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Use of Natural Fibers in Landfill Leachate Treatment

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Abstract**—**Due to the resultant leachate from waste decomposition in landfills has polluter potential hundred times greater than domestic sewage, this is considered a problem related to the depreciation of environment requiring pre-disposal treatment.In seeking to improve this situation, this project proposes the treatment of landfill leachate using natural fibers intercropped with advanced oxidation processes. The selected natural fibers were palm, coconut and banana fiber.These materials give sustainability to the project because, besides having adsorbent capacity, are often part of waste discarded. The study was conducted in laboratory scale.In trials, the effluents were characterized as Chemical Oxygen Demand (COD), Turbidity and Color. The results indicate that is technically promising since that there were extremely oxidative conditions, the use of certain natural fibers in the reduction of pollutants in leachate have been obtained results of COD removals between 67.9% and 90.9%, Turbidity between 88.0% and 99.7% and Color between 67.4% and 90.4%.The expectation generated is to continue evaluating the association of efficiency of other natural fibers with other landfill leachate treatment processes.

Keywords**—**Landfill leachate, chemical treatment, natural Fibers, advanced oxidation processes.

I. Introduction

CONSIDERING the most common destinations of solid waste on earth - dumps and landfills - the resulting leachate from waste at these sites require treatment to be released into the environment. The landfill leachate polluter potential is 10 to 100 times greater than the sewage [1]. Considering the problems in its treatment by biological processes and conventional physicochemical treatment processes, searches for efficient and sustainable treatment alternatives are required.

Biological processes used in the treatment of the landfill leachate have difficulties related to flow, the organic load and the need for large area for carrying out the process giving low efficiency in the treatment. The physical and chemical processes may have a high removal efficiency of organic matter in the treatment of leachate. However, the methods used today - coagulation, filtration and precipitation - have not shown good removal [2]-[5].

With regard to the advanced oxidation process (AOP), it presents itself as an alternative treatment which can increase the biodegradability of the leachate, and consequently, the flow of the landfill leachate treated, since they have high efficiency in removing pollutants and operational ease. The AOP's are processes that involve highly reactive radicals which are capable of destroying many organic pollutants. These processes use, for example, hydrogen peroxide (H_2O_2), an efficient oxidant, used in environmental applications worldwide [6].

Jointly with the method of advanced oxidation processes, this project sought to associate natural fibers to the landfill leachate treatment process. These fibers are of plant origin and have thick walls reinforced by cellulose and ligneous protective substance. Among the advantages of the use of natural or cellulosic fibers, is the production of these fibers in almost all countries, which add a social character in its cultivation.

The fibers chosen for the project are environmental liabilities and are they the palm fiber, coconut and banana fiber. The palm fiber is extracted from discarded parts from Australian Royal Palm tree, giving rise to the palm, as leaflets, external sheaths and stems. This fiber is the only one of the chosen which has thinner layer of ligneous substance which can make it even more effective in the process of oxidation and adsorption. The coconut fiber can be extracted from the exocarp and mesocarp of the coconut discarded after consumption of coconut water in tropical countries. Finally, the banana fiber is removed from banana pseudostem discarded after harvesting the banana bunch for consumption [7], [8].

As reported by [9], natural or cellulosic fibers have great potential for adsorption due to the fact that they contain electrostatic attraction. Adsorbent materials are elements which attract some substances to its surface, but do not allow them to penetrate inside [10]. The adsorption is linked to the surface tension of solutions. As [11] states, the greater the presence of solute at the surface of the solution, the lower the surface tension of the solution and the solute more easily will be absorbed by the solid. In this study, the addition of natural fibers before the advanced oxidation process, decrease the surface tension and increase the contact surface giving better results in the treatment of leachate.

Considering these aspects, the aim of this study was the use of advanced oxidation processes intercropped with the use of natural fibers for the reduction of pollutant levels in leachate generated in dumps and landfills. The specific goals would be the quantitative determination of parameters such as Chemical Oxygen Demand (COD), Turbidity and color in the raw effluent (for leachate) and the treated effluent for each trial, these tests being analyzed both by quantity of oxidative steps as for fiber used. From these results, the goal would be to conduct a comparative study of the same tests in terms of removal efficiency.

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II. Methodology

To conduct the treatment of leachate from the decomposition of waste in landfills using advanced oxidation processes in consortium with natural fibers were needed materials such as raw leachate obtained in a municipal dump, coconut fiber *in natura*, Australian Royal palm fiber *in natura* and banana pseudostem fiber pre-treated with H_2SO_4 (conc.: 1.00% w/v). These fibers were acquired through the cooperation of educational institutions and corporate donors.

