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Comparative Analysis of disposable diaper degradation using two biodegradable agents

Análisis Comparativo de la degradación de pañales desechables empleando dos agentes bio-degradantes

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Abstract

This project allows knowing the degree of degradation of disposable diapers using two different biodegradable agents: Isoptera Termites and Activated Sludge. For this degradation process, used diapers were used that contained liquid waste and in their original complete form, for the degradation control the following physicochemical parameters were evaluated: pH, TDS, CE, Temperature, % of degradation, mass and volume reduction. Being part of a very useful product on the market, diapers become part of the large amount of urban solid waste that is generated by excessive use over the years, becoming one of the most notoriously present wastes along with plastic waste. The search for an alternative to accelerate degradation made it possible to compare the best result to contribute to the improvement of the environment

Degradation, Biodegradable, Sludge

Resumen

El presente proyecto permite conocer el grado de degradación de los pañales desechables empleando dos agentes biodegradantes distintos: Isópteras Termitas y Lodos Activados. Para este proceso de degradación se emplearon pañales usados que contenían residuos líquidos y en su forma completa original, para el control de la degradación se evaluaron los siguientes parámetros fisicoquímicos: pH, TDS, C.E, Temperatura, % de degradación, reducción de masa y volumen. Al formar parte de un producto de gran utilidad en el mercado, los pañales pasan a formar parte de la gran cantidad de desechos sólidos urbanos que se generan por el uso desmesurado a lo largo de los años, convirtiéndose en uno de los desechos más notoriamente presentes junto con los desechos plásticos. La búsqueda de una alternativa para acelerar la degradación permitió comparar el mejor resultado para contribuir a la mejora del medio ambiente.

Degradación, Biodegradantes, Lodos

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Introduction

Solid urban waste is generated in large quantities as a result of the excessive use of containers, packaging, seals, storage, etc., mainly of different types such as plastics, paper, cardboard and glass. There is a waste that is widely used by human beings that represents around 12% of the total waste generated in large cities: disposable nappies.

Disposable nappies made of polyethylene have two types of disadvantages: (1) deterioration when, after use, they become litter and (2) visual and physical environmental pollution after use. In the latter case, due to their resistance characteristics, they are difficult to degrade.

In the latter case, due to their resistance characteristics, they are hardly degraded by soil micro-organisms, remaining visible in the environment for 500 years (Mangiarotti *et al*., 1994). In addition, when incinerated at low temperatures, they generate toxic volatile substances such as dioxins and furans, which are associated with cancer in humans, damage to the reproductive system and developmental disorders in most living beings (Klemchuk, 1990).

In recent years, microbial degradation of polymers and plastics has been considered as an alternative to solve the problem of the final disposal of these wastes, which, unlike incineration, present operating conditions that would not be drastic or costly. Some scientists have pointed out that the biodegradation of polyethylene by microorganisms could be a solution to reduce plastic pollution (Méndez *et al.*, 2007; Limón, 2001 and Silva, 2009).

In Mexico, there is no known process to treat this waste, so it is taken, in its entirety, to open dumps in rivers, ravines, in the open air, sewers and even thrown into the sea, or in the best of cases to sanitary landfills as final disposal (GODF, 2010). The study of the degradation of disposable nappies can mitigate the presence of this phenomenon by knowing the main factors that cause it and, consequently, a method can be determined that can inhibit it to a certain degree depending on depending on the conditions of use. On the other hand, when talking about polymeric materials as waste, it is best to consider the ageing of polymers to avoid further contamination.

Composition of disposable nappies

A disposable nappy generally consists of (I) a liquid-permeable membrane lining the inner surface made of non-woven polypropylene (PP) or polyethylene, (II) a waterproof membrane on the outer surface made of PP, HDPE, starch, cloth or woven rubber, (III) an absorbent core (spongy pulp material) consisting of a fibrous material (cellulose, hemp or synthetic materials) wrapped in waterproof paper, (IV) a polymeric material made of polypropylene (PP) or polyethylene (PP) or polyethylene (PE), (V) a waterproof membrane on the outer surface made of PP, HDPE, starch, cloth or woven rubber, (VI) an absorbent core (spongy pulp material) made of a fibrous material (cellulose, hemp or synthetic materials) wrapped in waterproof paper; (IV) a super absorbent polymeric material, usually sodium polyacrylate (SAP), which has a high water binding capacity, making it possible to retain urine within the absorbent part (the efficiency of a nappy is highly dependent on its ability to absorb and retain urine), and finally (v) minor amounts of tapes, elastic and adhesive material.

