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Studies on the solid waste management of high density polyethylene (HDPE) waste materials through recycling

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ABSTRACT

Studies on the solid waste management of HDPE waste materials through recycling have been under taken. Test specimens using virgin HDPE pellets (VHDPE), waste HDPE materials (TRHDPE) and 1:10 blend of the virgin HDPE with the waste HDPE material labeled VRHDPE were prepared using extrusion blowing machine. The test specimens were subjected to flexural test, tensile test, impact test and water absorption test according to ASTM standard. The results revealed that the virgin HDPE specimen had better mechanical properties than the other two specimens. That notwithstanding the recycled plastic TRHDPE had impact breaking energy of 3.62 J which is within acceptable range of 2 - 18 J for the toughness of HDPE plastic. The deformation pattern of the TRHDPE plastic for flexural and tensile tests is also similar to that of the virgin HDPE and VRHDPE plastics. The results have shown that recycling could be an appropriate and beneficial route for solid waste management of high density polyethylene.

KEYWORDS

Quality;
HDPE;
Properties;
Recycling;
Waste Materials;
Environment.

INTRODUCTION

Plastic solid waste recycling has been a major policy of the National Environmental Standards and Regulations Enforcement Agency (NESREA), the agency of the government of Nigeria saddled with the responsibility of enforcing compliance with laws, guidelines, policies, and standards on environmental matters. The Agency has 11 regulations for the control of environmental pollution, and the law regulating environmental pollution in the plastic industry clearly specifies recycling for the management of solid waste plastic materials[1].

According to Ayres[2], economic development in the developing countries over the next half century, at recent growth rates, combined with unavoidable population growth, would require a many-fold (more or less) increase in the consumption of natural resources. Every substance extracted from the earth crust is now a potential waste. With the exception of recyclable materials like plastics and metals, that are currently being recycled, in most cases it soon becomes an actual waste. This statement implies that there comes a time where the material can no longer be recycled on grounds of mass contamination with harmful impurities.

According to Ihom[3], recycling not only reduces land filling, but also ''produces'' vast amounts of plastics, paper, glass, aluminium, copper, cast iron, steel, and other materials for reuse. Recycling offers incredible economic benefits to communities with high land filling costs. It also adds benefits to businesses that use secondary materials, since the recycling of many materials saves substantial amounts of energy. Recycling aluminium, for instance, is 95% energy efficient. Aluminium recycling produces 95% less air pollution as well. Recycling steel reduces energy demand by 50% to 75%, reduces air and water pollution by 85% to 75%, respectively. The same story goes for recycling of plastic materials where 70% less energy is consumed as compared to production of virgin resins[4]. Energy savings results in lower input costs for manufacturing companies and because recycling generates considerably less pollution, additional savings result from avoided compliance costs and reduced expenditures on hazardous waste disposal. Numerous studies also show that recycling creates substantially more jobs than land filling and incinerating wastes, the less environmentally sustainable approaches to waste management. Today world over recycling of plastic scraps is in practice[1-4]. The immediate argument is corroborated by Esher and Kuo[5] who in their work argued that household solid waste recycling induced production values and employment opportunities in Taiwan. The duo further stated that the estimated production values for 1998 were USD 0.27 billion from collection/ sorting business and USD 1.27 billion from recycling industry. The collection/ sorting business represents about 0.28% of gross domestic product (GDP) in the service sector, and the recycling industry represents about 0.8% of GDP in manufacturing sector in 1998. The combined employment was 189551 of which 182538 was collection/sorting business (3.69% of service jobs) and 7013 positions (0.27% manufacturing jobs) in 1998. Takoungsakdakun and Pongstbodee,[6] observed in their work that the world's annual consumption of plastic materials has experienced a spectacular growth from 5 million tons in the 1950s to nearly 100 million ton in 2004, they argued that the escalating consumption has necessitated the current pressure for recycling, more so that most plastics are not biodegradable. Nnamdi[7] who equally carried out studies on recycling of solid waste plastics in Nigeria, said that Recycling is an economic development tool as well as an environmental tool. Reuse, recycling, and waste reduction offer direct development opportunities for communities. When collected with skill and care, and upgraded with quality in mind, discarded materials are a local resource that can contribute to local revenue, job creation, business expansion, and the local economic base. From Figures available from LAWMA (Lagos Waste Management Agency), 9,000 metric tonnes of waste is generated daily with about 1,200 metric tonnes being converted into other uses. Lagos is just one city out of the many cities in Nigeria.