Besides, were also used as members of advanced oxidation processes reagents like 30.00% (v/v) nitric acid (HNO_3), 20.00% (v/v) hydrogen peroxide (H_2O_2), 10.00% (w/v) calcium hydroxide ($Ca(OH)_2$) and 10.00% (w/v) aluminum sulfate ($Al_2(SO_4)_3$).

As glassworks and personal protective equipment was used beaker of 200 ml, glass rod, pH meter (pH-009 IA Pen Type pH Meter Digital Tester), measuring cylinder of 100 ml, paper filter nº. 15 Quanty Ø18cm, Digital Scale FWB (model 91379), gloves, safety goggles and lab coat.

To obtain results for the comparative study that would occur after the trials, it was elaborated two different methods divided by the number of oxidative steps involved, but using the same reactants and the same fiber for each of the tests.

The first method (Method 1) consisted of two oxidative steps aided by natural fibers. There were three trials in this method: Trial 01 aided by palm fiber, Test 02 aided by coconut fiber and Test 03 aided by banana fiber.

The second method (Method 2) was performed in three oxidative steps aided by natural fibers. Likewise method one (1) abovementioned, three tests were performed in which Trial 04 was supported by palm fiber, Trial 05 was supported by coconut fiber and Trial 06 aided by banana pseudostem fiber.

For methods 1 and 2, the two initial oxidative steps occur in the same way. This means that the second method is the first method itself, plus other oxidative step. It may be stressed that for every test was used only one type of fiber, with no mixing of different fibers in the steps of trials. The raw leachate used was the same for all the tests and is shown in Fig. 1.

Fig. 1 Raw leachate used for testing

In summary, for each test in Method 1 there were two oxidative steps that involve only one type of natural fiber. In the same way for each test with different natural fibers in Method 2, the two oxidative steps of Method 1 were performed adding an oxidative one step. The first two steps of each of the six proposed tests occurred as follows:

A. First Oxidative Step (Valid for Methods 1 and 2)

In the first step of the testing were measured 150mL of raw leachate poured into the beaker and measured initial pH of the effluent. Then it was added in order to increase the contact surface of the effluent and the adsorption of substances contained in the leachate by means of the natural fibers, 3 (three) grams of fiber (in each test a different fiber) and stirred at sample with the glass rod.

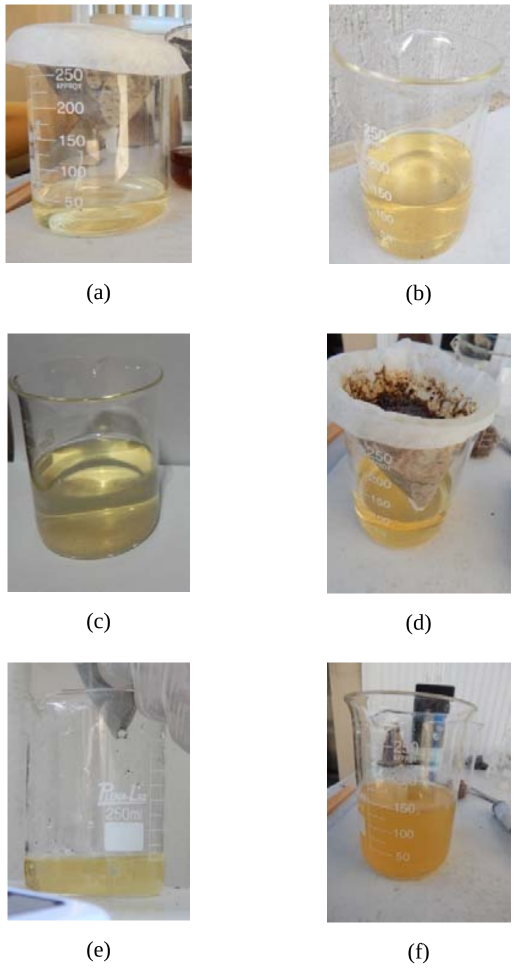

Fig. 2 Results obtained at the first oxidative step of methods 1 and 2 (a) in Trial 01, (b) Trial 02, (c) in Trial 03, (d) in Trial 04, (e) in Trial 05 and (f) in Trial 06