The typical composition of a disposable baby nappy has been described by EDANA (2011): cellulose pulp 36.6%, SAP 30.7%, PP 16%, HDPE 6.2%, tape, elastic and adhesive 10.5%. A used baby nappy will also contain residues formed by faeces and urine, consisting of approximately 30 g carbon, 10-12 g nitrogen, 2 g phosphorus and 3 g potassium that can be degraded. The mass of these wastes has been reported in several studies: Torrijos *et al*. (2014), determined a content of 192 g of excreta, composed on average of 18% faeces and 82% urine; Colón and colleagues (2011), reported an average waste per nappy of 171 g, with a different distribution (6% faeces and 94% urine).

Metodology

The methodological development of this project considered the following experimental stages:

a. Collection of used nappy waste from municipal waste dumps.

b. Construction of reactors for activated sludge and reactors for termite isoptera.

c. Procurement of sludge to be activated as a degradation agent.

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d. Procurement of termite isoptera as a degradation agent.

e. Preparation of samples of used disposable nappies for each reactor.

f. Physico-chemical analysis of the waste after degradation.

g. Determination of the percentage of degradation of the nappies with the two degradation agents.

Reactors for the degradation of the nappies.

The reactors were designed based on the model proposed by Kalamdhad and Kumar (2013); Fernandez, *et al*., (2010); and Kalamdhad and Kazmi (2009). They were constructed with a plastic container of 20 L and 2.5 L capacity respectively. A ¼ in. hose was placed in each reactor for aeration.

Activated Sludge Reactor

The recommendations indicated in the standard were followed: NOM-004-SEMARNAT-2002, (ENVIRONMENTAL PROTECTION. - SLUDGE AND BIOSOLIDS. - SPECIFICATIONS AND MAXIMUM PERMISSIBLE LIMITS OF CONTAMINANTS FOR FINAL USE AND DISPOSAL); to collect a portion of sludge taking care to maintain the physical, chemical and biological integrity of the sample to be placed inside the reactor.

The main constituents of sludge are: suspended solids, biodegradable organic matter, nutrients, pathogens, metals, and organic toxics. An aeration source must be available to transfer oxygen for degradation to take place.

Heukelekian and Ingols (1947) reported that the initial organic matter removal was always accompanied by oxygen uptake always accompanied by oxygen uptake, as the rate of oxygen consumption was maximal during the first 30-60 minutes of contact during the first 30-60 minutes of contact, and gradually decreased to a constant level. This experimental evidence was sufficient to support the idea that adsorption was not the predominant mechanism of the process. If adsorption were to occur, it would have to be accompanied by a biochemical reaction.

Termite isoptera reactor

For the construction of this reactor it was necessary to take a sample from a termite mound following all precautions and using personal protective equipment. The termite mound was taken from a tree next to a village in a rural area (Poblado C-23 Venustiano Carranza, H Cárdenas, Tabasco).

Figure 1 Sampling of Termite isoptera Termites
Source: Project collaboration team, 2020

The sample was placed in the reactors, which were constructed in triplicate to replicate and establish the degradation measurement parameter with greater certainty.

Figure 2 Termite isoptera reactors with sample of disposable nappies in place
Source: Project collaboration team, 2020

According to the research of Caballero (2014), showing the most appropriate conditions for the conservation of temperature, homogenisation and aeration of activated sludge was carried out to compare the results to be obtained against the degradation of Termite Isoptera.

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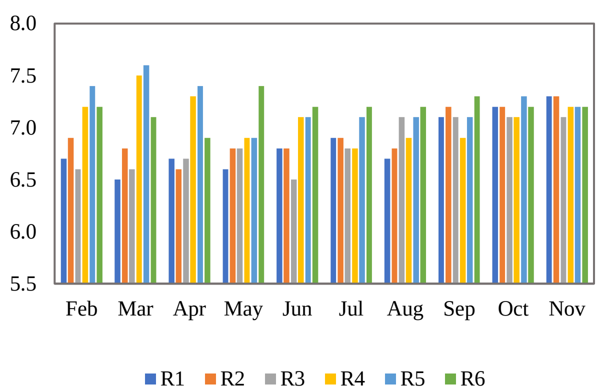
Results

