R&D ON PLASTIC WASTE BIODEGRADATION AND UTILIZATION

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Commercial plastics have largely contributed to the present worldwide pollution crisis on both land and water. Marine plastic has caused havoc on numerous biological species and will adversely affect human nutrition and health in the coming years. Multi-sectoral strategies are urgently needed in order to solve this pollution problem. For example, it is imperative to ban single-use plastics and require greater use of biodegradable plastics. Importation and use of non-biodegradable plastics, which are made from fossil-based feedstocks such as petroleum, should be reduced.

Some commercial additives, which are presently used by many plastic processors, have been claimed to be ‘pro-degradant’ or effective in enhancing biodegradability of non-biodegradable plastics. Biodegradability tests should be done on both imported and locally processed additives and their results should be the basis for product labeling. If the additives do NOT biodegrade a non-biodegradable plastic material (such as PE), according to standard tests, they should be not be labeled as ‘pro-degradant’.

In view of worsening plastic pollution, there is a global need to shift from the traditional throw-away linear economy to minimal-waste chain economy and, eventually, to the ideal zero-waste cyclic economy. The latter is governed by the 4 Rs (Reduce, Reuse, Recycle, Re-design) as applied to the plastic material’s life cycle.

In order to help find solutions to the present crisis due to plastic waste, the following policy recommendations are made under Philippine conditions:

1. Government incentives for processors/manufacturers of biodegradable plastic products through tax reduction/exemption, etc.
2. Funding and logistical support for R & D on:
    a. Physico-chemical and biological evaluation of commercial ‘pro-degradant’ additives for biodegradation of plastic materials under local conditions;
    b. Utilization of asphalt mix with plastic waste for road building;
    c. Thermochemical conversion of plastic waste into liquid fuel;
    d. Techno-economic feasibility studies on the production of biodegradable plastics from local feedstocks; and
    e. Multi-disciplinary studies on plastic biodegradation using local microbial isolates

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Introduction

Plastic waste presently contributes more than 300 million metric tons (MT) to worldwide pollution, more than half of which comes from Asia, and more than 10 million MT entering the ocean. Only 9 per cent of the 9 billion MT of plastics produced worldwide has been recycled (Jambeck et al. 2015; UNEP 2018). Without improvements in waste management infrastructure, the total quantity of plastic waste which could enter the ocean from land is predicted to increase by an order of magnitude by 2025. With this grim prospect of massive marine pollution, especially microplastics with particle size of less than 5 mm, it is now imperative to look at effective means of facing this crisis using science and technology, government policies, socio-economic measures and international cooperation.

Plastics are polymers or large molecules consisting of many replicated single units of the basic molecular structure; they represent one of the most widely used materials and are usually designed to have long lifetimes. Unfortunately, many desirable properties of plastics, such as their chemical, physical, and biological inertness and durability, create challenges and problems when plastics are released into the environment. Common fossil-based plastics such as polyethylene (PE) are extremely persistent in the environment because they undergo very slow fragmentation, which can take centuries, into small particles through physical and biological degradation processes. Unfortunately, this fragmentation of plastic materials into increasingly smaller pieces is a necessary step in the degradation process and presents potential serious harm to marine organisms and human beings.

Bioplastics refer to plastic materials that are either bio-based or biodegradable; the latter two terms are not synonymous. Bio-based plastics are derived from plant biomass in contrast to fossil-based plastics which are made from fossil substrates such as petroleum. In general, bioplastics are more expensive than fossil-based plastics per unit weight basis. There are several examples of bioplastic products that are already cost competitive. Furthermore, the costs of fossil-based plastics depend on oil prices, while costs of bio-based plastics generally depend on biomass prices that are more stable. With more favorable economies-of-scale production and logistics it is expected that the prices of bio-based plastics will come down.

