

Wealth Creation Through Waste Recycling

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Abstract: The need for waste reduction and recovery has been the sticking point for growing cities and municipalities owing to the attendant harm and deterioration such wastes pose to the environment when allowed to become part of the ecosystem. It is therefore, apposite that states and municipal authorities adopt waste management strategies that, in addition to getting rid of waste in our environment, would as well empower young people, women and children, hence, we espouse strategies of creating wealth through waste recovery and recycling. These strategies, when adopted, would help safeguard our environment and create jobs that would generate passive income for all the active players in the waste generation and recycling value chain in the short-run on one hand and on the other hand would clean our environment, improve the health of inhabitants in our campuses and the surrounding communities while noting that a healthy society is a wealthy society.

INTRODUCTION

Modern day activities generate enormous wastes from our homes, markets, schools, churches, sports stadia, parks and industries. The wastes are generated in the form of Municipal Solid Waste (MSW), chemical, industrial and radioactive waste. The MSW is made up of vegetable/kitchen waste, polymeric/textile waste, metallic waste, glass and paper waste. Industrial, chemical, electronic, radioactive and medical wastes are other specialized forms of wastes that are generated from oil and gas industries, nuclear plants, quarries, textile, chemical companies and hospitals. All chemical and industrial wastes are harmful both to human beings and the ecosystem, therefore, they require extensive treatment before they are released to the environment. Whereas, hospital wastes are handled specially due to their harmful

and infectious effects to human beings, MSW are handled through segregation at source, sorting at dumpsites manually by scavengers or by mechanical means, recycling and finally incineration of unrecyclable waste. It may not be possible to eliminate waste generation totally due to increasing human activities, socio-economic development, urbanization and technological advancements. An informal survey carried out by a team in the department of Polymer and Textile Engineering, Federal University of Technology, Owerri (FUTO), Nigeria has shown that there is no 100 square meters in the campus that does not contain a discarded pure water sachet or an empty Polyethylene Terephthalate (PET) bottle. The “Wealth Creation through Waste Recycling” project initiated by the FUTO management aims at curbing the menace of municipal solid waste in the FUTO campus and her host communities by recovering the

enormous paper, plastics, glass, metallic and biodegradable materials generated from the offices, different units, departments, schools/faculties, health services, hostels and canteens through “Waste-buying” and further recycling the recovered waste into marketable raw materials, semi-finished goods and reusable end-products.

Therefore, in order to create clean and healthy environment, there is need to regulate the volume of waste released to the environment on a daily basis as well as the volume of waste disposed and left to harm the environment. In doing so, various waste management strategies are abound which include incineration, landfilling, bioremediation and recycling^[1]. Whereas incineration and landfilling may not qualify as an ecofriendly strategy and depending on the nature and source of the waste, some of the sustainable waste management strategies that have been adopted in order to keep our environment safe, clean and healthy include 3R's, Start-to-Finish and Waste-to-Wealth. These sustainable strategies are meant to divert wastes from being incinerated and use as landfills but rather into recycled semi-finished goods and reusable end-products.

The 3R's strategy: The 3R strategy is an acronym for Reduce, Reuse and Recycle. This three-in-one strategy is about the first coordinated approach that aims at drastically redefining what is actually waste which waste material can be put back to use and which waste materials can be reclaimed, recovered and reproduced into another useful item or material. In defining the 3 words that make up the 3R's, Waste reduction involves all measures adopted to cut-down waste generation. In order to do this, what really serves as waste must be seen to have reached its end-of-life stage, must be defined as such and ascertained as waste before being discarded, thrown away or dumped in the dust-bin as waste. By so doing, we may come to the realization that certain items that may still be useful cannot actually be classified as waste to be discarded. Waste reuse refers to the act of putting back to use for a different purpose an item initially used. The item can be seen to be used multiple times and for multiple purposes with the certainty that the end of its service life has not reached. In achieving this, a number of countries such as South Africa, Kenya, Uganda and Rwanda, have banned the single-use plastic bags as a way of encouraging reuse of plastic bags instead of discarding them to the environment after the first use. Waste recycling is the series of actions geared towards reproducing the waste into a reusable form. International organizations have lent support to sustainable waste management, where all forms of waste are managed through recovery with a view to reprocessing them into other useful items without mitigating the environment. For example, whereas ISO 15270:2008 refers to recycling

plastic waste, ISO 14001:2004 generally talks about environmental management control concerning recycling practice.

