradable plastics. Therefore, to efficiently capture the complexity of aquatic environments, the testing methodology must take into account all habitats (supralittoral, eulittoral, sublittoral benthic, deep-sea benthic, pelagic, and sediment) along with stress factors. abiotic (pH, salinity, temperature, UV etc.) and the microbial communities that influence degradation. Other factors that affect the biodegradation of materials include salinity, moisture, the presence of oxygen, pH, and UV radiation.

Therefore, this article aims to establish a work methodology to assess the degree of biodegradation of textile materials, in a compost environment at accelerated ageing. In this paper we compare results from a microcrystalline cellulose with results from cotton fabric. The ecosystem for burial is made of compost and perlite, and the amount of CO2 is from the ecosystem is also taken into consideration.

2. MATERIALS AND METHODS

2.1 Materials

In this study, a glass container with a hermetic closure with a capacity of 2.5 L is used, which will contain perlite and universal cultivation soil, both acquired from Batlle, distilled water and a 100 % cotton fabric 115 g/m^2 sample to be evaluated. Microcristalline cellulose was used as control.

Biodegradability assessment is performed with potassium hydroxide (KOH) solution, barium chloride ($BaCl_2$) solution, hydrochloric acid (HCl) solution and phenolphthalein as indactor. All solutions were prepared with distilled water.

2.2 Methods

This test was conducted according to the methodology described by Miniyasami et al [7] and Modelli et al [8]. Three bottles were prepared as shown in figure 1. Every bottle has the same composition except the material subjected to the biodegradation. One was prepared with, perlite, soil, perlite, and water, placing a glass with 40 mL KOH on the top. The second one was prepared with microcrystalline cellulose in the middle of the soil and the third one with the cotton fabric to test. Every sample was tested twice and the average value was offered as the test result showed in this paper.

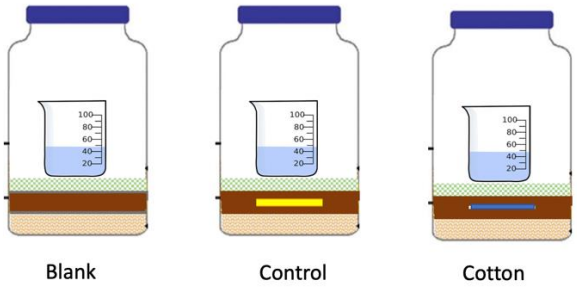

***Fig. 1**: Samples prepared for the burial test.*

Twice a week for 50 days, the beaker containing KOH is removed and a new one is inserted, the container is hermetically sealed again to maintain the ecosystem created inside. Then, an exces of mL of $BaCl_2$ are introduced into the KOH beaker that has captured the generated CO_2, to convert soluble K_2CO_3 into insoluble $BaCO_3$, and it is allowed to stand for 10 min so that all the precipitate forms are placed at the bottom of the glass. This process can be expressed as the chemical reaction (1):

$$2KOH + CO_2 \rightarrow K_2CO_3 \text{ (soluble)} + H_2O \quad \textbf{(1)}$$

Afterwards, 10 mL of the solution are extracted without taking precipitate and introduced into a clean beaker, magnetic stirring is applied, 2 drops of phenolphthalein are added as indicator and the titration is carried out by dropping HCl from a burette, previously prepared, until the color of the solution returns to the initial one, according to the chemical reaction (2).

$$K_2CO_3 + BaCl_2 \rightarrow 2KCl + BaCO_3 \text{ (Precipitate)} \quad \textbf{(2)}$$

The volume in mL of HCl consumed is noted, and then the mg of CO_2 determined according to the equation 1:

$$\text{mg } CO_2 \text{ sample} = \text{mg } CO_2 \text{ test} - \text{mg } CO_2 \text{ blank} \quad \textbf{(3)}$$

where:

- Sample = Fabric to analyse
- Test = bottle with soil, perlite and the fabric
- Blank = bottle with soil and perlite

Substracting the CO_2 from the blank allows to obtain results from the fabric or the sample buried, without including the CO_2 due to the soil nor the perlite.