Present Controversy on ‘Pro-Degradant’ Additives and ‘Oxo-biodegradable’ Plastics

Some commercial additives, which are presently used by many plastic processors, have been claimed to be ‘pro-degradant’ or effective in enhancing biodegradability of non-biodegradable plastics. However, recent scientific studies in the U.S.A. and Europe have shown that several of these additives did not perform as claimed by the processors under standard composting conditions. Thus, these additives should undergo standard physical tests for evolution of gases (CO_2 and CH_4), quantitative loss of mass and sample integrity, as well as visual inspection of surface features and disintegration. These are important tests on both imported and locally processed additives and their results should be the basis for product labeling. Therefore, if the additives do NOT biodegrade a non-biodegradable plastic material (such as PE) according to standard tests, they should not be allowed to be labeled as ‘pro-degradant’.

Ocean microplastics are mainly ‘oxo-degradable’, which partially degrade chemically especially under sunlight and fragment into microplastics or nanoplastics, but do not really biodegrade. The process of disintegration results in the formation of invisible plastic fragments. Therefore, ‘oxo-degradable’ or ‘oxo-biodegradable’ plastics should be treated as NOT biodegradable and their use should be discouraged (Kubowicz and Booth, 2017).

Plastic Waste Management

Most fossil-based plastics cannot be fully degraded by microorganisms, although some (polyesters, etc.) are biodegradable and can be fully degraded into CO2, methane and microbial biomass. Bio-based plastics (PLA, PHA, etc.), which are derived from biomass such as starch or cellulose, are mainly biodegradable although a few, such as bio-PE, are non-biodegradable. In view of worsening plastic pollution, there is a global need to shift from the traditional throw-away linear economy to minimal-waste chain economy and, eventually, to the ideal zero-waste cyclic economy. The latter is governed by the 4 Rs (Reduce, Reuse, Recycle, Re-design) as applied to the plastic material's life cycle (McManus, 2018).

Utilization of Plastic Waste

Plastic-asphalt mix for road pavement

R&D studies have been done in several countries, such as United Kingdom, Australia, India and Thailand, on the utilization of plastic waste as binder/modifier in a mix with asphalt for road building. Although local utilization of plastic waste as asphalt additive for road pavement has been started, more R&D efforts are needed for improvement and country-wide adoption of the technology. Furthermore, life cycle assessment (LCA) studies should be done on the optimized technology (Loughran, 2019). Life cycle assessment is a technique for assessing the environmental impacts associated with a product's life from raw material through processing, manufacture, distribution, and use, or from "cradle to grave".

Conversion of plastic waste into liquid fuel

Plastic waste utilization involving thermochemical methods have been reported such as conversion of polypropylene (PP) into oil using using supercritical water. Preliminary analyses indicate that the conversion process is net-energy positive and potentially has higher energy efficiency and lower greenhouse gas emission than incineration and mechanical recycling. Local R & D studies are needed on the cost-effective conversion of plastic waste into liquid fuel, with minimal environmental impact and favorable LCA (Chen et al., 2019).

Some Local R&D on Bioplastics and Plastic-degrading Microorganisms

Some researches at the University of the Philippines (UP) Diliman deal with the utilization of locally available agricultural by-products for the production of bioplastics. After extraction, chitin and cellulose were blended to obtain more pliable polymer films for the packaging industry. Nanoclay was also incorporated to produce a nano-composite polymer. Despite modifications the polymers were still biodegradable. Plastic degrading microorganisms have been isolated by researchers at UP Los Baños from local sources, including plant root nodules, alkaline spring and different soil samples. Thirteen local bacterial isolates, as well as a fungus, were found to be potential biodegraders of PE. Four fungal isolates were able to degrade polyurethane.

Recommendations

Based on present problems regarding non-biodegradability of most commercial plastics, the following policy recommendations are made under Philippine conditions:

1. Government incentives for processors/manufacturers of biodegradable plastic products through tax reduction/exemption, etc.
2. Funding and logistical support for R & D on:
    a. Physico-chemical and biological evaluation of commercial 'pro-degradant' additives for biodegradation of plastic materials under local conditions
    b. Utilization of asphalt mix with plastic waste for road building
    c. Thermochemical conversion of plastic waste into liquid fuel
    d. Techno-economic feasibility studies on the production of biodegradable plastics from local feedstocks
    e. Multi-disciplinary studies on plastic biodegradation using local microbial isolates

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Experts' talks about plastics and plastic wastes during the NAST PHL Annual Scientific Meeting on July 10-11, 2019, are available on the **NAST PHL Talks YouTube channel**.

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