

## Mechanical properties of rice husk reinforced low density polyethylene composite

<sup>1</sup>Nwosu-Obieogu K, <sup>2</sup>Ejim I.F, <sup>3</sup>Adekunle K.F

<sup>1,3</sup>Chemical Engineering Department, Michael Okpara University of Agriculture, Umudike, Abia, Nigeria.

<sup>2</sup>Chemical Engineering Department, Institute of Management and Technology, Enugu, Nigeria

### Abstract

The effect of pulverised rice husk (local filler) on the mechanical properties of low-density polyethylene (LDPE) was investigated. The experiment was carried out by measuring and mixing various proportion of pulverised rice husk with a definite (100%) proportion of Low Density Polyethylene in semi-solid form. The results were obtained by conducting the tensile test using the Monsanto Tensometer on the various specimens produced from the experiment. The results show that the pulverised rice husk increases the mechanical strength of low-density polyethylene (LDPE) with useful mechanical properties manifesting at filler values above 4 grams. The 10 grams filler gave the highest stress value of 52.63N/m<sup>2</sup>, strain values of 0.18, Young's modulus of 292.38N/m<sup>2</sup>, and Poisson's ratio of -0.999999304 while the 12gram filler ruptured at the second stretch. These mechanical properties increased with increase in the filler content because the filler acts as local crystallites thereby increasing the capability of the material to withstand higher stress as a result of increased modulus. In conclusion, the effect of pulverised rice husk on the mechanical properties of low-density polyethylene was found to enhance the tensile properties, tear strength, young's modulus, and Poisson's ratio of the polymer and elongation at break was also found to be reduced with increasing filler concentration.

**Keywords:** Low-density polyethylene, Young's Modulus, Stress, Strain, Poisson's ratio

### 1. Introduction

Environmental safety and sustainability issues have led researchers to give attention to materials that will encourage emission reduction to mitigate climate change, regulate demands underlining the need for clean environment and utilize renewable resources. [1]

As reinforcement in polymer composites, natural fibres have many advantages over the synthetic fibres like lower processing price, low density, high modulus, corrosion resistance, high creep resistance, high toughness and higher strength to weight ratio as well as renewable and biodegradable properties. [2, 3]

It has been used in composite materials to reduce cost rather than improving mechanical properties but the environmental problems linked with the production and use of synthetic fibres like the release of greenhouse gases, its non-renewability and escalating prices has changed the scenario and forced researchers to develop natural fiber reinforced polymer composites as a viable alternative. [2, 3, 4]

In the previous decade, natural fibers have been extensively used as reinforcement materials for synthetic, partially biodegradable and complete bio-degradable matrices and most of these fibres are regarded as non-economical viable materials, hence the need to apply it in the development of polymer composites has attracted attention all over. It also offers a possibility to developing countries to use their own natural resources in their composite processing industries. [2, 3, 4] Several works on the application of natural fibers as the reinforcing agent in polymer composites has been reported, though our focus in this study is on rice husk, for instance Atuanya C.U *et al.* [5] investigated the effect of rice husk filler loading on the mechanical properties of recycled low density polyethylene (RPE) mixed with a fraction of virgin

polyethylene (MPE) composites and found that the tensile modulus, flexural strength and modulus of the composites were increased as the filler were loaded but with reduced impact and tensile strength. Nwanonyi S.C *et al.* [6] analysed the mechanical properties of LDPE/Rice husk composites and still concluded that the tensile modulus and hardness showed gradual increase while tensile strength and percentage elongation decreased during filler loading.

Another important issue related with these composites is the interfacial adhesion between a natural reinforcing filler and matrix polymer. In order to obtain good properties by improving compatibility between these two materials with different properties, reinforcing fillers are used after chemical modification, degradation at relatively low temperature due to the presence of cellulose and hemicelluloses and poor resistance to moisture can be reduced if the fibers are impregnated in the polymer with good adhesive properly between the fibers and the matrix using a compatibilizer. [7, 8] Even if, at present natural fibre reinforced composites are gaining importance, the composites available in the market are generally regarded as such, thanks to the use of reinforcements from plant fibres, with, in most cases, their remaining matrix made from fossil fuels making it partially biodegradable, though they have high tensile strength than the complete biodegradable composites.