Start-to-Finish strategy: The Start-to-Finish strategy in waste management refers to all activities undertaken to collect waste from the generation point, process the waste and transform the waste into useful products that may be put into other uses, sold to generate income or applied in other forms to solve various needs. This strategy is adopted to reproduce useful items from waste plastics, paper, glass and metal^[2]. At the start is the waste material which serves as the raw material for the process. The raw material is dirty, muddled up and mixed with other materials, sand, food/vegetable waste and other biodegradables while at the finish end is the new article produced from the waste. This strategy is an uninterrupted process that starts at the waste collection point and the waste is processed in a continuous uninterrupted process till a finished product is obtained at the end. Under the Start-to-Finish strategy, the waste undergoes various stages as sorting, washing, drying, agglomeration or crushing, extrusion, pelletizing and moulding. Moulding may be achieved by any of extrusion blow moulding or injection moulding. The various stages in the Start-to-Finish are shown in Appendix 1 and are hereby explained thus:

Sorting: The raw material waste is sorted out manually. Plastics waste are sorted out on one side, glass waste on another bin, paper waste are put in another bin, aluminum cans are sorted into another bin, while the biodegradable wastes are carted away into a dump where they are expected to decay. However, in advanced countries of the world, the social consciousness of the need to sort waste at generation point, has made it easy to gather and collect similar waste materials in one bin, for handling and recycling same way. Therefore, plastics waste are collected in one bin, wood and paper waste in another bin, glass waste in another bin, aluminum cans/metal waste in another bin and other vegetable, kitchen and biodegradable waste in a separate bin. The bins are coloured differently to indicate the materials to be disposed in them as shown in Fig. 1.

Washing: The sorted plastics, aluminum cans and glass waste are washed separately and severally with detergent and disinfectants, rinsed and sterilized. The washing is done mechanically or manually. This helps to kill germs, wash off sand, dirt, dust, oil and other debris that may have been picked up by the materials in the waste dump.

Drying: Drying may be achieved using open-air drying or oven drying. Open air drying may be achieved by spreading the washed materials openly under the sun and



Fig. 1: Bins on display for waste collection at various schools, departments and units in the campus



Fig. 2: Commingled pure water sachets

allowing the sun to heat and dry the water on the materials. Otherwise, the materials may be dried with oven heat at a temperature range of 40-50°C.

Agglomeration of commingled plastic waste:

Commingled plastic waste include used pure water sachets littered in open fields, along the streets, drainages and gutters. Linear Low Density Polyethylene (LLDPE), Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) form 100% of commingled plastic waste material^[3]. These commingled plastic waste as shown in Fig. 2 are light weight and get entangled in the course of being used, discarded and/or transported^[4] by flowing water in drainages. In order to process this form of plastic waste, an agglomerating machine is used to reduce the size of the commingled plastic films into agglomerated round plastics of various dimensions. Shiri *et al.*^[4] has presented a detailed drawing of an agglomerating machine shown in Fig. 3. The agglomerating machine uses an arrangement of fixed and rotary blades to cut and shred the commingled waste pure water sachets into small sized pieces of plastic films as products. The machine cuts into bits the commingled plastic waste using rotating blades against a fixed blade, under heat generated by the rotating action of the blades,

softens the plastics and rolls them up into pellets. Added drops of water helps to cool the pellets before final discharge. The produced pellets would now serve as semi-finished resin/raw material with a percentage mixture with virgin polyolefin resin, for further processing using the extrusion blow moulding machine, injection moulding and rotational moulding machines. Additionally, the waste materials may be used as additives in a mix ratio with cement, sand and water to make outdoor floor tiles. The floor tiles are formulated in other to have high compressive strength, withstand high impact and reduce water percolation.