3. RESULTS

Generally, the biodegradation process of a polymeric material is divided into two steps, initially the depolymerization or rupture of the polymeric chain is generated, and later the mineralization is obtained [8,9]. During the biodegradation, CO_2 is generated. Test conducted in our study allowed to measure its production. Figure 2 shows the behavior of both microcrystalline cellulose and cotton fabric. Apparently, both samples show similar behavior. As cotton is mainly comprised of cellulose, such similarity was expected. Cotton fabric is generating slightly lower quantities of CO_2 in comparison to microcrystalline cellulose.

Once results are analysed concisely, it can be clearly observed that during the first 10 days the CO2 generation is quite similar although, once the test has been conduted for more than 10 days, there is a change in tendency, and CO_2 generated from cotton is not increasing as fast as the CO_2 from microcristallyne cellulose. This can be since, cotton has cellulose but some other components which are not being degradated by soil burial at the same speed as cellulose.

It is also noticeable, there are some slight fluctuations in the results which can also be observed for both samples. This can be due to the fact that every measurement was conducted on Thuesday and Friday weekdays, what implies every 3 or 4 days, but it can also be due to some fluctuations on the temperature of the heater which are accelaerating or reducing the speed of the sample degradation.

In order to determine the final degradation of the process, the test should have been conducted until the CO_2 produced from the fabric is equal to cero what would imply the CO_2 is solely due to the blank composition, and there is no more influence of the fiber, nor the cellulose tested as reference. Some authors [7] stated that the test must be conducted for at least 180 days to get the final degradation of cellulose used as reference.

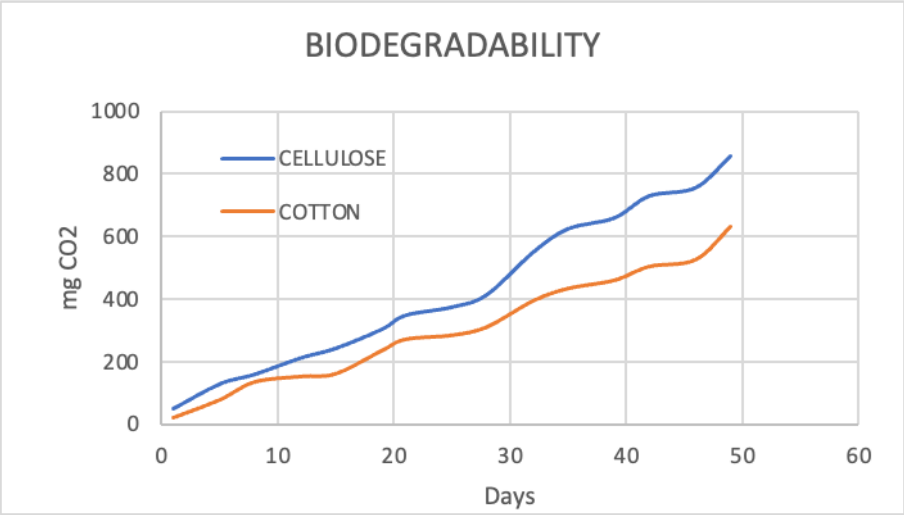

***Fig. 2**: Biodegradability of cotton fabric.*

4. CONCLUSIONS

According to the suggested procedure, we have demonstrated it is possible to obtain results which are sensitive enough to estimate the CO_2 produced from the degradation of fabrics buried in soil. Althoug at first sight it would be easy to state that cotton generated lower quantity of CO_2 gas than cellulose, this cannot be affirmed as we don´t know the total amount of this gas generated by every tested samples. This test allows to stablish comparisons with some reference materials such as the microcristallyne cellulose used in our study, and it will allow to compare the biodegradability of different materials.

Furhter studies must be conducted with different materials and stablishing comparisons between the quantity of CO_2 generated. Considering the speed of degradation can be different from different samples, comparisons must be conducted not only for the same period of time, but for the final degradation of the tested sample. This will allow to determine the total quantity of CO_2 generated per gram of fiber and stablish compmarisons between fibers.

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