Low-density polyethylene (LDPE) is a thermoplastic made from petroleum and is commonly recycled and has the number "4" as its recycling symbol. LDPE is defined by a density range of 0.910–0.940g/cm3. It can withstand temperatures of 80 °C continuously and 95 °C for a short time. Made in translucent or opaque variations, it is quite flexible, and tough but breakable. Examples of low density material are pure water sachets and cellophanes bags.

High-density polyethylene (HDPE) or polyethylene high-density (PEHD) is a polyethylene thermoplastic made from petroleum. It takes 1.75 kilograms of petroleum (in terms of energy and raw materials) to make one kilogram of HDPE. HDPE is commonly recycled, and has the number "2" as its recycling symbol. It is a high molecular weight polymer with long chains made up of carbon and hydrogen atoms[8]. The return on investment in the trading of waste nylon and polythene materials is estimated at 10%- 20% in Nigeria[7-8]. In most of the literatures reviewed not much emphasis is laid on the issue of chemical composition and contamination because it is assumed that that aspect is dealt with at the sorting and washing stages. Compositional changes may occur but may not seriously affect utilization and applicability[8].

The benefits associated with the recycling of plastic as stated above are many, however, the grade of plastic scrap available today is a cause for concern and requires careful sorting and handling for quality to be maintained. Care must be applied in sorting and washing of recycled HDPE in contact with food items. This work is restricted to the recycling of HDPE solid waste from plastic bottles and jerry cans and the alike. The objective of this work is to carry out studies on the solid waste management of HDPE through recycling.

This shall include properties assessment of the recycled HDPE in comparison with virgin and blended plastic products.

MATERIALS AND METHODS

Materials

The materials used for this work were, waste plastic jerry cans made from HDPE (HBG00346) (shown in Plate 2), virgin granules of HDPE (HBG00346) (shown in Plate 1), and the blend of 10% virgin HDPE (based on weight of recycled HDPE) with HDPE from recycled waste plastic jerry cans. The samples for the work were obtained at Bonsaac Plastics Nigeria Limited Aba.

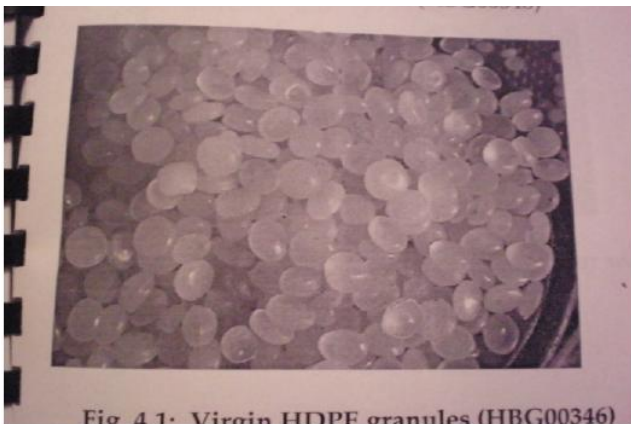

Plate 1 : Virgin HDPE granules (HBG00346)

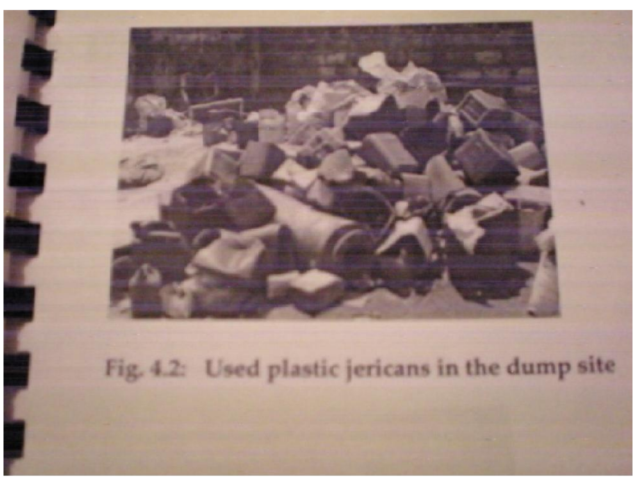

Plate 2 : Used plastic jerry cans in the dump site

Equipment

The equipment used for the research work were those of the Mechanical Engineering Laboratory of Standard Organisation of Nigeria (SON), Enugu and University of Uyo Chemical Engineering Laboratory. These included extrusion blow molding machine (shown in Plate 3), crushing machine (shown in Plate 4), impact tester, tensile testing machine, digital wash bath, analytical balance and universal strength testing machine.

