SYSTEM AND METHOD OF CONVERTING WASTE MATERIALS INTO REUSABLE BYPRODUCTS

TECHNICAL FIELD

The present invention relates to the use of a biological process for the elimination of plastic waste in landfills. The invention comprises of bacteriological culture methods, consisting of specific bacterial strains capable of degrading petroleum-based plastics. The method also allows the extraction of the plastics from the bacterial cells, which is fully degradable in the environment.

BACKGROUND ART

Plastics refer to a wide range of synthetic or semi-synthetic materials, that usually consist of large molecules called polymers. Polymers, in turn, consist of many identical small particles that are strung together like a chain. These individual small particles are called monomers. The length of these polymer chains determines the properties of plastic. The flexibility of these polymer chains makes it possible for plastics to be moulded, extruded, or pressed into solid objects of various shapes. This makes plastics an adaptable material for human usage. The process through which monomers are linked is called polymerisation. Therefore, plastics can be classified according to the chemical processes used in manufacturing, namely, condensation, poly-addition, or cross-linking, or according to the chemical structure of the polymer's backbone and side chains.

However, plastics are frequently categorised according to their key characteristics which usually relate to product design and end-use. Some examples include thermoplastics and thermosets. Thermoplastics are plastics that can be melted when heated and hardened when cooled down. These characteristics are reversible and may theoretically be carried out indefinitely, which means that that these materials can be reheated, reshaped, cooled, and re-used repeatedly. Thermosets are a family of plastics that strengthen when heated and cannot be re-moulded or re-heated after the initial forming.

Some examples of thermoplastics are Polyethylene (PE), Polyamides (PA), Polypropylene (PP), Polycarbonate (PC), Polystyrene (PS), Expanded Polystyrene (EPS), Polyethylene terephthalate (PET) and Polyvinyl chloride (PVC). Some examples of thermosets are like Polyurethane (PUR), Silicone, Epoxy and Phenolic resins and Acrylics.

Plastics derived from petroleum waste have become essential in modern life due to its lightness, robustness, durability and high resistance to degradation. In addition, due to its easy manufacturing, low cost, permeability, and resistance to chemicals, temperature and light, plastics are used in a wide range of products and have replaced and displaced many other materials, such as wood, paper, stone, leather, metal, glass and ceramic. There are few types of synthetic, petroleum-based plastics in our market such as polyethylene terephthalate (PET), high-density polyethylene (HDPE), polyvinyl chloride (PVC), low density polyethylene (LDPE), polypropylene (PP) and polystyrene (PS). These different plastics have their own uses in our daily life. PET and HDPE are usually found in water bottles, detergent bottles, and milk jugs, and these are easily recyclable. LDPE is a plastic which is similar to PET, while PS is used to make insulation products or packaging. PVC is found in building materials, and PP on the other hand is found in flooring products.

Due to the high demand for plastics, petroleum-based plastic is widely used, causing the global production to reach 380 million tonnes each year. However, these plastics are not being recycled as fast as the rate of consumption, leading to the accumulation of plastic waste in the environment. It has been estimated that the amount of plastic produced in the first 10 years of this century will be close to the volume produced in the entirety of the previous century. Plastics are found in almost all major municipal solid waste (MSW) categories. According to an article by the Plastic Oceans International, a non-profit organization in California, approximately 500 billion plastics bags are used worldwide with more than 1 million new bags used every minute.

Majority of plastic waste are sent to landfills or disposed into the environment due to the poor product design and lack of political infrastructure. The ability of plastics to resist degradation results in growing landfill areas, increasing the cost for waste disposal and posing a significant risk to the environment. A significant portion of petroleum waste plastics comes from personal consumption.

Plastics are non-biodegradable and slowly break down into smaller fragments, first as microplastics, then further as nano plastics. Microplastic (MP) pollution has been highly detected in marine and terrestrial environments. Microplastic particle, are characterised as particles with an upper size limit of 5 millimetre (mm) and a lower limit of 50 micrometre (µm), produced from man-made polymers, and are derived from petroleum, petroleum by-products, non-synthetic polymers such as natural rubber and polymer modified bitumen. Microplastic particles are a heterogenous, complex group of different polymers, sizes, colours, shapes, age, tear strength and additives.

Microplastics can be divided into two types namely, primary microplastics and secondary microplastics. Primary microplastics are deliberately manufactured within the millimetric or sub-millimetric size. They are found in various household items, including personal hygiene products, such as facial cleansers, toothpaste and exfoliating creams. These products are of special concern, as it has been estimated that approximately 6% of all liquid skin-cleaning products sold in the European Union (EU), Switzerland and Norway contain microplastics, of which more than 93% consist of polyethylene (PE) plastic. Secondary microplastics are the result of the breakdown of larger plastic particles. They are formed when exposed to physical, chemical and biological processes which leads to a reduction of the structural integrity and therefore can be fragmented.

These particles, whether in the form of larger or smaller plastics, have profound detrimental consequences for ecosystems, biota and the environment, which may affect the economy and human health. Plastics have been found in the stomach contents of many organisms, including earthworms, birds, turtles, dolphins and whales. Smaller particles may be even more pervasive, as these may be ingested by organisms that are at the base of different food webs. One such example is the recently discovered new species *Eurythenes plasticus*, an amphipod found at a depth of 6,900 meters (m) and named after the plastic found to have contaminated its gut.

This shows that creatures living in the most remote places on earth have already ingested plastic before they were even discovered by humans. Plastics is present in the air that we breathe, in the water that we drink and also in animals that live 6000 metres (m) below the sea level, far away from human civilisation.

One major solution to the accumulation of plastic waste is the utilization of bioplastics, also known as "*green*" plastics, as an alternative. Bioplastics simply refer to plastics produced from plant or other biological material instead of petroleum. It can either be made by extracting sugar from plants like corn and sugarcane to convert into polylactic acids (PLAs), or it can be made from polyhydroxyalkanoates (PHAs) engineered from microorganisms. The PLAs are commonly used in food packaging, while PHAs are often used in medical devices like sutures and cardiovascular patches.