Hence, this study tends to look at the mechanical properties of partially biodegradable composites by analysing its stress, strain, young's modulus and Poisson ratio.

### 2. Theoretical Analysis

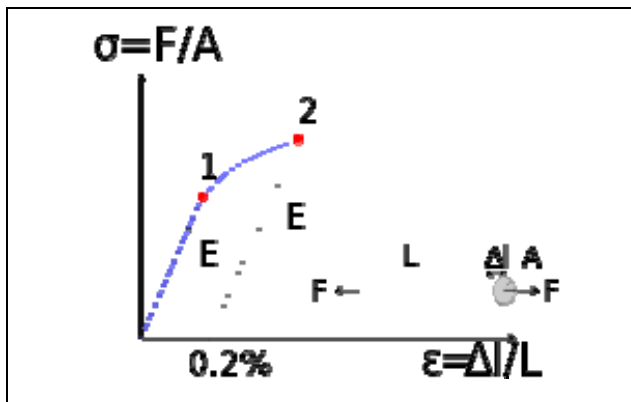
The relationship between the stress and strain that a particular material displays is known as that particular material's stress-strain curve. It is unique for each material and is found by

recording the amount of deformation (strain) at distinct intervals of tensile or compressive loading (stress). These curves reveal many of the properties of a material (including data to establish the Modulus of Elasticity, E).<sup>[9]</sup>

Stress-strain curves of various materials vary widely, and different tensile tests conducted on the same material yield different results, depending upon the temperature of the specimen and the speed of the loading. It is possible, however, to distinguish some common characteristics among the stress-strain curves of various groups of materials and, on this basis, to divide materials into two broad categories; namely, the ductile materials and the brittle materials.<sup>[10]</sup>

Consider a bar of cross sectional area (A) being subjected to equal and opposite forces (F) pulling at the ends so the bar is under tension. The material is experiencing a stress defined to be the ratio of the force to the cross sectional area of the bar:

$$\text{Stress} = \frac{F}{A}$$



**Fig 1:** Stress-strain curve showing typical yield behaviour for nonferrous alloys. Stress ( $\sigma$ ) is shown as a function of strain ( $\epsilon$ )

Where,

1: Elastic (proportionality) limit and 2: Offset yield strength (0.2% proof strength)

This stress is called the tensile stress because every part of the object is subjected to tension with unit of stress as Newton per square meter ( $N/m^2$ )

Young's modulus, E, can be calculated by dividing the tensile stress by the extension strain in the elastic (initial, linear) portion of the stress-strain curve:

$$E = \frac{\text{Tensile stress}}{\text{Extensional strain}} = \frac{\sigma}{\epsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{FL_0}{A_0 \Delta L}$$

Where,

E is the Young's modulus (modulus of elasticity)

F is the force exerted on an object under tension;

$A_0$  is the original cross-sectional area through which the force is applied;

$\Delta L$  is the amount by which the length of the object changes;

$L_0$  is the original length of the object.

### 3. Materials and Methods

Low density polyethylene granules (LDPE), Rice husks (local fibre), External mould release agent (vegetable oil), Metal

mould (100mm X 50mm), 500ml beakers, Glass rod, Water bath, Thermometer, Furnace, and Monsanto Tensometer.

#### a. Preparation of Rice Husk (Local Fibre)

The fibers were separated from undesirable foreign materials (matter) and pith and then ground with hand grinding machine. The ground rice husk was then sieved to get very smooth fine textured particles. They are measured out in grams in the order of 2 grams, 4 grams, 6 grams, 8 grams and 10 grams respectively.

#### b. Preparation of Test Sample

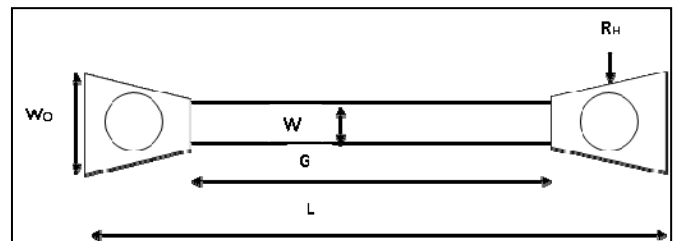
The test sample was prepared by heating the low density polyethylene (LDPE) in a beaker to its melting point ( $120^\circ C$ ). The heating was continued until the semi-solid melt liquefied. The first 2 grams of rice husk (fibre) was added and the mixture stirred intermittently with the aid of a glass rod to ensure complete dispersion of the filler.