Crushing of PET bottles: The crushing of polyethylene terephthalate (PET) bottles is another processing method used to reduce waste PET bottles to flakes. This is achieved using a plastic crushing machine which is designed to reduce large plastic PET bottles into smaller pieces, shapes or flakes. The flakes measuring between 1-3 mm are obtained when an amplified force due to mechanical advantage of the drive shaft creates an amplified force which is transferred by the belt drive to it, causing two counter rotating crushing jaws to disintegrate the plastics which falls on it through a chute. The disintegrated plastics which now appear in small sized flakes are collected in a trough built into the lower end of the machine. The flakes are bagged for further processing into different products. Depending on the quality expected of the product to be manufactured, the flakes may be mixed at different proportions with virgin polymer resins. This creates value into the crushed waste plastic bottles, making them raw materials for further processing. The plastic crushing machines are normally designed to different performance efficiencies and production capacities. Figure 4a and b show PET bottles crushing machines.

Reprocessing of plastic solid waste: The recovered plastic waste flakes or pellets and agglomerated commingled pure water sachets may be reprocessed into different household items including cloth hangers, buckets, water cans, flower vases, floor tile moulds, sewage pipes and so on and so forth^[5]. The processing machines that may be used in this conversion process of waste plastic flakes in combination of virgin resins include extrusion moulding technique, injection moulding, extrusion/injection blow moulding technique and rotational moulding technique.

Injection moulding technique: This is a polymer processing technique whereby polymer pellets, granules or blends are heated, homogenized and plasticated in a barrel and a predetermined quantity of the plasticated melt, injected into a tightly closed, relatively cold mould to assume the shape of the mould. After allowing

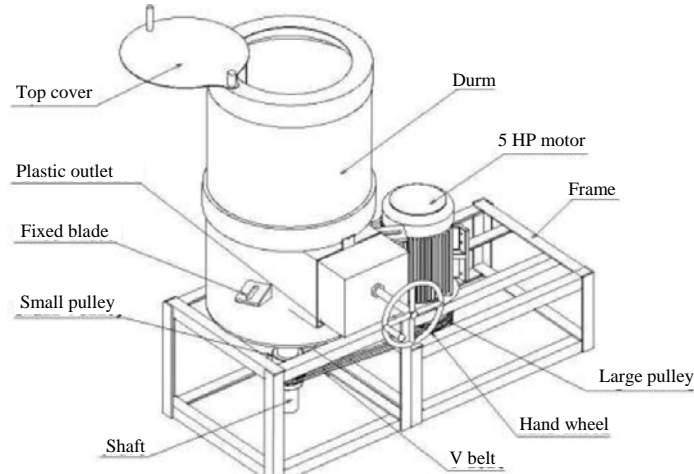


Fig. 3: Detailed diagram of an agglomerating machine^[4]



Fig. 4(a-b): (a) Washed PET bottles and (b) PET Plastic crushing machine

sufficient time for the mould to solidify, the melt having filled the mould, the article is ejected. This process goes on and on and on in a virtual cycle technically termed the “injection moulding cycle”.

The injection moulding cycle is a six step cyclic process to achieve one moulded article. The injection moulding cycle is represented with a pie chart in Fig. 5.

The injection moulding cycle: Mould closes and moves against the nozzle.

Injection time: Screw stops rotating, moves in the direction of the cylinder and injects the melt through the nozzle into the mould. The injection time must not be too short so as to allow sufficient quantity of the melt that should fill the mould to be injected into the mould cavity for the intended article.

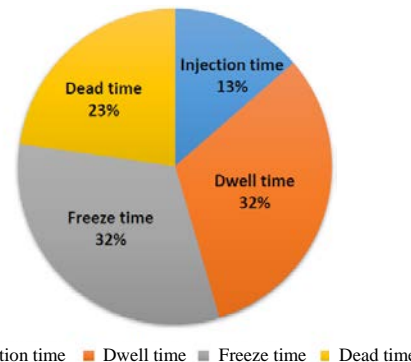


Fig. 5: The injection moulding cycle indicating the percentage of the total time for each stage

Dwell time: Screw stays in the forward position for some time to maintain the injection pressure through the nozzle. This has to be the case because the material in the mould

shrinks as it cools gradually but with the screw maintaining the pressure with injected molten plastic, more molten plastic moves into the mould to counter-balance the dimensional changes or losses due to shrinkage.