Some companies like Innovia, NatureWorks, Cereplast, Novamont and Toyota produce bioplastics made from renewable materials. Some examples are corn-based polylactic acid, wood pulp, sugars, starches from tapioca, wheat and potatoes, vegetable oils and cellulose. These materials do not include petroleum, do not emit toxins when burned and are "bio-compostable," which means that if provided the proper environment, they would degrade within a span of 1 to 14 months. Products that can be made from bioplastics include films that seal in heat or are used for packaging, beverage cups, clothing, carpet and upholstery fabrics.

There are two types of bioplastics: bio-based plastics (plastics made at least partly from biological matter) and biodegradable plastics (plastics that can be completely broken down by microbes in a reasonable timeframe, given specific conditions). This means that not all bio-based plastics are biodegradable, and not all biodegradable plastics are actually bio-based.

Some materials, previously marketed as "biodegradable", "oxo-degradable" or "oxo-biodegradable", comprise of an oxidising agent to facilitate with the disintegration of the material in the presence of oxygen, UV light and heat. However, the end-result of the process usually provides for the formation of microscopic plastic fragments.

Currently the methods and materials used to eliminate plastic waste in the environment are mostly available for larger plastic waste, and not commonly for microplastics. Therefore, much has been invested into research and development of biotechnology-based strategies on the biodegradation of microplastics. Many types of bacteria and fungi have been reported as potential tools in the biodegradation of plastics, including the bacterial species *Pseudomonas aeruginosa*, P. *stutzeri*, *Streptomyces badius*, S. *setonii*,

Rhodococcus ruber, *Comamonas acidovorans*, *Clostridium thermocellum* and *Butyrivibrio fibrisolvens*. Fungal strains described as viable biotechnological agents in the bioremediation of plastics include *Aspergillus niger*, A. *flavus*, *Fusarium lini*, *Pycnoporus cinnabarinusand* and *Mucor rouxii*. These organisms have been isolated from diverse environments, namely landfills, plastic surfaces buried in soils, aquatic water and mangrove soil.

The capacity for microorganisms to break down plastic polymers is advantageous in dealing with problems arising from the increasing accumulation of plastic waste every day. Some microorganisms produce a variety of enzymes, both intracellular and extracellular, to catalyse plastic polymer degradation into smaller fragments. Biodegradation is a specific enzymatic process whereby different types of enzymes can break down a certain type of substrate. Microbial and enzymatic degradation of waste petroleum based-plastics is a promising strategy for depolymerization of waste petroleum based-plastics into polymer monomers for recycling, or to convert waste plastics into higher value bioproducts, such as biodegradable polymers via mineralization.

During the degradation process, the released enzymes will break down complex polymers into smaller and simpler chains. These decomposed small molecules will be easily dissolved in water and can then be absorbed through microbial semipermeable cell membranes to be used as carbon and energy sources. Assimilation occurs within the microbial cytoplasm in which the metabolic process occurs to produce energy, biomass, food reserves, and primary and secondary metabolites. These components enter the microbial cell metabolism system to undergo a subsequent degradation process to form energy and biomass for microorganisms. Even though monomers have formed, sometimes they do not fully assimilate. They will be released outside of the cells and will be used by other microorganisms that have a suitable assimilation pathway for these monomers.

Mineralization is the final metabolic process of plastic waste toxic compounds. This process changes these hazardous compounds into more environmentally safe compounds. Mineralization is defined as a process where biodegradable materials or biomass are converted into gases, water, salt, minerals, and other residues. Some of the gases formed are carbon dioxide, methane, and nitrogen components. The mineralization

process is expected to end when all biodegradable compounds have been completely used by microorganisms.

PCTUS2018054473 discloses the use of microorganisms and methods to produce polyhydroxy butyrate (PHB), a type of bioplastic from gaseous substrate. Although the invention discloses about production of potentially degradable plastic material, this does not give a clear solution to reduce microplastic waste.

PCTCN2012083789 generally teaches the use of biological processes to degrade waste plastics and recycled plastic. The invention specifically relates to the use of insects, bacteria and microbes that can degrade petroleum-based plastics. However, this invention only discloses the breakdown of petroleum-based plastics from large components rather than focusing on the smaller microplastics which are potentially environmental contaminant.

EP3224367 discloses the extraction of bioplastic from bioplastic producing microbial cells. The invention aims to produce bioplastics using a selected bioplastic producing microbe species via a two-step process, subsequently producing monomers from the bioplastics. However, this invention does not relate to the utilization of the microbes to break down the smaller microplastics in the environment and reusing the same.

US20200338789 discloses a method of processing municipal solid waste which includes extracting food waste, inert materials, ferrous and non-ferrous metals from the solid waste and shredding the same. The end product from this invention is that at least 99.7% of the waste will be converted into a cellulose based material or plastic. However, this invention does not disclose the use of microplastics (small plastic scraps) that are formed from the waste processing steps.

CN210617030U tries to overcome the shortcomings of low accuracy and high cost of microplastic extraction in the existing microplastic flotation device. The invention however does not utilize microbes for the microplastics extraction and instead uses mechanical methods for the microplastics pollution.

WO2014194219 discloses a method of manufacturing biodegradable plastic from a high percentage of recyclable plastic feedstock and the product thereof from the solid waste generation point. However, this invention does not utilize biological organisms to extract microplastic scraps from the source of pollution.

PCT/IN2020/050346 discloses a method to bioremediate polluted areas using microorganisms. The map of microbes is used to design a first microbial consortia and a second microbial consortia which together contributes genes, proteins and enzymes required for degradation of the pollutants. This invention develops a system which can specifically address and mitigate a certain type of pollutant. However, this invention does not discuss a complete waste management system inclusive of the collection of municipal solid waste, waste separation, extraction of the reusable items (recovery of recyclable materials) and reuse of the waste.