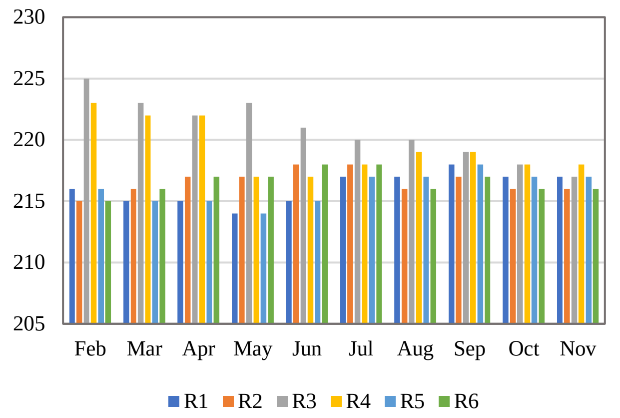
During the degradation process of used disposable nappies by means of activated sludge and Termite Isoptera, the following parameters were analysed every 3 days: pH, Electrical Conductivity, Total Dissolved Solids (TDS), Humidity and temperature, as established by the standard: NOM-004-SEMARNAT-2002 ENVIRONMENTAL PROTECTION. - SLUDGE AND BIOSOLIDS. - SPECIFICATIONS AND MAXIMUM PERMISSIBLE LIMITS OF CONTAMINANTS FOR USE AND FINAL DISPOSAL, and the analysis techniques were worked according to the MEXICAN STANDARD NMX-AA-25-1984. ENVIRONMENTAL PROTECTION - SOIL POLLUTION - SOLID RESIDUES - pH DETERMINATION - POTENTIOMETRIC METHOD, the KURSCHNER AND HOFFER method was used in the analysis of mass reduction and cellulose quantity.

The results of the determinations carried out during the period in which the reactors were kept in the reactors are presented.



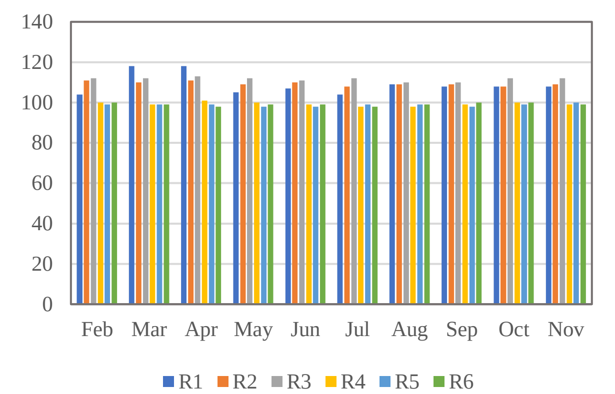
Graph 1 pH Behaviour from Feb to Nov
Source: Project collaboration team, 2020

The pH results are between 6 and 8 "pH classification of the sample (sludge)", most of the essential elements perform well at pH between 6.5 and 8 complying with the specific standard for this item.



Graph 2 Behavior of the Electrical Conductivity from Feb to Nov
Source: Project collaboration team, 2020

Salinity is a parameter used to evaluate the electrical conductivity of a saturation extract of the sludge at the point of salinisation; the results obtained for this parameter indicate that it is a non-saline residue which does not affect the crops in the environment; this salinity is suitable for the development of pastures for livestock activity, as well as for use as fertiliser.



Graph 3 TDS Factor Behaviour from Feb to Nov
Source: Project collaboration team, 2020

The TDS factor of an extract of disposable nappies with termites and activated sludge showed results of 97 and 114 PPM, with a high TDS range, however, these values are within the parameters established by the current Standard. To compare the mass loss reduction between the different reactors, the final weight of each sample and the percentage of dry weight reduction were obtained.

The mass reduction on a dry basis in the controls was from 31% to 35% in the activated sludge reactors, for the reactors with Termite Isoptera from 96.88% to 98.53%. The greatest mass reduction (98.53329%) was obtained from reactor number six corresponding to the one with the presence of Termite Isoptera as a degrading agent.

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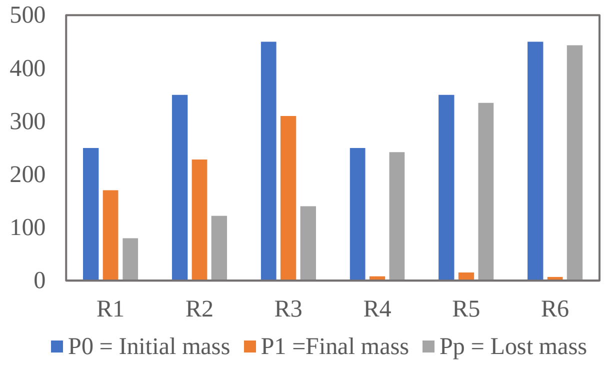

