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Degradation of Plastic and Polythene Materials by Some Selected Microorganisms Isolated from Soil

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Abstract: This study determined the degradation of plastic materials by three different species of microorganisms under both laboratory and field conditions using standard techniques. Results obtained revealed that *Pseudomonas fluorescens* was the most active of the tested microorganisms degrading approximately 18% and 16% of polythene at 9 and 12months period respectively and 3.8% of plastics in twelve month period under field condition. Also, 8.06 and 5.63% of polythene and plastics were respectively degraded in a month under laboratory condition. The biodegradation of the polythene material was relatively faster and earlier than that of the plastics with the polythene degrading for up to 12.94, 16 and 15% at 9 months of analysis while only 2, 3.8 and 4.8% of the plastic materials were degraded at 12month Kfor each of *Staphylococcus aureus*, *Pseudomonas fluorescens* and *Aspergillus niger* respectively. It can thus be concluded based on our research findings that the studied microorganisms posseses biodegradability properties to varying degrees of efficiency.

Key words: Biodegradation · Plastic Materials · Microorganisms · Soil

INTRODUCTION

Plastics are defined as polymers (solid materials) which on heating become mobile and can be cast into mould. They are non metallic moldable compounds and the materials that are made from them can be pushed into any desired shape and sizes [1]. These plastics are advantageous as they are strong, light-weighted and durable. However, their demerit includes resistance to biodegradation, pollution as well as their harmful effect on the natural environment. This coupled with the fact that most of these wastes cannot be renewed and degraded encourages research and studies in the field of biosynthetic and biodegradation material. One of the waste that can not be destroyed is plastic waste, which is a type of polyethylene plastic. Low density polyethylene is one of the major sources of environmental pollution. Polyethylene is a polymer made of long chains of ethylene monomers. The use of polyethylene growing worldwide at a rate of 12% per year and about 140 million tons of synthetic polymers are produced worldwide each year. With such a large amount of polyethylene accumulating in the environment, thousands of years are required to efficiently degrade them [2]. Biodegradation is the process in which microorganisms like fungi and bacteria degrade the natural polymers (lignin, cellulose) and synthetic polymers (polyethylene, polystyrene) [3]. These microorganisms possesses different characteristics, so the degradation varies from one microorganism to another. Microorganisms degrade the polymers like polyethylene, polyurethane by using it as a substrate for their growth [4]. Various factors which are responsible for biodegradation are kind of polymers, organism characteristics and the type of treatment required [5,6]. Discoloration, phase separation, cracking, erosion and delimitation are some of the characteristics which indicate the degradation of polymers. Breakage of bonds, transformation due to chemicals and synthesis of new

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functional groups are responsible for the variations [7]. Characteristics of microorganisms represent the type of enzymes which are produced for biodegradation like extracellular or intracellular enzymes which helps in the degradation of polymers [8, 9]. The cellular membranes of the microorganisms accumulate the substrate which is then degraded by cellular enzymes.

Microbes can easily degrade the small subunits of polymeric molecules found in the form of monomers or oligomers because high molecular weight causes insolubility which is not suitable for the degradation of plastics by microbial flora [10]. Degradation of polythene is a great challenge as the materials are increasingly used. A very general estimate of worldwide plastic waste generation is annually about 57 million tons [11]. This solid waste related problems pose threat to mega cities. This study was therefore aimed at determining microorganisms that can degrade plastic materials

MATERIALS AND METHODS

Identification of Test Microorganisms: The test isolates were isolated from dump sites by Miss Avoseh Zansi Tobi in her previous study. These isolates were further identified and reconfirmed in this study to species level following the guidelines of Analytical Profile index(API).

Microbial Degradation of Plastics under Field Conditions: Plastic cups and polythene bags were buried at a depth of 5 cm in pre-sterilized soil aseptically introduced into different pots. Each of this pot was inoculated with 0.5 McFarland standards each of *Staphylococcus aureus*, *Pseudomonas fluorescens* and *Aspergillus niger* respectively. The experiments were carried out in duplicates. The materials were allowed to degrade in these artificially inoculated pre-sterilized soil and they were sampled at the intervals of 3, 6, 9 and 12 months. One set of samples was thoroughly washed using distilled water, shade-dried and then weighed for final weight. The degradation was determined in terms of percent of weight loss of the materials over a period of time

Microbial Degradation of Plastics under Laboratory Conditions: To assess this, the pre-weighed discs of 1-cm diameter prepared from polythene bags and disposable plastic cups were aseptically transferred to the conical flask containing 50 ml of culture broth medium, inoculated with different bacterial and fungal species separately. Nutrient broth medium was used for bacteria and Potato dextrose broth for fungi. Control was maintained with plastic discs in the microbe-free medium. Four flasks were maintained for each treatment and left in a shaker. After one month of shaking, the plastic discs were collected, washed thoroughly using distilled water, shade-dried and then weighed for final weight. From the data collected, weight loss of the plastics and polythene bags, was calculated

RESULTS

The biodegradation of the studied plastics are depicted in the above Figure 1. As shown in this figure, biodegradation of polythene takes lesser time compared to plastics degradation that took approximately a year before the commencement of its deterioration. However, polythene degradation started from the ninth month but not before that period. When the degradation of both plastics and polythene were compared statistically using student t test, it was found that polythene degraded significantly faster and better especially when also measured in terms of percentage waste loss ($t=2.805$, $p<0.05$). When the microbial degradation of both polythene and plastics were measured in terms of percentage weight loss, it was found that *Pseudomonas fluorescens* significantly degraded each of the material more than the other two microbes. Consequently, *Staphylococcus aureus* had the lowest degradation power in terms of percentage weight loss of the tested materials for both plastics and polythene (Figure 2).