Therefore, all the above listed prior arts are not specifically able to reduce the formation of microplastics in the landfill. Further, not all prior arts above focus on the use of biological processes to eliminate plastic waste in landfills.

SUMMARY OF THE INVENTION

Waste management is associated with the method of collecting waste from various sources and thereafter depositing the waste into landfills, bioreactors, or incinerators (amongst others). More than half of the waste deposited in landfills can be recycled into energy or reused as raw materials. Currently, petroleum based plastic products are the main raw material source of plastics for human use.

The present invention eliminates the need to manage and recover potential waste materials from landfills by developing a method to separate the waste according to their categories (metal, plastic, paper etc) and process the wastes to be reused and recycled. The invention also involves the conversion of petroleum-based plastic into bio-based plastic, which can be consumed by using microorganisms. This process is also known as microbial technology which is regarded as the technological application that uses microbiological systems, microbial organisms, or their derivatives, to manufacture or modify products or processes for specific use.

In the present state, the plastic waste possible of producing microplastics, a potent pollutant as described earlier comes not only from petroleum-based plastics but also from the biodegradable plastics. This is because some biodegradable plastics do not fully decompose in the environment as they require certain conditions crucial for disintegration. Besides that, some plastic wastes require adequate temperature or moisture and humidity levels for the decomposition process to take place. Research shows that, sometimes only the starch portion of the bioplastic will be disintegrated or decomposed, while the petroleum component will remain in nature for almost 100 years. This makes the problem of microplastics become more common even though we think that the utilization of biodegradable plastics will solve the current problem caused by microplastics.

In many countries, the waste is disposed in nature or directly brought to the landfill due to the lack of industrial technology. There are not enough measures and lack of a systematic approach in waste separation and management. Besides that, landfill is the source of small scraps of plastic waste (microplastics) which are the products of decomposition of larger plastic waste. In this invention, the plastics produced from the waste materials will be able to disintegrate themselves and degrade in standard environmental conditions. Therefore, this will help to save up costs for landfill management, overcome microplastic pollution and allows waste recovery from the landfills to be almost 100%.

This invention allows a systematic approach of landfill waste management by incorporating waste towards a resource-based approach as well as providing a solution to microplastic pollution. The waste will be first collected and separated using certain type of instruments that cater to the types of waste in the landfill, namely plastic, metal, wood and paper. A series of steps inclusive of mechanical involvement are used for this waste separation. The waste that has been separated according to their nature will then be grouped and brought into the respective facilities for recovery or further processing.

Further, the smaller plastic scraps or the microplastics will be extracted and converted into a cellulose-based bioplastic by using microorganisms, also known as microbial technology. The plastic scraps will be extracted via a series of stages, which includes waste sorting, pre-processing, microbial growth and the extraction and granulation stage.

The details of the processes involved during each stage is further described on the detailed description part.

In summary, two types of output will be formed from the microbial technology approach used which is the gaseous output and the solid and liquid output. These outputs will then undergo two separate processing which will finally yield a type of cellulose based bioplastic which is regarded as food grade or plastics material that are either safe for human consumption or for human use. This invention utilizes microorganisms which has the ability to degrade the petroleum-based plastics, the use of these plastics for their growth, resulting with an environment friendly bioplastic. Therefore, the plastic which are generated from this invention will also serve as an eco-friendly alternative to the present petroleum-based plastics namely, polyethylene, polypropylene, HDPE and LDPE.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the sorting of large waste materials.
Figure 2 shows the sorting of ferrous metals and non-ferrous metals.
Figure 3 shows the sorting of thin film waste, low density or low weight plastics and other plastics.
Figure 4 shows the detailed view of the conveyor tray in Figure 1, 2 and 3.
Figure 5A shows the overview of the thin film waste and the low density or low weight plastics processing stage.
Figure 5B shows the thin film waste and the low density or low weight plastics being compressed.
Figure 5C shows the elongation stage of the hydraulic piston rod to compress the plastic input.
Figure 5D shows the output of the plastic cubes extracted from the output door.
Figure 6 shows a detailed view of elongation of the hydraulic piston rod to compress the plastic waste.
Figure 7 shows the granulation chamber for plastic & thin film, paper, cardboard, and organic waste.
Figure 8 shows the acetogenic chamber.
Figure 9 shows the cellulose based plastic extraction from solid and liquid accumulation.
Figure 10 shows the cellulose based plastic extraction from gaseous accumulation.

DETAILED DESCRIPTION

The present invention can be divided into five major stages as listed below.

a. Waste sorting stage
b. Pre-processing stage
c. Microbial growth stage
d. Extraction and granulation stage

In the present invention, during the waste sorting stage, the landfill waste will be sorted into categories according to their material type or recyclability. Generally, there are three main groups of waste types found in landfill waste, which are categorised as the organic waste, plastic waste, paper wastes, glass and metal waste. Organic waste are by-products of food or the waste from agricultural waste products such as, fruits, decayed fruits, barks, decayed leaves. Plastic waste are usually thin fragments of plastics. Some of the common types of plastics found in landfill waste are Polyethylene, Polypropylene, HDPE and LDPE. The waste sorting process will be carried out using equipment and techniques employed to recover reusable or recyclable materials from the waste stream.

The wastes will be brought into a waste processing facility by the collection vehicles. These waste collection vehicles generally include waste collection vehicles – garbage trucks. The collected waste materials will be weighed and recorded to compute the value and measure of daily waste received into the waste processing facility.

a) <u>Waste Sorting Stage</u>

The collected landfill waste will be sorted according to material types and sizes. The waste sorting stage in the present invention is described in Figures 1, 2 and 3.

Figure 1 consists of optical recognition sensors, image recognition sensors and thermal sensors – which can be collectively referred to as sensors (101), the automated mechanical waste pickers (102), the conveyor trays (103), the controller unit (104) which comprises of processors connected to the sensors, and the output segregators for the waste are (105), (106) and (107), which will collect waste that are further separated.