Freeze time: As the plunger or screw remains in position, the article cools gradually and solidifies. The time it takes for the screw or plunger to remain in position until the moulded article solidifies completely till ejection is regarded as the freeze time. If the freeze time is too short, it results in a soft, weak and dimensionally distorted article.

The screw begins to rotate again when the moulded article has sufficiently cooled and no other melt is required by the moulded article.

Dead time: The mould moves away from the nozzle, opens and the article ejected. The time it takes to eject the article is regarded as the dead time. The mould closes and the cycle continues for another article to be produced.

Figure 6 and 7 present pictures of fully labelled 2D and 3D views respectively of an injection moulding machine. Examples of products that may be produced by injection moulding include crates for soft drinks and beer, kitchen wares, hangers, buckets, machine parts, syringes, toilet plastic parts, electronic casings and component parts and toys. The advantages associated with this type of moulding include; products come in finished state and ready to use form, moulding cycle are relatively fast and can be programmed by balancing the cooling rate and the injection time, metal parts otherwise called inserts, can be moulded into the plastic part, simple and complex moulding and shapes can be produced with dimensional accuracy and superb surface finish.

Plastic blow moulding: Plastic blow moulding are a range of techniques for processing hollow polymer products. In this case, a thermoplastic material is heated to its forming temperature which is below the melting temperature of a material. The forming temperature range of any plastic material is the range of temperature within which the polymer may be moulded into different shapes, thus the polymer may be moulded and remoulded into various shapes, drawn into tapes, spun into fibres, blown into films or hollow items. The graph shown in Fig. 8 shows the thermal response curve for plastics.

The molten plastic may be extruded using an extruder machine into a molten or heated and softened plastic rod called parison or injected into a cold mould to produce preform. This leads to two types of blow moulding which are:

- Extrusion blow moulding
- Injection blow moulding

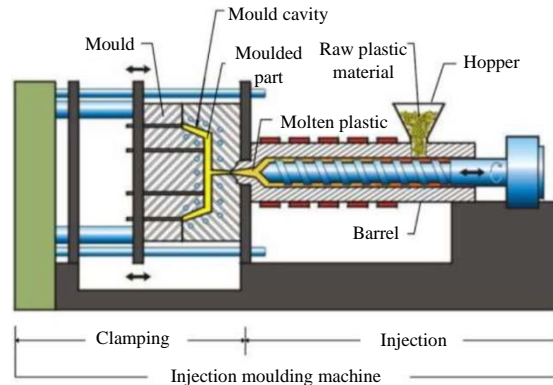


Fig. 6: 2D view of the injection moulding machine

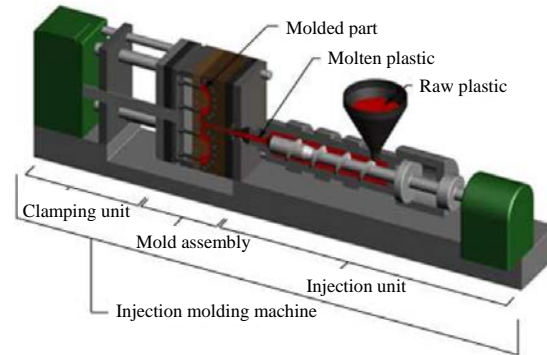


Fig. 7: 3D view of the injection moulding machine

Extrusion blow moulding: A representation of extrusion blow moulding is presented in Fig. 9. Here the parison is extruded in between two mould parts. The mould parts are then closed and air is used to inflate the parison to take the shape of the mould and produce a hollow container. Machine designs differ depending on the direction of the extruded parison. In the case of the process shown in Fig. 9, the extruder die-head points downwards.

The steps involved in extrusion blow moulding may be enumerated thus:

- A plastic is melted and extruded into a hollow tube
- The parison now attached to a blow pin, is then captured by closing it into two mould parts
- Air or gas is then blown into the parison via the blow pin, thereby inflating it into the bottle-like shape of the inner walls of the mould
- The plastic bottle is cooled to solidification
- The mould is opened for the plastic bottle to be ejected

The following products shown in Fig. 10 are products of extrusion blow moulding. These products are basically made of Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) or their blends.