Graph 4 Loss of mass of samples placed in the reactors
Source: Project collaboration team, 2020

For the determination of the cellulose content, the six samples of disposable nappies were analysed, taking into account that each nappy has a cellulose content of 68% in its original state, the formula used to calculate the percentage of cellulose was:

$$\%\ Cellulose = \frac{C}{M} * 100 \qquad (1)$$

Where:
C: Weight of filtered cellulose
M: Weight of the sample

Total cellulose content						
R1	R2	R3	R4	R5	R6	UNITS
170	238	306	170	238	306	g. of Cellulose
127.50	171.36	195.84	34.00	45.22	42.84	g. of Cellulose Remaining
75.00	72.00	64.00	20.00	19.00	14.00	% Cellulose Remaining
42.5	66.64	110.16	136.0	192.78	263.16	g Gradients
25	28	36	80	81	86	% Degraded

Table 1 Results of the calculation of the total cellulose content in % and in grams
Source: Project collaboration team, 2020

When determining the percentage of cellulose content for each of the reactors, a lower percentage of cellulose content was observed in the reactors containing termite isoptera (from 14% to 20% as shown in the results in Table 1, R4, R5 and R6) compared to the activated sludge reactors where the percentage of cellulose content was 64% to 75% (R1, R2 and R3, from Table 1), indicating that in the termite isoptera reactors there was more cellulose degradation.

Conclusions

According to the results obtained in this study of degradation of used disposable nappies (contaminated with urine), which were treated with two degradation agents, activated sludge and Termite Isoptera, in order to accelerate their degradation, a higher percentage of degradation was observed in the Termite Isoptera reactors compared to the activated sludge reactors.

The percentage of cellulose content at the end of the experiment allows us to see the degradation action over time, indicating that a nappy is composed of 68% cellulose. In the reactors with the first degradation agent (activated sludge) the cellulose reduction was for R1-25%, R2-28%, R3-36%, with the second degradation agent (Isoptera termites) the cellulose reduction reached R4-80% R5-81% R6-86%; therefore, there is a higher level of degradation of the disposable nappies in the reactors containing Isoptera termites.

References

Aumonier, S. y Collins, M. (2005). *Life cycle assessment of disposable and reusable nappies in the UK*, Environment Agency: Bristol, UK. p. 203.

Bonilla, V., & N. T. (2008). Secado Solar de Lodos. *Tesis de Maestria.* Mexico.: ingeniería Ambiental. UNAM

Caballero, J. (2012). Estudio de los efectos de la densidad de lombriz y la relación superficie/volumen en un vermireactor *de alta tasa*, alimentado con lirio acuático seco y lodo residual precomposteados. Tesis Doctoral en Ciencias del Agua. Centro Interamericano de Recursos del Agua. Facultad de Ingeniería. Universidad Autónoma del Estado de México. México.

Colón, J., Ruggieri, L., Sánchez, A., González, A., Puig, I. (2011). Possibilities of composting disposable diapers with municipal solid wastes. Waste management research the journal of the International Solid Wastes and Public Cleansing Association ISWA, 29, pp.249–259.

Conway, M., Jooste, F. y Smith, M. (1996). Treatment of absorbent sanitary paper products. p.14.

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Cordella, M., Bauer, I., Lehmann, A., Schulz, M., Wolf, O. (2015). Evolution of disposable baby diapers in Europe. Life cycle assessment of environmental impacts and identification of key areas of improvement. Journal of Cleaner Production. 95, 322-331.

Delfín Alcalá, Irma, Durán-de Bazúa, Carmen, (2003), *Biodegradación de Residuos Urbanos Lignocelulósicos por Pleurotus*, Universidad Nacional Autónoma de México, Distrito Federal, Revista internacional de Contaminación Ambiental, 19(1) 37-45.

DOF. (2000). NOM-0021-SEMARNAT-2000. Protección ambiental. Lodos y Biosolidos. Establece las especificaciones de la fertilidad, salinidad y clasificación de suelos, estudio, muestreo y análisis. México.

DOF. (2002). NOM-004-SEMARNAT-2002). Lodos y Biosólidos. Especificaciones y límites máximos Permisibles de contaminantes para su aprovechamiento y disposición final.

DOF. (2003), *Ley General para la Prevención y Gestión Integral de los Residuos.* México, (Fecha de consulta: 4 de noviembre 2019), Disponible en: http://www.diputados.gob.mx/LeyesBiblio/pdf/263.pdf.

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