The wastes comprised of residential waste, industrial waste, agricultural waste, and construction waste, are collected by collection vehicles and will be emptied onto a designated space for sorting. During the sorting stage, most of the non-recyclable materials will be removed. The waste will then be placed on the conveyor trays (103) which will mechanically convey the waste towards the sensors (101). The sensors (101) are able to sort the waste materials according to the particle size, position, colour, and shape.

The sensors (101) can detect and differentiate the different types of waste materials by identifying them using optical sensors namely cameras that captures the image or using the thermal sensors that detect temperature. The sensors (101) correspond with the controller unit (104) which comprise of processors with specifically programmed algorithms. The controller unit (104) will receive signals from the sensors (101) which will then be further processed. Based on the programmed algorithms, the controller unit (104) will then convey a set of commands to the automated mechanical waste pickers (102). The command from the controller unit (104) will then prompt the automated mechanical waste pickers (102) to pick these waste materials based on the signals received. The waste materials picked by the automated mechanical waste pickers (102) will then be transferred to the designated trash collecting bins, also known as the output segregators (105), (106) and (107).

The output segregators are divided into three different portions, wherein the output segregators (105) is for aluminium cans, (106) is for shoes and material consisting of fabrics, and (107) can be for other type of waste products found in the landfill waste. The waste transferred into the output segregators will then be sent to the respective facility to be further processed.

From the above-mentioned process, many waste materials will be filtered out of the conveyor trays (103). The remaining waste from the conveyor trays (103) that remain unfiltered will be sent to a shredder. The conventional waste shredding process will be able to shred and reduce the size of the earlier unfiltered waste to between 5 centimetres (cm) to 10 centimetre (cm) in size. The waste shredding process is configured to reduce the waste into a more manageable size, apart from homogenizing and volumetrically expanding the raw materials within the waste. This means that the particle size will be

reduced to enable the separation of particles based on their characteristics. Subsequently, the shredded waste will then be further sorted. The processes involved in this stage is illustrated in Figure 2, wherein ferrous metals and non-ferrous metals, thin film and plastics will be sorted and further processed.

Figure 2 comprises of a magnetic conveyor belt (201), an air suction system which is further comprised of air suction nozzles (202) and an air suction chamber (203), a controller (204), air pressure fans (205), the conveyor to transport magnetic particles (ferrous and non-ferrous metals) (206) and the conveyor to transport thin film and plastics (207). Both (206) and (207) will transport the collected waste items towards designated collection chambers, namely a metal collection chamber and a plastic collection chamber. There are optical and thermal sensors (208) coordinated by processors which will send signals to the controller (204).

Firstly, the shredded waste will be conveyed past the magnetic conveyor belt (201). The magnetic conveyor belt (201) which has electromagnetic property will attract waste particles comprising of ferrous metals and non-ferrous metals as mentioned above. The magnetic conveyor belt (201) is rotatable and as it rotates, the shredded ferrous and non-ferrous metal scraps will be magnetised at the lower part of the magnetic conveyor belt (201) and demagnetized at the upper part of the magnetic conveyor belt (201). Magnetised particles at the top of the magnetic conveyor belt (201) will then be passed onto the conveyor to transport magnetic particles (ferrous and non-ferrous metals) (206) towards the metal collection chamber. In the metal collection chamber, the ferrous and non-ferrous metals which has been separated from the waste will be sent to the respective recycling facilities.

Upon extraction of the metals, the remainder shredded waste will then be conveyed to the second part of Figure 2. The air suction system comprised of air suction nozzles (202) and the air suction chamber (203). The air pressure fans (205) will blow high pressured air on the remainder shredded waste which will disseminate the waste, increasing the efficiency of the waste sorting process.

Accordingly, thin film waste [size range of less than 10 millimetre (mm)], low density or low weight plastics [less than 10 grams (g)] and other plastics will be extracted by the air

suction nozzles (202) and passed towards the air suction chamber (203). The air suction nozzles at (202) and the air suction chamber at (203) will be controlled by the optical and thermal sensors (208). These sensors are connected to the controller (204). The air pressure fans (205) will coordinate with the air suction system through the controller (204) which will blow the shredded waste and create an environment with varying pressure [between 2 Pascal (Pa) to 100 Pascal (Pa)]. This change in air pressure will cause the plastics to float, besides increasing the efficiency of the air suction system to separate and collect the plastic wastes.

The extracted plastic waste will then be conveyed through the air suction chamber (203) and transmitted to the conveyor to transport thin film and plastics (207). The extracted plastic waste will be further conveyed into the plastic collection chamber. In the plastic collection chamber, these plastics will be further separated into three categories, namely the thin film waste, low density or low weight plastics and other plastics.

The remaining waste from Figure 2 which are not extracted by the magnetic conveyor belt (201) and the conveyor to transport thin film and plastics (207) will be further sorted. The same is illustrated by Figure 3, which comprise of gas sensors (301), controller (302), organic material collection baskets (303) and (304) and the conveyor trays (305).

The gas sensors (301) will sense and detect the type of gases present in the waste conveyed. The controller (302) which comprised of processors will then process and analyse these data based on the output received from the gas sensors (301). The objective of this sorting stage is to determine the type of organic waste present. The conveyor trays (305) are specifically manufactured in such a way where each tray includes an inbuilt motor. These inbuilt motors will be responsible to actuate the conveyor trays (305) during the left or right tilting, so that it tilts at desired angles for the waste to fall into the organic material collection baskets (303) and (304). The titling motion (left or right) of the conveyor trays (305) will depend on the types of gases released by the waste. The main gases found in landfill waste is methane gas (CH_4) and carbon dioxide gas (CO_2) along with other gases in trace amounts such as nitrogen gas (N_2) and ammonia gas (NH_4) amongst others. When required, the tilting of the conveyor trays (305) can also be done manually.