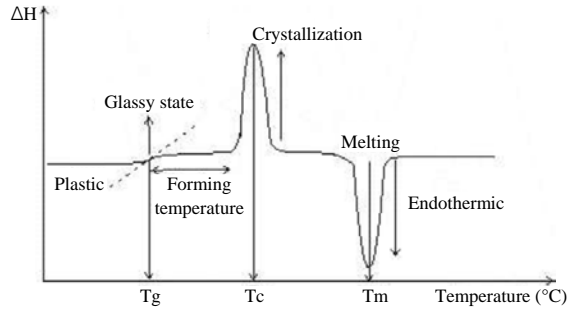


Fig. 8: Thermal response curve for polymer materials

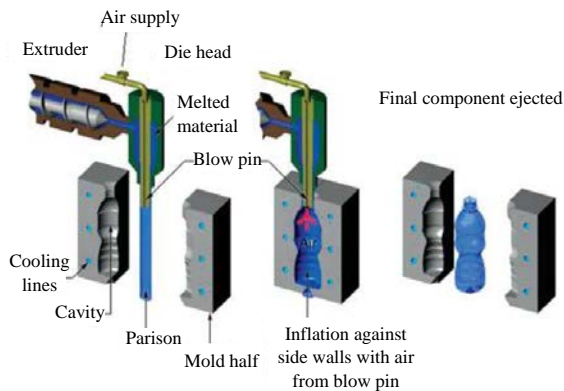


Fig. 9: 3D view of the extrusion blow moulding machine



Fig. 10: Extrusion blow moulded hollow containers for oil and cosmetic products

Injection blow moulding: In the case of injection blow moulding, the difference is the pre-production of injection moulded semi-finished hollow plastics called “preforms”. The preforms are then placed inside the mould chamber between core pins. The mould chamber is heated to the preform’s softening point, that is, up the temperature slightly above the glass transition Temperature (T_g) of the polymer material. The soft material is then pressurized with gas or air to expand the hollow preform to assume the shape of the mould.

Lastly, the part is ejected after sufficiently cooling the bottle. Polymer material used for injection blow moulding most times is Polyethylene

Table 1: Similarities and differences between injection blow moulding and extrusion blow moulding and their products

Injection blow moulding	Extrusion blow moulding
Characterized by injection blow moulded neck finish	Characterized by blown neck finish or calibrated neck finish. Neck is created during blowing
Scrap free	Lots of scrap produced because tails and finish lines must be trimmed off
No pinch marks	Can have several pinch marks
Fast cycle process for high output	Slower cycle
Expensive tooling as a result of core pin and mould	Moderate tooling-no core pin
Surface finish is very good	Surface finish is very good
Absence of die lines	Possible die lines as a result of extrusion
Easy automation possible	Cumbersome automation
Small factory floor needed	Bigger factory floor

Terephthalate (PET). The differences between injection blow moulding and extrusion blow moulding is presented in Table 1.

Blown film extrusion moulding: The third type of blow moulding is extrusion film blow moulding. This process involves the extrusion of molten polymer and the blowing of the extruded molten polymer vertically upwards through an annular die into a thin-walled tube which is then inflated with air into a bubble or balloon. As this bubble rises, it is air cooled, collapsed between metallic or wooden guides by a set of nip rollers at the top and hauled off to a take-up roller. In a downstream process, the rolled up film is unwound from the take-up roller, unto a flat table and gusseted or cut-off into specific lengths and then heat sealed at one end for plastic bags. The dimension of the balloon depends on the size of the die which determines the Lay-Flat-Width (LFW) of the rolled up film which ultimately determines the width of the plastic bag. The process diagram for extrusion blow moulding for plastic films production is shown in Fig. 11^[6].