In sequence, it was added 2(two) mL of HNO_3 in the sample also stirred with a glass rod for 10 seconds. After stirring, the pH measurement showed that it was reduced to the range of 1.0 pH units, which was devised in this step. In order to promote the advanced oxidation, 1 (one) mL of H_2O_2 was poured in the sample and the pH was maintained in the range of 1.0 pH units after 10 seconds of stirring with a glass rod. Then was added 7 (seven) mL of $Ca(OH)_2$ with the intention to raise the pH to the range of 9.0 pH units, also stirring for 10 seconds with a glass rod. To conclude this oxidative step it was performed the filtration with paperfilter in a beaker for 10 minutes, to retain solids from the sudden change in pH and oxidation with hydrogen peroxide. Fig. 2 shows the result of the first oxidative step for Trial 01 (a), Trial 02 (b) Trial 03 (c), Trial 04 (d), Trial 05 (e) and Trial 06 (f).

B. Second Oxidative Step (Valid for Methods 1 and 2)

For the second step of the test, it was added to the effluent obtained in the first oxidative step 2 (two) grams of fiber (it is important to emphasize that for each test a different type of fiber was used) and measured the initial pH of the effluent. The sample was stirred for 10 seconds with a glass rod. This step aims at increasing the contact surface, the decrease of surface tension and adsorption promoting substances. Then again added 2 (two) ml of HNO_3 and the sample stirred with glass rod for 10 seconds.

(a)

(b)

(c)

(d)

(e)

(f)

Fig. 3 Results obtained at the second oxidative step of methods 1 and 2 (a) in Trial 01, (b) Trial 02, (c) in Trial 03, (d) in Trial 04, (e) in Trial 05 and (f) in Trial 06

After stirring, the pH measurement showed that it was reduced to the range of 1.0 pH units, leading to the same situation of the previous step to sudden pH change and degradation of organic matter. It was also added to promote the advanced oxidation, 1 (one) mL of H_2O_2 and the pH measurement showed that pH was maintained in the range of 1.0 pH units after stirring. Sequentially were added 3 (three) mL of $Ca(OH)_2$ with the intention to raise the pH to the range of 7.5 pH units, also stirring for 10 seconds with a glass rod.

The next step was the addition of 0.5 g of $Al_2(SO_4)_3$ in the sample to promote flocculation in the effluent. As a final step in this oxidative step it was performed the filtration with paper filter in beaker for 10 minutes, retaining solid formed in that step. Fig. 3 shows the results of the second oxidative step for Trial 01 (a), Trial 02 (b), Trial 03 (c), Trial 04 (d), Trial 05 (e) and Trial 06 (f).

These steps conclude tests performed in Method 1 and are part of the tests performed in Method 2. A continuation to the tests in Method 2 which still has the third oxidative step is described below.

C. Third Oxidative Step (Valid for Method 2)

In the third step of the tests included in Method 2 it was added to the effluent obtained in the second step oxidative 1 (one) mL of HNO_3 in the sample and then it was stirred with a glass rod for 10 seconds. The pH meter showed values ranging from 3.5 pH units. This step aimed to abruptly reduce the effluent's pH. It was also added, promoting advanced oxidation, 1 mL of H_2O_2 which, after being stirred for 10 seconds, maintained the pH in the same range. Subsequently, it was added 3 mL of $Ca(OH)_2$ with the intention of raising the pH to the range of 7.5 pH units, while stirring with a glass rod for a period of 10 seconds. Furthermore, it was also added 0.5g of $Al_2(SO_4)_3$ in the sample to obtain flocculation in the effluent. The pH of in this step is reduced, but not significantly as in the nitric acid step, remaining in the range of 7.0 pH units. To conclude the Method 2, the effluent passes by filtration on filter paper for 10 minutes. Fig. 4 shows the result of the third oxidative step for Trial 04 (a), Trial 05 (b) and Trial 06 (c).

The samples obtained in trials of Method 1 and 2 were characterized in terms of Chemical Oxygen Demand, Turbidity and Color by accredited laboratory. The analytical method was performed according to the SMEEWW (Standard Methods for the Examination of Water and Wastewater 21ªEd 2005-APHA, AWWA, WEF) [12]. The equipment for analysis were the Reactor for COD 003, Macherey Nagel, NanocolorVario 3, the SpectrophotometerUV/VIS-004, Macherey Nagel Nanocolor, UV/VIS, number NUV 0286 and the Turbidimeter 002, Instruthem, TD-300, number Q699507.