The hot melt was then cast into sheet on a metal mould which is lubricated with the external mould release agent (vegetable oil) to give the sample good slip, lubricious, and release properties as well as water repellence to curved parts. The release agent also prevents the sample from breaking on removal from the mould. The cast was then transferred to a water bath for rapid cooling. After cooling the cast was allowed to stand for 48 hours and then weighed on weighing balance.

The procedure was repeated for 4 grams, 8 grams and 10 grams of the filler using low-density polyethylene, which stands as the control.

#### c. Machining of Test Sample

The test sample was machined (using hack saw, hand file, scriber, rule, 8 mm drill bit) to the required dumbbell shape with specifications as given by ASTM D638 specification. The schematic diagram of the dumbbell-shaped sample is shown in figure 3. Marking length = 10mm (each at both ends)



**Fig 2:** Dumb-bell shape sample

Where, G (Gauge length) = 80mm,  $W_0$  (Gauge width) = 10mm, L (Overall length) = 100mm,  $R_H$  (Diameter of hole) = 8mm, W (Overall width) = 4mm

#### d. Tensile test

The six test samples were prepared in accordance with the ASTM D638, D3039 standard specifications and the Monsanto tensometer was used to obtain the tensile strength for each of the samples.

### 4. Results and Discussion

Specifying how stress and strain are to be measured, including directions, allows for many types of elastic moduli to be

defined such as; young's modulus (E) which is detailed in equation 2, shear modulus (G), bulk modulus (K), and poisson ratio ( $\nu$ ).

$$\nu = \frac{E}{2G} - 1$$

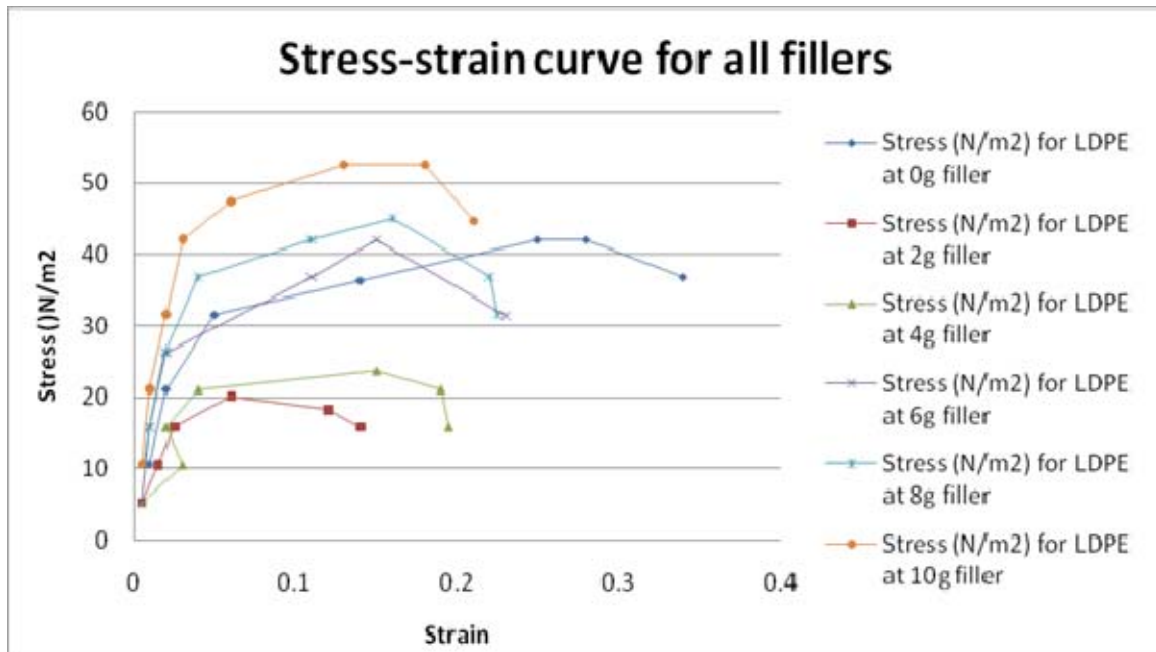
Where G = Shear modulus for low-density polyethylene from literature was deduced as 0.21 Giga Pascal  $\approx$  2.1e8 Pascal.