Recycling waste aluminum cans: Magnetic test is used to sort aluminum cans from metal cans. Whereas metals are heavier than aluminum cans and would stick to magnets, aluminum cans wouldn’t stick to magnets. The sorted waste aluminum cans are then stamped into flat mass of aluminum using a bailing machine. Figure 12 shows a bailing machine used for this process. This helps to reduce the bulkiness of the waste aluminum cans thereby making it easy for transportation. The flat mass of aluminum makes it easy for weighing, bagging and transportation and can be sold to off-taker companies that need the compressed cans as raw materials for their products. However, in a full-scale aluminum recycling plant, the flattened aluminum cans are shredded mechanically, de-coated using hot air blowing at 500°C, melted at 750°C and cast into ingots each measuring 15 m in length and weighing about 27 tonnes. The ingots are

transported to the aluminum rolling mill where they are pre-heated to 600°C for the first rolling and then cold rolled to the exact specification and thickness required by the can-maker for new cans. One ingot can be used to produce 1.5 million cans.

The aluminum sheets are lubricated and fed through a cupping press which cuts them into shallow cups. The shallow cups are then rammed through a series of rings which raises the over-cuts of the shallow cups to assume the full cup shape, trimmed and washed for lacquer application before decoration, labeling. At this point, the semi-finished aluminum cans may be sold to beverage companies to package their drinks.

Glass waste: Glass waste is sorted from the municipal solid waste and put into a ball milling machine which breaks the glass material and ball mills it into powdered glass. The powdered glass is recovered from the ball milling machine and sieved into various particle sizes for different purposes.

The particulate glass may be used for composite applications to reinforce plastics, concrete and impermeable interlocking floor tiles. It has also been reported that micro and macro sintered ceramic glass may

be produced from recovered glass waste as a way of getting rid of discarded glass bottles and applying them into other uses^[7].

Biogas and organic fertilizer production: The biodegradables which is made up of the organic portion of the municipal solid waste, are gathered for biogas production. The process of biogas production typically refers to the anaerobic biodegradation of the organic portion of municipal solid waste to produce methane and carbon IV oxide gas^[8, 9]. This is an innovative way of utilizing biodegradables from rotten vegetables, fruits, orange peels, yam, potatoes and plantain peels, rotten meat, in short all kitchen waste.

The other aspects of biodegradables utilization is in its use as organic fertilizer. The fertilizer may be used to replenish agricultural soils for cultivating different varieties of high yielding cucumbers, green vegetables, tomatoes and potatoes.

Paper waste: Paper waste when collected in bails are shredded into pieces and bagged. The bagged shredded paper are sold to off-takers companies involved in the making of toilet/tissue paper, card board packaging and ceiling boards.

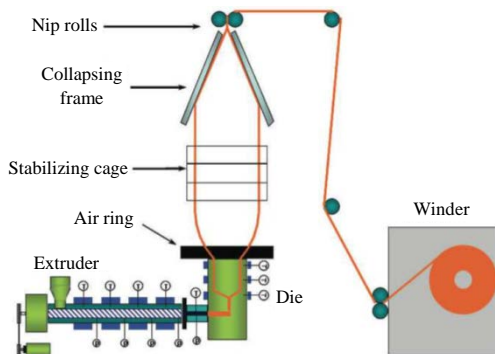


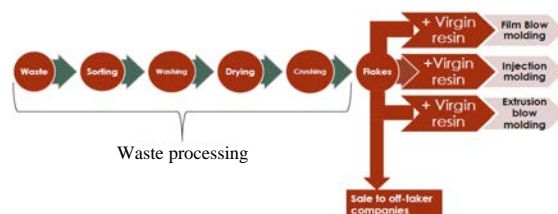
Fig. 11: Extrusion blown film moulding



Fig. 12: Waste plastic/aluminum cans bailing machine

Research and Development (R&D): Further studies on how best to reduce, collect, handle, recycle and transform the ubiquitous plastic, aluminum, paper, glass and biodegradable waste littered all over FUTO and her host communities, on the one hand and create wealth from diverse waste materials, is currently ongoing. Two complimentary research projects, the first on the production of biodegradable plastics based on starch, to replace the synthetic based Linear Low Density Polyethylene (LLDPE), Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) plastics which form majority of the plastics waste in our environment while the second project on the production of biodegradable starch-based plastic composite material are also ongoing. There is need for the federal government to support this research effort in finding lasting solution to this menace.

Appendix 1: Production flow chart for waste plastics recycling



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