Figure 4 in the present embodiment further illustrates the conveyor trays which is used in the previously mentioned Figures 1, 2 and 3. At each above-mentioned stage, the waste will be conveyed via several conveyor trays (305). Each conveyor trays (305) is comprised of 5 parts, male lock (401) and female lock (404) which serves to latch the conveyor trays (305) to each other, air pores (402) on the conveyor trays (305), vertical separator (403) and the controller (405). The male lock and female lock (401) and (404) will interlink the conveyor trays (305) throughout the waste separation process as illustrated in Figure 1, 2 and 3.

The air pores (402) have small holes and pores which allows particles smaller than 1 millimetre (mm) or 2 millimetres (mm) to enter during the air suction process. Further, the small holes at the air pores (402) will provide air circulation to the organic wastes from the bottom during the air suction process. The vertical separator (403) acts as a divider when the conveyor trays (305) are being tilted by the inbuilt motors. The vertical separator (403) ensure that the waste accumulated in the two chambers within the conveyor trays (305) will not mix with each other. The inbuilt motor is controlled by the controller (405).

b) Pre-processing Stage

The remainder waste involved in this stage is amongst the following:

1) thin film plastic wastes, low density or low weight plastics and other plastics,
2) organic wastes,
3) paper and cardboard wastes.

In the plastic collection chamber, the plastic wastes will be further processed, specific to their types. The thin film plastic waste and low density or low weight plastic are unable to be shredded as they tend to wrap around the shredder rotors, and this does not allow for shredding to function as intended. Therefore, the thin film plastic waste together with the low density or low weight plastics will undergo a melting and compression process.

The melting and compression process for the thin film plastic waste and the low density or low weight plastics is illustrated further in Figure 5A, which comprises of 7 parts. A piston motor controller unit (501), a hydraulic piston rod (502), a piston cylinder (503), an

input feeder (504), controller of output door (505), a thin film and plastic accumulation chamber (506) and an output door (507). The thin film waste and low density or low weight plastics will be fed into this chamber via the input feeder (504).

The hydraulic piston rod (502) will elongate to 95% of the chamber and again will de-elongate to 30% of the chamber. The plastic fed into the thin film and plastic accumulation chamber (506) will be either softened (semi-solid) or melted down into liquid by weakening of the Van der Waals forces between the polymer chains using high temperature. Upon being softened and melted, the plastic will then be crushed by the piston cylinder (503) from the elongation by the hydraulic piston rod (502).

The piston cylinder (503) will crush and compress the softened or melted plastic mixture to form a solid plastic cube. The output which consist of solid plastic cubes from this process will be extracted from the output door (507). The opening and closing of the output door (507) will be controlled by the controller of output door (505). Whereas the elongation of the hydraulic piston rod (502), the piston cylinder (503) and the regulation of the piston temperature will be controlled via the piston motor controller unit (501).

The similar plastic melting and compression process in the present invention is further illustrated in Figure 5B and the entire compressed plastic cubes are further illustrated in Figure 5C. The output of the plastic cubes from the output door (507) is further illustrated in Figure 5D.

Figure 6 in the present embodiment describes the motion of the piston. As described above and in relation to Figure 5, the movement of the piston cylinder (503) and elongation of the hydraulic piston rod (502) is controlled by the piston motor controller unit (501) which has dynamic positioning capabilities depending on the amount of plastic waste that is present. The piston cylinder (503) will compress the plastic waste within this chamber at a very high pressure, therefore the position of the piston cylinder (503) is dynamic and constantly changes. The piston cylinder (503) will stop at different levels, which ranges from 98% to 38% of the total volume within the processing portion, depending to the elongation of hydraulic piston rod (502).

Figure 6 illustrates how the hydraulic piston rod (601) is connected to the piston cylinder (602) and its elongation along the chamber to compress the plastic waste at the plastic compressor area (603). The hydraulic piston rod (601) will elongate and cover a certain portion of the chamber, which depends on the volume of waste to be compressed. The same is denoted as hydraulic piston rod elongation (601a) and (601b), in Figure 6.

The organic waste will be sent into the heating chamber. Heat treatment will be used on the organic waste to absorb the moisture and dry the waste. Once the water has been absorbed, the dried organic waste will then be shredded in a normal shredding machine. The paper and cardboard waste obtained from the sorting stage will be shredded using a specific shredder comprised of nitride blades. The waste materials upon completion of the pre-processing stage will consist of small plastic cubes, plastic particles, organic waste, paper and cardboard waste. These waste materials will then be granulated according to the waste groups as mentioned above.

Figure 7 illustrates the granulation machine which comprises of 5 parts, the input waste conveyor (701), the cylinder crusher (702), the neodymium walls (703), the vertical crushing blades (704) and the granule collection chamber (705). The small plastic cubes and plastic particles, organic waste and paper and cardboard waste will be separately fed into the cylinder crusher (702) within the granulation machine via the input waste conveyor (701). The neodymium walls (703) that are of high strength supports the granulation process and reduce the volume within the granulating machine. The vertical crushing blades (704) comprised of nitride blades, will crush the waste in the granulation machine.

Thereupon, the fine granules in the range of less than 5 millimeters (mm), will be collected via the granule collection chamber (705). The finely grinded waste (which separately consists of plastic cubes and plastic particles, organic waste or paper and cardboard waste) will then be fed in an ideal proportion into the microbial growth chamber. The ideal proportion to be used are 1 portion of plastic cubes and plastic particles, 1 portion of organic waste and 1 portion of cardboard waste, which can be represented in a ratio of 1: 1: 1. These ideal proportion is chosen to ensure the amount of carbon available in the internal environment within the microbial growth chamber is conducive for the microbe’s growth processes.

c) Microbial Growth Stage

The granulated waste from the pre-processing stage will then be passed into the microbial growth stage. In the present invention, Figure 8 illustrates the microbial growth chamber also known as the acetogenic chamber. Two types of microbial growth will take place within the acetogenic chamber, which is the pre-microbial growth and the actual microbial growth. There are 11 important components in this chamber, a dry waste inlet (801), a liquid waste inlet (802), a gaseous output (803), an output for solids and liquids (804), a moisture and gas control chamber (805), a mixed chemical and bacteria chamber (806), a spraying nozzles (807), sensors (808), a main chamber controller (809), a thermal chamber (810) and waste mixing blades (811).