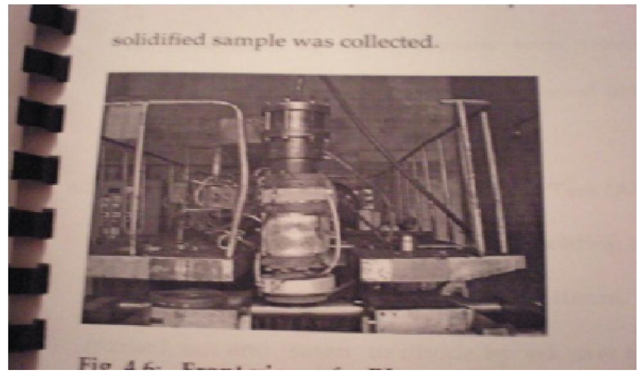

Plate 3 : Blow moulding machine

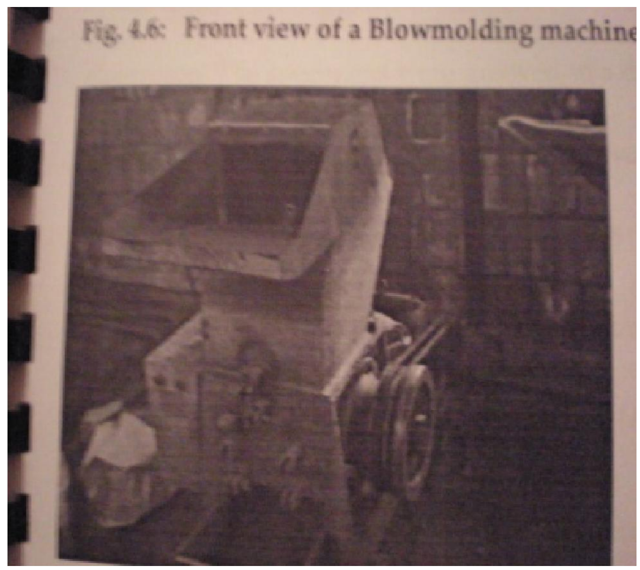

Plate 4 : Crushing machine

Methods

Raw material preparation

The used HDPE were sorted out and every paper label on it was removed. The material was shredded and washed (see Plate 5) using sponge and detergent to remove contaminants. The washed sample was allowed to dry and was then ground in a crushing machine (see Plate 6). The ground material was sifted to remove all unwanted particles while metallic particles were removed with the aid of a magnet in the sieve (see Plate 7). The virgin HDPE needed no further preparation. The blend of 10% virgin HDPE with the used HDPE was made in the ratio 1: 10, 2kg of virgin HDPE was mixed with 20kg of the used HDPE before pouring in the hopper for moulding.