DISCUSSION AND CONCLUSION

Microorganisms play a significant role in biological decomposition of materials, including synthetic polymers in natural environments. High-density and low-density polyethylenes are the most commonly used synthetic plastics and they are slow in degradability in natural environments, causing serious environmental problems. In this regard, there is a growing interest in non-degradable synthetic polymer biodegradation using effective microorganisms [12,13]. The fact that *Pseudomonas fluorescens* was the most active of the tested microorganisms degrading approximately 18% and 16% of polythene at 9 and 12months period respectively and 3.8% of plastics in twelve month period (Figure 1) under field condition and 8.06 and 5.63% in month under laboratory condition was not surprising as similar observation had been documented by Kathiresan [13] where *Pseudomonas* and *Moraxella* sp. were found to be

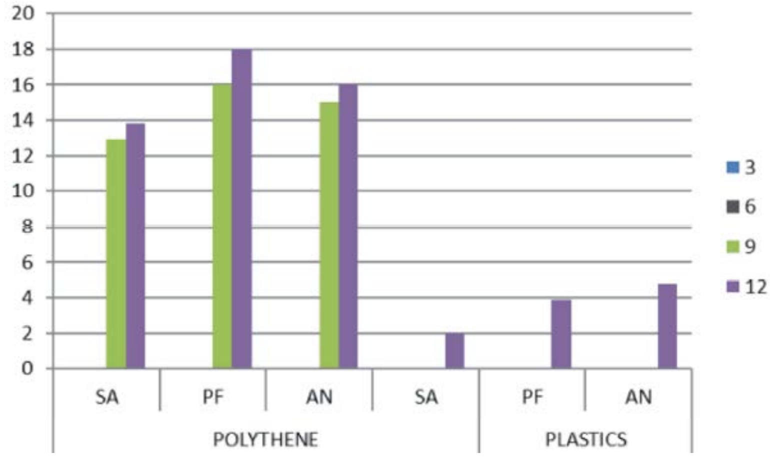

Fig. 1: Biodegradation of plastics under field condition

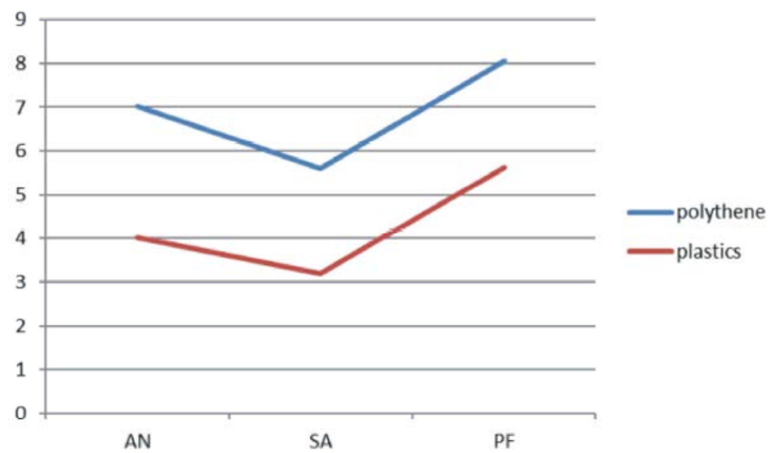

Fig. 2: Biodegradation of plastics under laboratory condition

the most active in degrading 20.54% of polythene and 8.16 % of plastics in one month period. The mechanism of degradation is not known exactly but it had been reported that the turning of plastic material surface from smooth to rough, cracking of polyethelene materials, molecular weight reduction, increase in carbonyl double bond groups and erosion on the surface of polyethylene are some of the techniques employed by microorganisms in degrading plastic materials [14]. In the process of de-polymerization, at least two categories of enzymes are actively involved in biological degradation of polymers: extracellular and intracellular depolymeration [12]. During degradation, exo-enzymes from microorganisms break down complex polymers yielding smaller molecules of short chains, e.g., oligomers, dimers and monomers, that are smaller enough to pass the semi-permeable outer membranes of the microbes and then to be utilized as carbon and energy sources [15,16]. The biodegradation of the polythene is relatively faster and earlier than that of the plastics with polythene degrading for up to 12.94, 16 and 15% at 9 months of analysis. Also, plastics materials degraded by 2, 3.8 and 4.8% only at 12 months (Fig 1) for each of *Staphylococcus aureus, Pseudomonas fluorescens* and *Aspergillus niger* respectively. This may be attributed to the thickness of the polythene that is 5-times thinner than the plastics [13]. It can however be concluded based on our result findings that the studied microbial isolates are capable of degrading plastics material. However there may be need to do further studies on the molecular mechanisms of plastics degradation in order to maximize the ecofriendly nature of this type of degradation.

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