(a)

(b)

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(c)

Fig. 4 Results obtained in the third oxidative step of method 2 (a) in Trial 04, (b) Trial 05 and (c) in Trial 06

III. Results

The results obtained in the tests performed are shown in Table I. It is worth remembering that in trials 01, 02 and 03 it was used advanced oxidation process with two steps associated with the respective fibers: Australian Royal Palm Fiber, Green Coconut Fiber and Banana Pseudostem Fiber. In tests 04, 05 and 06 was used an advanced oxidation process of three steps associated with the fibers in the same order.

TABLE I
Analytical Results

Effluent	COD (mg/L)	Color (CU)	Turbidity (NTU)
Raw Leachate	3100.00	500.00	657.00
Trial 01	283.00	48.00	6.26
Trial 02	501.00	58.00	35.49
Trial 03	776.00	163.00	79.00
Trial 04	720.00	92.00	32.71
Trial 05	994.00	92.00	1.92
Trial 06	766.00	58.00	45.52

Based on the physicochemical characteristics considered in the leachate treatability study, removal percentages were calculated for Chemical Oxygen Demand (COD), Color and Turbidity as shown in Table II.

TABLE II
Percentage Removal By Studied Parameter

	% Removal		
Effluent	COD	Color	Turbidity
Trial 01	90.9	90.4	99.0
Trial 02	83.8	88.4	94.6
Trial 03	75.0	67.4	88.0
Trial 05	67.9	81.6	99.7
Trial 04	76.8	81.6	95.0
Trial 06	75.3	88.4	93.1

In order to evaluate the performance by trials and by parameters studied were prepared Table III which consists of a ranking among the trials performed classifying them from the best results in terms of removal of pollutants to the lowest result in the removal percentage. This strategy has facilitated a better view of what is believed to be the most efficient technique in the treatment of leachate.

TABLE III
Ranking Among The Trials Performed (1- Best Result To 6-Worst Result)

Parameter	1	2	3	4	5	6
COD	Trial 01	Trial 02	Trial 04	Trial 06	Trial 03	Trial 05
Color	Trial 01	Trial 02	Trial 06	Trial 04	Trial 05	Trial 03
Turbidity	Trial 05	Trial 01	Trial 04	Trial 02	Trial 06	Trial 03

IV. Discussion

From the analytical results and the comparative study between the fibers and between the methods executed in this project, it can be said that the untreated fibers (palm and coconut) seem to contribute more forcefully for greater efficiency in the removal of the studied pollutants possibly by the hydrophilic character and surface porosity of these fibers.

Besides this fact, removals by parameter show that for COD and Color parameters, the palm fiber both in Method 1 as in Method 2, were more efficient which may indicate that the same substances present in the effluent measured as COD and color were slaughtered . For the coconut fiber it was obtained better results in COD and Color parameters, on trials conducted in Method 1 obtaining 83.8% removal of COD and 88.4% color removal.

The color reduction was also favored by banana fiber reaching in both methods percentage above 75% removal. The reason may be the property of these fibers to reduce coloration by electrostatic attraction [7]-[9].

In the removal of turbidity parameter, the fibers were most efficient palm and coconut indicating that they acquired after adsorption a particle size that allowed their retention in the filtration process.

The use of fibers also confirmed the hypothesis that due to their physicochemical properties such as porosity, adsorption and electrostatic attraction is possible to contribute to color removal, turbidity and COD in the treatment of leachate.

As a limiting factor in the project, it is believed that due to the aspect of the reagent H_2O_2 used in the process, be an interference to COD analysis according to [13], the lack of using a neutralizing agent such as potassium permanganate, while the realization of the laboratory analysis of COD, caused the removal results did not reach even higher levels leading to low concentrations in the final values and therefore better accepted by environmental agencies when evaluating the possibility of release of effluent into water bodies.

Considering that the leachate composition characteristics vary according to the type of solid waste discarded, with the residence time and the physical environment in which this residue is deposited, performance variations of the proposed and used methods may occur even opening the possibility of using other types of natural fiber in the treatment of leachate.

V. Conclusion

From the results obtained it can be inferred that the natural fibers used can be entered in efficient advanced oxidation processes currently used in the treatment of leachate, with significant ecological gains, due to the possibility of reuse of this material. The use of natural fibers in this study provides an opportunity to apply the concept of reuse of organic waste to promote the solution to one of the largest worldwide environmental impacts related to solid waste: leachate.

The expectation is to continue the evaluation of the efficiency of the natural fiber's association with other leachate treatment processes, taking into account not only the techno-scientific aspects as well as socioeconomic, in order to align studies the guideline proposed by the United Nations Environment Programme (UNEP) in terms of the establishment of the green economy [14].

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