**Table 1:** Comparison of calculated values of yield at various loads fillers

<b>Stress (N/m<sup>2</sup>) for LDPE at 0g filler</b>	<b>Strain</b>	<b>Young's Modulus, E (N/m<sup>2</sup>) at 0g filler</b>	<b>Poission's Ratio (<math>\nu</math>) at 0g filler</b>
10.52	0.01	1052	-0.999997495
21.05	0.02	1052.5	-0.999997494
31.57	0.05	631.4	-0.999998497
36.34	0.14	259.5714286	-0.999999382
42.1	0.25	168.4	-0.999999599
42.1	0.28	150.3571429	-0.999999642
36.84	0.34	108.3529412	-0.999999742
<b>Stress (N/m<sup>2</sup>) for LDPE at 2g filler</b>	<b>Strain</b>	<b>Young's Modulus, E (N/m<sup>2</sup>) at 2g filler</b>	<b>Poission's Ratio (<math>\nu</math>) at 2g filler</b>
5.26	0.005	1052	-0.999997495
10.53	0.015	702	-0.999998329
15.79	0.025	631.6	-0.999998496
20.05	0.06	334.1666667	-0.999999204
18.21	0.12	151.75	-0.999999639
15.78	0.14	112.7142857	-0.999999732
<b>Stress (N/m<sup>2</sup>) for LDPE at 4g filler</b>	<b>Strain</b>	<b>Young's Modulus, E (N/m<sup>2</sup>) at 4g filler</b>	<b>Poission's Ratio (<math>\nu</math>) at 4g filler</b>
5.26	0.005	1052	-0.999997495
10.52	0.03	350.6666667	-0.999999165
15.79	0.02	789.5	-0.99999812
21.05	0.04	526.25	-0.999998747
23.68	0.15	157.8666667	-0.999999624
21.05	0.19	110.7894737	-0.999999736
15.78	0.195	80.92307692	-0.999999807
<b>Stress (N/m<sup>2</sup>) for LDPE at 6g filler</b>	<b>Strain</b>	<b>Young Modulus, E (N/m<sup>2</sup>) at 6g filler</b>	<b>Poission's Ratio (<math>\nu</math>) at 6g filler</b>
5.26	0.005	1052	-0.999997495
15.78	0.01	1578	-0.999996243
26.32	0.02	1316	-0.999996867
36.85	0.11	335	-0.999999202
42.11	0.15	280.7333333	-0.999999332
31.57	0.23	137.2608696	-0.999999673
<b>Stress (N/m<sup>2</sup>) for LDPE at 8g filler</b>	<b>Strain</b>	<b>Young Modulus, E (N/m<sup>2</sup>) at 8g filler</b>	<b>Poission's Ratio (<math>\nu</math>) at 8g filler</b>
10.52	0.007	1502.857143	-0.999996422
15.78	0.01	1578	-0.999996243
26.32	0.02	1316	-0.999996867
36.84	0.04	921	-0.999997807
42.11	0.11	382.8181818	-0.999999089
45.11	0.16	281.9375	-0.999999329
36.84	0.22	167.4545455	-0.999999601
31.58	0.225	140.3555556	-0.999999666
<b>Stress (N/m<sup>2</sup>) for LDPE at 10g filler</b>	<b>Strain</b>	<b>Young Modulus (E) at 10g filler</b>	<b>Poission's Ratio (<math>\nu</math>) at 10g filler</b>
10.52	0.005	2104	-0.99999499
21.05	0.01	2105	-0.999994988
31.57	0.02	1578.5	-0.999996242
42.1	0.03	1403.333333	-0.999996659
47.36	0.06	789.3333333	-0.999998121
52.51	0.13	404.8461538	-0.999999036
52.63	0.18	292.3888889	-0.999999304
44.73	0.21	213	-0.999999493

The virgin LDPE has the highest strain as shown in both table 1 and figure 4, the LDPE in its purest form recording the highest elongation at break (0.34), the highest stress value is at 36.84 N/m<sup>2</sup>, which is still an appreciable mechanical strength for the Virgin LDPE. Reinforcement of the LDPE with 2 g of rice husk, the highest strain value was 0.14, and the highest stress value was 15.78N/m<sup>2</sup>. Reinforcement of LDPE with 4g