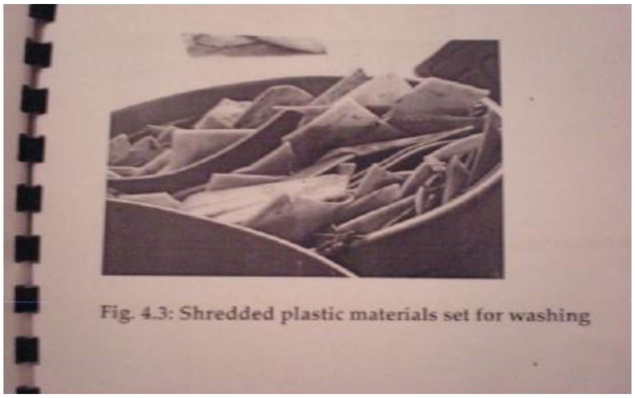

Plate 5 : Shredded plastic materials set for washing

Plate 6 : Crushed Plastic materials

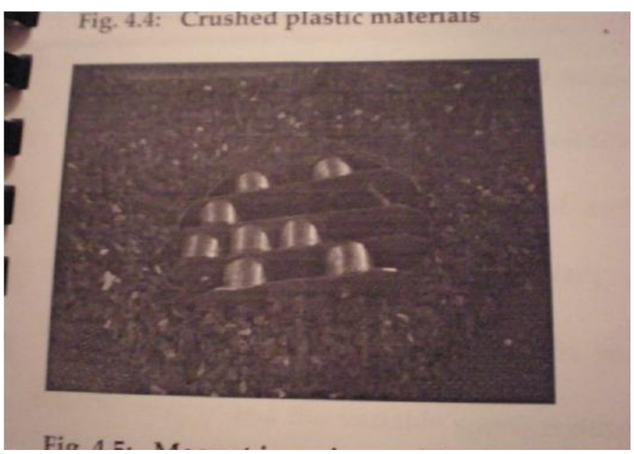

Plate 7 : Magnet in a sieve with crushed plastic materials

Test Specimen preparation

Extrusion blow moulding machine was used for the production of test specimens. The samples as prepared under raw materials preparation section were individually poured into the hopper of the extrusion blow moulding machine where it was melted in the heating chamber and blown into the dies and compressed to solidify into the test specimen shape. After the cooling of the dies the specimens were removed. The virgin HDPE specimens were first produced followed by the used HDPE and then the 10% virgin blend with the used HDPE. The operational temperature was between 150-200^{O}C and the flow speed was raised from zero to 10mm per second.

Properties test

The test specimens as produced above were then subjected to Tensile Property Test (Plate 9 showed the machine that was used for the testing), Flexural Property Test, and Izod Impact Test (Plate 8 showed the impact tester used) with the associated standards of ASTM D638, ASTM D790, ASTM D256, respectively in that order. To ensure accuracy five specimens were used for each test and the average was taken.

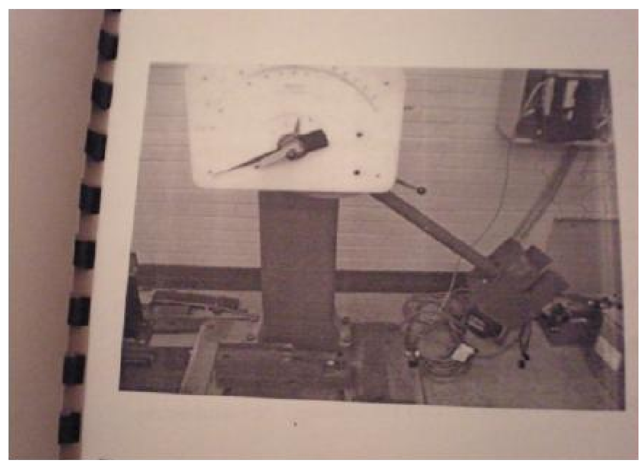

Plate8 : Impact tester

Plate 9 : Mounting specimen on universal strength testing machine

RESULTS AND DISCUSSION

Results

The results of the work are presented in TABLE 1 and Figures 1-6.

TABLE 1 : Izod Impact test result

	Breaking Energy (J)		
Specimen	**VHDPE**	**VRHDPE**	**TRHDPE**
1	4.0	3.70	3.70
2	4.1	3.80	3.60
3	3.9	3.70	3.60
4	4.0	3.70	3.60
5	4.0	3.70	3.60
Average	4.0	3.72	3.62

VHDPE= virgin high density polyethylene specimen VRHDPE= blend of virgin high density polyethylene with recycled or used high density polyethylene in the ratio 1:2 TRHDPE= recycled or used high density polyethylene specimen.

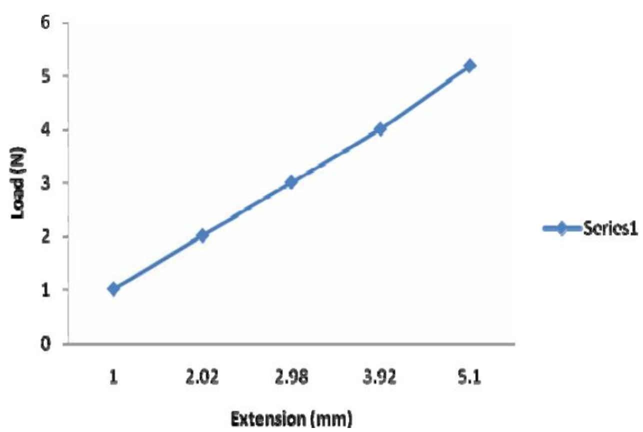

Figure 1 : Flexural property of VHDPE plastic showing the Loading versus bending extension