First, the granulated waste will be passed into the acetogenic chamber which consists of two parts, namely the dry waste inlet (801) (granulated waste input) and the liquid waste inlet (802) (wastewater input). The liquid waste inlet (802), namely wastewater that is connected to the chamber helps to enhance microorganism growth by providing more nutrients and moisture to the mixture inside the acetogenic chamber. During the pre-microbial growth stage, specified acids like sulphuric acid (H_2SO_4) and ammonia gas (NH_4) will be sprinkled from the spraying nozzles (807) to the granulated waste inside the chamber. This will prepare the waste within the acetogenic chamber before the inclusion of microorganisms. The specific acids and bacteria during this pre-microbial and the actual microbial growth stage will be inserted from the mixed chemical and bacteria chamber (806).

The sensors (808) can detect the pH level (the acidity or alkalinity), gas level, water level, temperature, humidity, and other parameters depending on the waste composition and the type of microorganisms introduced within the acetogenic chamber. The data on the thermo-chemical environment and the bacterial properties in the acetogenic chamber will be recorded and controlled by the main chamber controller (809). The sensors (808) will send signals to the main chamber controller (809). The main chamber controller (809) will analyse the data received from the sensors (808) and convey a set of commands to the moisture and gas control chamber (805). The moisture and gas control chamber (805) will regulate all the parameters involved during both the pre-microbial stage and the actual microbial growth stage, as mentioned above.

The temperature within the acetogenic chamber will be maintained around 120 Celsius (°C) by the thermal chamber (810). This will be optimum temperature to speed up the microbial cultivation process within the acetogenic chamber. The waste mixing blades (811) will ensure that the sprinkled chemicals and the bacteria inside the acetogenic chamber are evenly mixed.

During the pre-microbial growth process, the acids, and the chemicals from mixed chemical and bacteria chamber (806) that flows into the acetogenic chamber will be mixed by the waste mixing blades (811). The waste mixing blades (811) consist of the nitride blades. After a certain amount of settling time, the actual microbial growth stage will take place. The mixture in the acetogenic chamber will then be mixed with a specific type of bacteria. The bacteria used for this purpose can be one or more, depending on the granulated waste composition fed through the dry waste inlet (801) into the acetogenic chamber. Some examples of bacteria utilized in this process will be *Methylomonas*, *Alcaligenes latus*, *Bacillus megaterium*, *Cupriavidus necator*, *Pseudomonas oleovorans* and *Helomonas hydrothermalis* and any other cultivated bacteria or relevant bacteria invented or existing.

The entire microbial growth process will take place in the absence of oxygen gas (O_2). The chamber is then filled with gases like carbon dioxide gas (CO_2) and nitrogen gas (N_2) and prepared for the actual microbial growth process. The waste within the acetogenic chamber will be set for a certain duration which may range from hours, days or even weeks, depending on the volume of waste fed into the acetogenic chamber. After the addition of the bacteria(s) the waste will release a certain type of gases together with a slurry mixture consisting of solids and liquids as an output. Both these outputs are formed from the result of the bacterial metabolism processes which occur within the acetogenic chamber.

The gases formed will be extracted out of the acetogenic chamber via the gaseous output (803). An example of the type of gas which will be extracted from the gaseous output (803) will be methane gas (CH_4) in addition to other types of gases. Meanwhile, the slurry mixture of solid and liquid waste will be extracted via the output for solids and liquids (804). All the output extracted from the acetogenic chamber will be passed to the extraction and granulation stage for further processing.

d) Extraction and Granulation Stage

The extraction and granulation process are illustrated in detail in Figure 9 and Figure 10. As mentioned above, there will be two types of outputs obtained and extracted out from the acetogenic chamber, which is the output for solids and liquids (804) and the gaseous output (803). Since these outputs consists of different types, namely slurry mixture and gases, therefore these outputs will undergo two different processing stages. Further processing of the output for solids and liquids (804) is illustrated in Figure 9 and the gaseous output (803) is illustrated in Figure 10.

Figure 9 in the present invention is comprised of an input of solids and liquids (901), a sedimentation tank (902), a connector (903), a centrifugal pump (904), a residual output (905), a cultivation chamber (906), a drying chamber (907), a plastic granulation chamber (908) and an output collector (909). The solid and liquid mixture accumulated in the output for solids and liquids (804) at the acetogenic chamber will enter through the input of solids and liquids (901). The solid and liquid mixture will enter the sedimentation tank (902) where, the particles within the mixture will be allowed to settle down under the effect of gravity. The duration for the solid particles to settle down from the mixture varies depending on the composition of waste formed at the acetogenic chamber.

The solid particles that settle down from the mixture within the sedimentation tank (902) is known as the suspended solids. The sedimentation process will help to separate the solid particles within the mixture as well as to reduce the water content within the mixture in the sedimentation tank (902). Post the sedimentation process, the mixture within the sedimentation tank (902) will consist of few layers namely the clear liquid, zone of variable composition (mixture of liquid with solid particles which did not settle down) and the sediment layer. The clear, nutrient rich liquid portion will be drained out from the sedimentation tank (902) and reused again as wastewater at the acetogenic chamber via the liquid waste inlet (802). While the zone of variable composition and the sediment layer will be sent into the centrifugal pump (904) to be centrifuged.

Post centrifugation, the water content within the sediment will be eliminated up to 99%. The centrifugation process will efficiently separate the remaining mixture from the sedimentation tank (902) to form two distinct portions, namely the sediment portion and liquid portion. The top layer will be the centrifugate (also known as the supernatant liquid)

and the sediment comprised of solid particles will be suspended at the bottom. The centrifugate which is high in essential nutrients for microbial growth will be extracted out via the residual output (905) and will be reused in the acetogenic chamber as wastewater input.