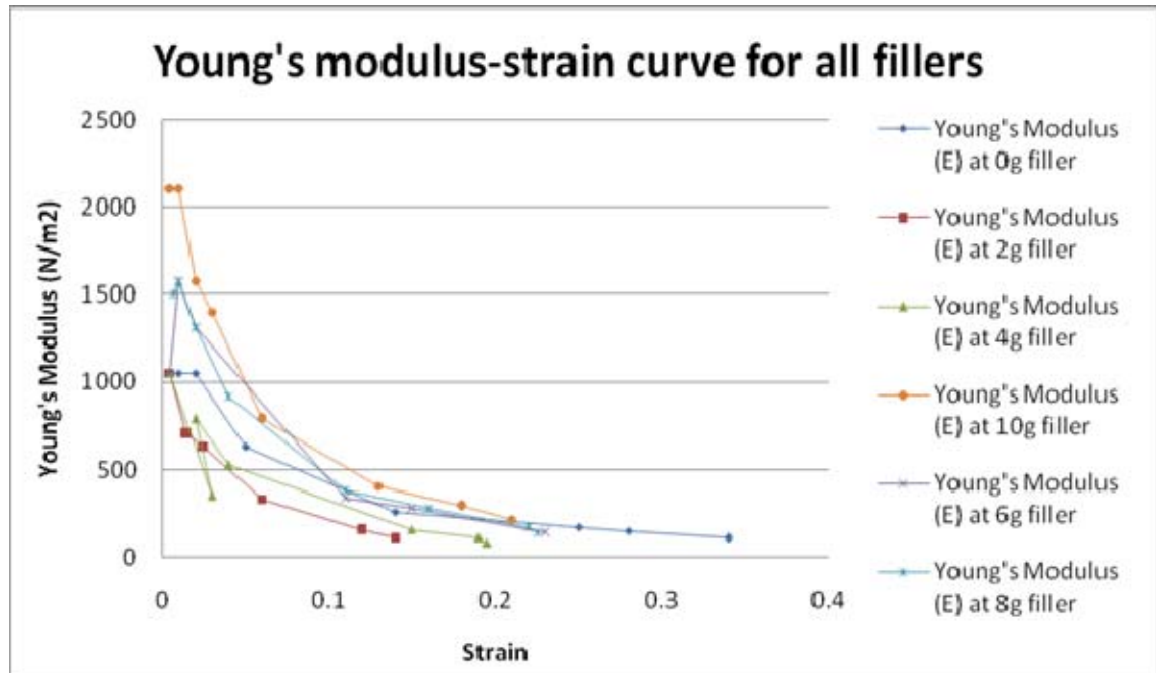
of rice husk, the highest strain value is 0.195, while the highest stress value is at 15.78 N/m<sup>2</sup>, the effect of rice husk has not been noticed at this point. Reinforcement of LDPE with 6g of rice husk, the highest strain value is 0.23, while the highest stress value is 42.11, at this point, useful mechanical properties of the rice husk on the LDPE were been noticed.



**Fig 3:** Stress–strain curve showing typical yield behaviour for LDPE with different fillers Stress ( $\sigma$ ) is shown as a function of strain ( $\epsilon$ )

Reinforcement of LDPE with 8g of rice husk, the highest strain value is 0.225, while the highest stress value is 45.11N/m<sup>2</sup>, it was observed at this point, that the ultimate tensile strength obtained is higher than that obtained at the LDPE reinforced with 6g filler, this explains that the addition of the filler increased the stress value of the LDPE.