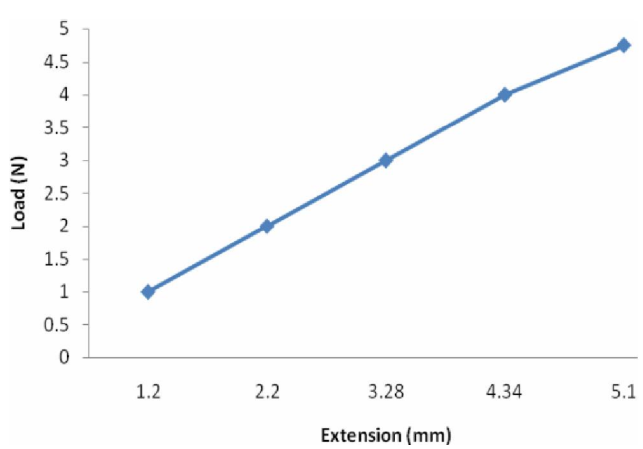

Figure 2 : Flexural property of TRHDPE plastic showing the Loading versus bending extension

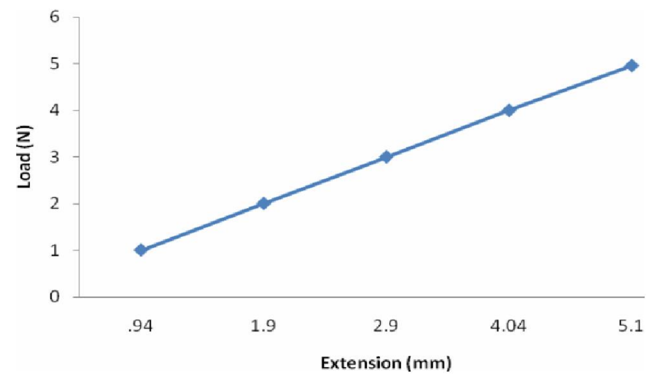

Figure 3 : Flexural property of VRHDPE plastic showing the loading versus bending extension

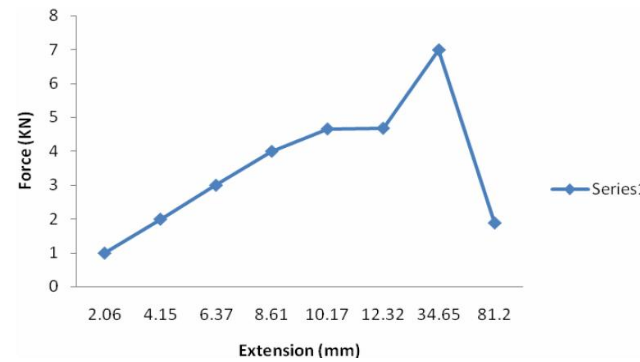

Figure 4 : Tensile property of VHDPE plastic showing deformation force versus extension

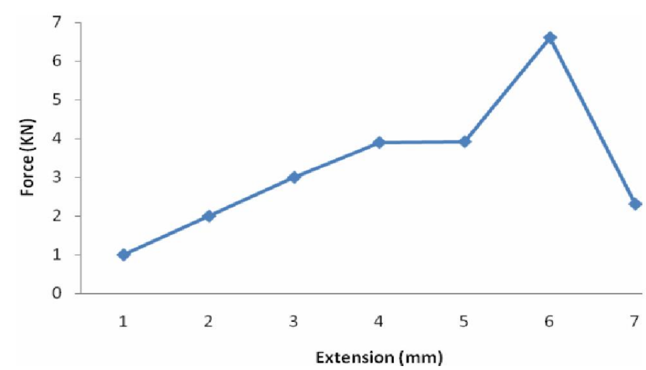

Figure 5 : Tensile property of TRHDPE plastic showing deformation force versus extension