The sediment comprised of solid particles extracted from the centrifugation process is a type of cellulose-based bioplastic. The extracted solid cellulose will be sent into the drying chamber (907) to be completely dried. The end mixture which is the extracted plastics will be passed into the plastic granulation chamber (908) to be granulated. Post that the granulated plastics will be extracted via the output collector (909). The granulated plastic obtained from this process is made up of cellulose which is entirely biodegradable and safe for human consumption.

However, the same extracted solid cellulose may also be cultivated again with different combination of bacteria(s) for specific type of plastics within the cultivation chamber (906). Via this process, the extracted solid cellulose will be eaten by the plastic producing bacteria which will release the end output, a bio-based plastic. A different combination of bacteria(s) is used for different types of plastics. This is because not all type of bacteria(s) is able to digest/consume all type of plastics by excreting the desired enzymes for the digestion process. Further, sometimes the cultivation process will require a combination of different bacteria(s) to obtain a desired type of plastics. Upon cultivation, the same cultivated cellulose-based plastics will then undergo similar processing as described above, namely dried within the drying chamber (907), granulated at the plastic granulation chamber (908) and the collected via the output collector (909).

Meanwhile, the gases from the gaseous output (803) will be further processed as illustrated in Figure 10. Figure 10 in the present invention comprises of a gaseous input (1001), a bacteria and gas supply nozzle (1002), a chamber (1003), a heat generator (1004), an acid and moisture controller (1005), a centrifugal pump (1006), a centrifugal pump output (1007), a sedimentation tank (1008), a heater (1009) and a granulation chamber (1010). The gases from the gaseous output (803) produced from the acetogenic chamber will flow into the chamber (1003) via the gaseous input (1001). The chamber (1003) will have multiple functions, to carry out two types of processes namely the condensation and cultivation process.

The first step within the chamber (1003) will be the condensation process where the gaseous input (1001), which comprised of methane gas (CH_4) and other gases. During the condensation process, these gases will be cooled down within the chamber (1003). Post the condensation process, these gases will be converted into liquids. The liquified gases will then undergo the second step within the chamber (1003), which is the cultivation process. During the cultivation process, the liquified gas mixture will be added with a specific combination of bacteria which can breakdown and utilize the different chemical compound(s) found within the liquid mixture. The acid and moisture controller (1005) will monitor and control the pH balance and moisture content within the chamber (1003). The temperature for bacterial growth within the chamber (1003) will be maintained by the heat generator (1004).

The output products from the cultivation process will then be sent to the centrifugal pump (1006) to be centrifuged. The centrifugation process efficiently separates the output products into two distinct portions, namely the sediment portion and liquid portion. The sediment obtained will be sent into the sedimentation tank (1008). In the sedimentation tank, any type of gaseous vapour present will be extracted out of the mixture. These gases will undergo the same process similar to the other types of gases output, as described above. Post that, the mixture will be sent to the heater (1009) to be completely dried before transferred into the granulation chamber (1010) to be granulated. The granulated plastic obtained from this process is made up of cellulose which is entirely biodegradable and safe for consumption. While the liquid portion obtained from the centrifugation process will be extracted and reused again into as wastewater input in the acetogenic chamber.

CLAIMS:

1. A method to separate and process landfill wastes resulting in a cellulose-based, biodegradable bioplastic comprising of;

   the sorting stage, the pre-processing stage, the microbial growth stage and the extraction and granulation stage whereby;

   the sensors (101) will be used to detect and differentiate the types of waste materials; prompting the automated mechanical waste pickers (102) to separate the waste according to particle size, position, colour, and shape and transferring the same into the output segregators (105),(106) and (107) and;

   using a shredder the remaining waste will be reduced in size to an approximate of 5 centimetre (cm) to 10 centimetre (cm), which will then be conveyed to a magnetic conveyor belt (201) which will separate the ferrous and non-ferrous metal scraps;

   thereupon, the air suction system which comprises of air suction nozzles (202) and air suction chamber (203), with the air pressure fan (205) will blow high pressured air on the remainder waste which will separate the thin film waste, low density or low weight plastics and other plastics;

   the gas sensors (301) will then detect the gases and the controller (302) will actuate the conveyor trays (305) to the left or right and separate the organic wastes into the organic material collection baskets (303) and (304);

   the sorted waste comprised of thin film waste, low density or low weight plastics and other plastic, organic waste and paper and cardboard wastes will then undergo a separate pre-processing stage;

   the thin film waste and low density or low weight plastics will then undergo melting and compression process by using piston cylinder (503) to form plastic cubes, where the plastic cubes and other plastics will be granulated;

the organic waste will then be heated to absorb the moisture and granulated;

the paper and cardboard wastes will then be shredded and granulated whereby;

at the microbial growth stage, all the granulated wastes will be fed inside the acetogenic chamber in a specific proportion and the waste medium will undergo pre-microbial growth and the actual microbial growth processing, whereby;

during the pre-microbial growth, the waste will be sprinkled with specified acids by the spraying nozzles (807) while during the actual microbial growth, the mixed chemical and bacteria chamber (806) will release specific types of bacteria whereby;

there will be two outputs from this process, the output for solid and liquids (804) and the gaseous output (803) whereby;

both these outputs will undergo a separate extraction and granulation stage whereby, the end product will be a granulated cellulose based plastic which is entirely biodegradable and of food grade.

2. The method of Claim 1, and wherein the landfill waste can come from municipal solid waste, residuals from municipal recycling facility and other industrial wastes.

3. The method of Claim 1, and wherein the magnetic conveyor belt (201) has an electromagnetic property which will cause particles to be magnetised at the lower part and demagnetized at the upper part of the magnetic conveyor belt (201).

4. The method of Claim 3, and wherein the magnetic conveyor belt (201) also comprises of optical and thermal sensors (208) to increase the efficiency of the collection of the iron-based particles.

5. The method of Claim 1, and wherein the air pressure fans (205) coordinate with the air suction system to create an environment with pressures varying from 2 pascal (Pa) to 100 pascals (Pa), therefore increasing the efficiency of waste separation.