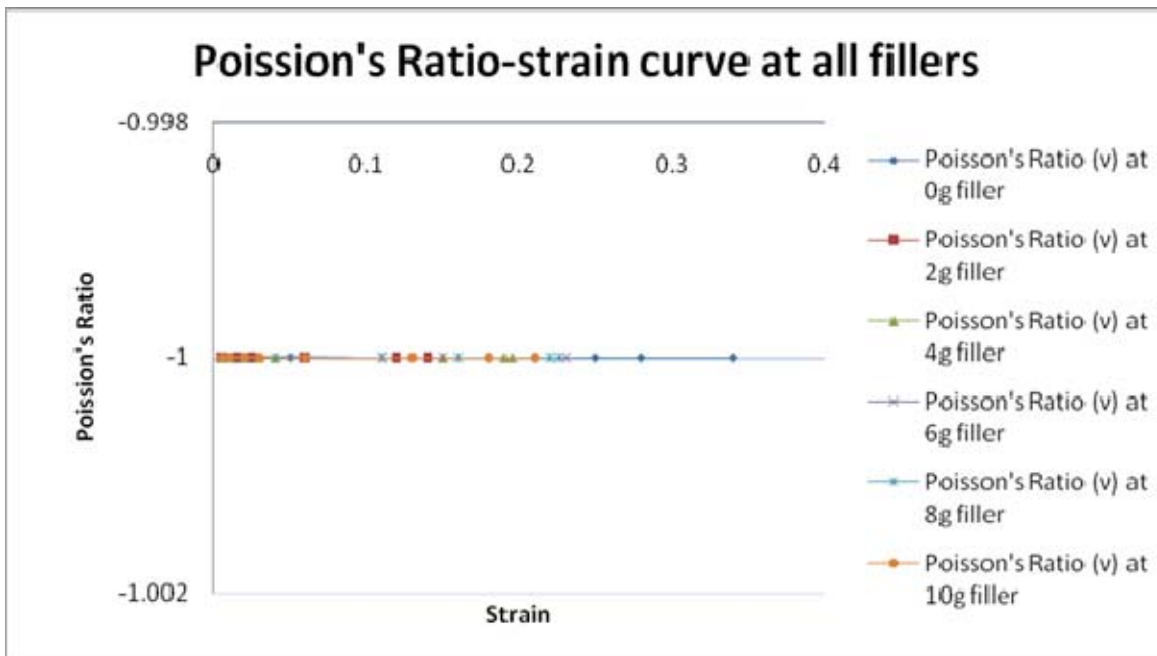
Reinforcement of LDPE with 10g of rice husk, the highest stress value obtained is 52.63 N/m<sup>2</sup> while the highest strain value is 0.210m, at this point, the optimum tensile strength was obtained from this particular reinforcement, because the LDPE + 12 g filler ruptured at the second stretch.



**Fig 4:** Young’s modulus–strain curve showing yield behaviour for LDPE with different fillers.

From figure 5, Young's modulus of elasticity can be thought of as a measure of how well a substance stands up to tension. The LDPE's ability to withstand increasing strain improves quickly at lower levels of strain for 2g, 4g, 6g, 8g and 10g, but past 10g, this improvement increases more slowly until a

break occurs. This predicts how much a LDPE sample extends under tension or shortens under compression. The rate of deformation has the greatest impact on the data collected, LDPE.



**Fig 5:** Poisson's modulus-strain curve showing yield behaviour for LDPE with different fillers.

Figure 6, shows poisson's ratio, which is a negative ratio of transverse to axial strain. Conversely, when LDPE was stretched, it contracted in the directions transverse to the direction of stretching. From literature, the Poisson's ratio of most elastic materials cannot be less than  $-1.0$  nor greater than  $0.5$  due to the requirement that young's modulus, shear modulus and bulk modulus have positive values and this was practically shown in figure 6 where poisson's ration of LDPE was seen to be between  $-0.999995$  to  $-0.99999807$ . Most materials have Poisson's ratio values ranging between  $0.0$  and  $0.5$ . A perfectly incompressible material deformed elastically at small strains would have a Poisson's ratio of exactly  $0.5$ . Most steels and rigid polymers when used within their design limits (before yield) exhibit values of about  $0.3$ , increasing to  $0.5$  for post-yield deformation.

### 5. Conclusion

The effect of pulverised rice husk (local fibre) on the mechanical properties of low-density polyethylene was found to enhance the tensile properties of the polymer. Elongation at break was also found to be reduced with increasing filler concentration. It was also deduced that mechanical properties of the low-density polyethylene (LDPE) increased with increase in the quantity of filler added to the matrix to a certain point when the filler tend to supersede the matrix, it now drops. LDPE, like most synthetic polymers are non-biodegradable, therefore, the use of rice husks (a cellulosic material) as filler not only improved the tensile strength, modulus and Poisson's ratio, but also renders the materials biodegradable. Knowledge gathered from this work will help to combat the environmental pollutions problems associated with the non-biodegradable materials.

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