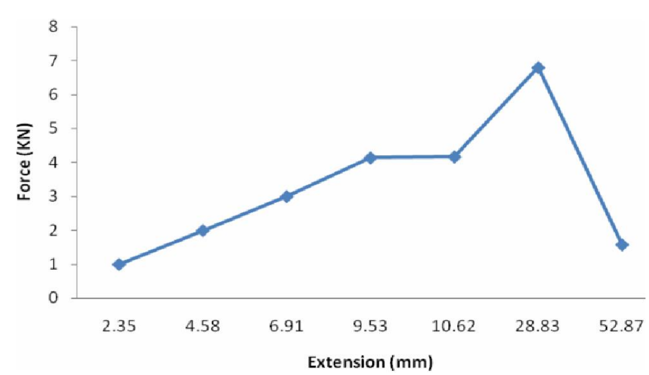

Figure 6 : Tensile property of VRHDPE plastic showing deformation force versus extension

Discussion

TABLE 1 is the izod impact test result, the result has shown that VHDPE plastic specimen has the highest breaking energy of 4 J followed by VRHDPE plastic with a breaking energy of 3.72 J and TRHDPE plastic which has the least value of 3.62 J. This result has shown that the blended plastic and the used and recycled plastic are lower in breaking energy than the virgin HDPE plastic. Impurities may be responsible, but the general believe or explanation is that the degree of crystallization is higher in VHDPE and it is responsible for the higher value[9]. The standard for toughness of a high density polyethylene is 2.0- 18.0 J[9] all the three plastics are within the range however previous works have agreed that there is always a drop in properties when plastic is recycled[9-10]. The mechanical properties of plastics is largely influenced by the degree of crystallinity and the glass transition temperature Tg these two also affect the melting point Tm of the plastic[9-10]. Research has shown that as the degree of crystallinity and the extent of orientation increases so the tensile strength and stiffness[10-11]. HDPE is known to have ordered regions in its structure called crystallites and disordered regions, during deformation this straighten out resulting in some ordered structure this increases the toughness and other mechanical properties[10-14].

Figures 1-3 show the flexural deformation pattern of specimens, VHDPE, TRHDPE, and VRHDPE. In all the three specimens the optimum or peak deformation is 5.10 mm. The equivalent deforming force is however, higher with VHDPE which has a corresponding load of 5.19N followed by VRHDPE with 4.96N. TRHDPE plastic has 4.75N, and it is 100% recycled plastic. The deformation of the three specimens agrees with that of a thermoplastic above Tg where the elastic deformation will be due not only to bonds between individual atoms in chains but also, if crystallites are present, to intermolecular forces as well. The load – extension curves also agrees with work by several researchers[8-13]. In the amorphous regions of such thermoplastics, however, the molecules are only attracted to each other by relatively weak Van der Waals forces, so that they are able to 'slip' into new permanent positions relative to each other. This type of movement is not instantaneously but is dependent upon the viscosity of the material. Viscoelastic deformation thus occurs.

Figure 4-6 show the tensile loading of specimen VHDPE, TRHDPE and VRHDPE. VHDPE specimen attained the ultimate tensile force of 6.99 KN before deforming plastically to an extension of 81.2mm under just a small load of 1.89KN. TRHDPE attained the ultimate tensile force of 6.61KN during loading before deforming plastically under a small load of 2.31KN to an extension of 50.72 mm, and VRHDPE attained the ultimate tensile force of 6.8KN during loading before deforming plastically under a small load of 1.58 KN to an extension of 52.87 mm. These deformation curves agree with one of the five groups as classified by Carswell and Nason for different types of polymers and several other researchers[8-13]. The three plastics are in the group of high tensile strength, modulus of elasticity and toughness as a result of the presence of crystallites in their structure[8-14]. The recycled plastic TRHDPE when compared with the control VHDPE has not performed badly under deformation.

CONCLUSION

The properties of recycled waste HDPE plastic have being studied vis-à-vis the properties of virgin HDPE and the blend. The result has shown that Recycled plastic has comparable properties to virgin HDPE though not as good as virgin HDPE properties the reason being that the virgin HDPE has more crystallites than recycled TRHDPE.

This study has equally proven that recycling could be an appropriate and beneficial route for solid waste management of high density polyethylene.

HDPE is not biodegradable however; the recycled TRHDPE plastic has properties that are close to those of the virgin HDPE plastic, recycling is therefore recommended for the solid waste management of HDPE waste materials.

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