6. The method of Claim 1, and wherein each conveyor trays (305) has air pores (402) which provides air circulation during the waste sorting stage.

7. The method of Claim 6, and wherein the vertical separator (403) inside the conveyor trays (305) will act as a divider to prevent mixing during the left and right tilting for the organic waste separation process.

8. The method of Claim 1, and wherein the hydraulic piston rod (502) will elongate to 95% of the chamber, and again will de-elongate to 30% of the chamber and controlled by the piston motor controller unit (501).

9. The method of Claim 8, and wherein the elongation of the hydraulic piston rod (502) will enable the piston cylinder (503) to compress the melted plastics into smaller cubes.

10. The method of Claim 1, and wherein the acetogenic chamber also comprises of sensors (808) which can detect the pH, gas level, water level, temperature, humidity and other parameters of the granulated waste within the acetogenic chamber.

11. The method of Claim 10, and wherein at the acetogenic chamber, a certain mixture of bacteria which may consists of *Methylomonas*, *Alcaligenes latus*, *Bacillus megaterium*, *Cupriavidus necator*, *Pseudomonas oleovorans* and *Helomonas hydrothermalis* and any other cultivated bacteria or relevant bacteria invented or existing will be added during the actual microbial growth.

12. A system to separate and process landfill wastes to produce a cellulose-based, biodegradable bioplastic, the system comprises of;

    the conveyor trays (103) which will bring the waste into the sorting stage which comprised of sensors (101) to detect and prompt the automated mechanical waste picker (102) to sort the desired waste types and transfer the same into output segregators (105), (106) and (107) wherein the remaining waste will be shredded and further sorted;

next, the ferrous metals, non-ferrous metals, thin film, and plastic wastes will be sorted whereby;

at the magnetic conveyor belt (201) the ferrous and non-ferrous metal scraps will be sorted and, at the air suction system the thin film waste, low density or low weight plastics and other plastics will be sorted;

the organic materials will be sorted whereby the gas sensors (301) will send information to the controller (302), based on the input from the controller (302), the conveyor trays (305) will be tilted to the left or right, the tilting of the conveyor trays (305) is specific to the type of gases in the waste and the organic wastes will be collected at the organic material collection baskets (303) and (304);

subsequently at the pre-processing stage, the thin film waste, low density or low weight plastics and other plastic, organic waste, paper and cardboard waste will undergo separate processing whereby;

the thin film waste and low density or low weight plastics will be melted and compressed using a piston cylinder (503) resulting in plastics cubes collected at the output door (507);

the organic waste will be sent to a heater to absorb the moisture;

the paper and cardboard waste will be shredded using nitride blades;

all the pre-processed waste will be granulated whereby;

the granulated wastes will be fed into the acetogenic chamber in a specific proportion where, two types of microbial growth will occur;

during the pre-microbial growth stage, the spraying nozzles (807) will sprinkle specified acids like sulphuric acid (H_2SO_4) and ammonia gas (NH_4);

after the settling time the actual microbial growth stage will take place and the mixture within the chamber is added with a specified type of bacteria;

the mixture will yield two types of output which will be extracted at the gaseous output (803) and the output for solid and liquids (804);

the extracted solid and liquid mixture and gaseous mixture from the gaseous output (803) and output for solids and liquids (804) will undergo a separate processing at the extraction and granulation stage which will yield a plastic made-up of cellulose which is biodegradable and safe for human consumption;

upon processing, the waste the materials recovered (recovery rate) will be between 80 to 100 percent (%)

13. The system of Claim 12, and wherein the sensors (101) will identify and separate the different types of waste according to particle size, position, colour, and shape, both optically and thermally.

14. The system of Claim 12, and wherein the air pressure fans (205) will blow high speed air to disseminate the small and thin plastic particles.

15. The system of Claim 12, and wherein the conveyor trays (305) consists of holes and air pores (402) which will allow particles less than 1 millimetre (mm) or 2 millimetre (mm) to enter during the air suction process.

16. The system of Claim 15, and wherein the conveyor trays (305) comprised of a vertical separator (403) which acts as a divider between the two portions of the conveyor trays (305) to prevent mixing.

17. The system of Claim 12, and wherein piston motor controller unit (501) will control the elongation of the hydraulic piston rod (502) and regulate the temperature within the piston.
18. The system of Claim 17, and wherein the elongation of the hydraulic piston (502) is dynamic and will stop at different levels as illustrated by the hydraulic piston rod

elongation (601a) and (601b), which ranges from 98% to 38% of the total volume within the processing portion.

19. The system of Claim 12, and wherein the gaseous output (803) and output for solids and liquids (804) will undergo a separate processing to yield cellulose based biodegradable plastics, which is non-toxic and safe for human consumption.

20. The system of Claim 19, and wherein the gaseous output generated from the gaseous output (803) at the acetogenic chamber can be methane gas or even other types of gases.

21. The system of Claim 20, and wherein the gaseous output (803) will undergo condensation process to be converted into liquids and cultivated inside the chamber (1003) with a specific combination of bacteria to breakdown and utilize the different chemical compounds.

22. The system of Claim 21, and wherein post cultivation processes the mixture will undergo centrifugation where, the sediment portion containing the cellulose based bioplastic will be sent to a heater (1009) to be dried completely and granulated.

23. The system of Claim 12, and wherein the output for solids and liquids (804) will undergo sedimentation process and the sediment will be centrifuged at the centrifugal pump (1006).

24. The system of Claim 23, and wherein the product from the centrifugal pump (904) which is the sediment consist of cellulose based bioplastic will be sent to drying chamber (907) and granulated at the plastic granulation chamber (908).

25. The system of Claim 23, and wherein both the sediment mixture obtained at the centrifugation pump during the processing of gaseous output (803) and the output for solids and liquids (804), is comprised of cellulose based bioplastic, which can be processed to produce the desired type of plastic (PLA, PHA PET etc) by further cultivating with a specific type of bacteria, if required.