Chapter 14
Biodegradation of Low Density Polyethylene Films

Soumita Dutta Laha
University of Calcutta, India

Kingshuk Dutta
University of Calcutta, India & Cornell University, USA

Patit Paban Kundu
Indian Institute of Technology Roorkee, India

ABSTRACT
With its ever-increasing demand, the enormous production of low density polyethylene (LDPE) is leading to its huge accumulation in the environment. LDPE remains durable and inert to natural degradation and deterioration. This chapter focuses on various microbial effects and approaches on biodegradation of LDPE. Biodegradation takes place through several different strategies, such as assimilation, biodeterioration, biofragmentation, etc. Few microorganisms have so far been isolated which can grow on LDPE. Degradation by microbial enzyme is considered to be one of the most powerful tools to study the biodegradation of LDPE. Some blends and composites of LDPE with natural polymers have been found to be biodegradable; however, their manufacturing is costly. Thorough analysis of the microbial degradation of LDPE helps us realize the overall mechanism involved. In essence, this chapter aims to objectify the in situ biodegradation of LDPE via development of microbial biofilm on the polymer surface.

INTRODUCTION
Polyethylene (PE) represents a versatile synthetic hydrocarbon resin composed of long polymeric chains synthesized via combination of the ethylene (\(\text{C}_2\text{H}_4\)) monomer. As per the reports, PE is the most widely utilized non-degradable solid waste. The most important grades of PE consist of high density polyethylene (HDPE), low density polyethylene (LDPE) and linear low density polyethylene (LLDPE). LDPE, made from petroleum, is semicrystalline in nature. Materials and commodities made from versatile and effective LDPE are found to be strong, durable, light-weight and are thus widely utilized for the production
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and fabrication of dispensing bottles, various containers, various molded laboratory wares and plastic bags. It has been estimated that annually 500 billion to 1 trillion bags made from LDPE get consumed worldwide. After a very short service life, these materials are dumped in landfills; leading to pollution. PE, especially LDPE, amounts to ~64% of the total synthetic plastics which gets discarded (Lee, Pettitto, Fratzke, & Bailey, 1991). This accumulated LDPE wastes in landfills and natural habitats demand strategizing efficient waste management techniques (Thompson, Swan, Moore, & vom Saal, 2009). In addition, the fact that the bio-degradation of PE under normal environmental conditions is extremely slow aggravates the situation (Gu, Ford, Mitton, & Michiel, 2000; Hakkarainen & Albertsson, 2004; Koutny, Lemaire, & Delort, 2006a; Arutchelvi et al., 2008; Eubeler, Bernhard, & Knepper, 2010). The bio-degradation rate of PE has been reported to be <0.5% in 100 years and ~1% if pre-exposed to sunlight for 2 years (Khabbaz & Albertsson, 2001).

LDPE is an odorless and non-toxic material. LDPE thin films possess low production cost, excellent electrical insulation, easy to process, transparency, flexibility, and toughness (Brydson, 1999). In addition, it is resistant to acids, alcohols, bases, esters and is biologically inactive. This inertness is due to its high molecular weight, hydrophobicity and lack of functional groups that can be recognized by microbial enzymatic systems (Harshvardhan & Jha, 2013). The recalcitrant behavior of LDPE towards attack by biological microorganisms is believed to be owing to the contribution of the hydrophobic backbone, 3-dimensional structure and high molecular weight. As a result, the biodegradation aspect of LDPE films has served as a subject of concern over years among waste management researchers and activists.

Several studies have revealed that PE disposed in moist soil exhibited no signs of weight loss even after 12 years, owing to its inert nature (Potts, 1978). In a separate study, the authors have observed partial degradation of LDPE films after 32 years of long incubation in soil (Otake, Kobayashi, Asabe, Murakami, & Ono, 1995). There are reports that state blockage in the intestines of marine mammals, fish and birds due to intake of PE as food. Ingestion of this waste, thereby, results in endangering hundreds of different species (Secchi & Zarzur, 1999; Spear, Ainley, & Ribic, 1995). Finally, it leads to an ever-increasing ecological threat to marine and terrestrial wildlife (Shimao, 2001; Barnes, Galgani, Thompson, & Barlaz, 2009). Thus, a cheap, effective, less time consuming and completely environmental friendly process to degrade LDPE films is required to be developed in order to save the environment from this enormous pollution. A safe and eco-friendly method of recycling of PE was conducted by Sivan et al. (2006); however, they failed to provide a safe disposal for all PE materials. Therefore, microbial degradation remains as one of the best options for PE degradation.

Definition and Categorization of Biodegradation of LDPE

Degradation is defined as any chemical or physical alteration in LDPE occurring as a result of any environmental factor, including heat, light, moisture, biological activity, chemical conditions or wind. By the help of physical means, LDPE films can be subjected to specific temperatures varying from 50°C to 80°C under UV rays for a particular time period to achieve highest level of oxidation (Figure 1).

Biodegradation is a subcategory of degradation, which involves degradation via biological activities. As mentioned above, biodegradation of LDPE is a slow process owing to its inert attribute and resistance to attack by microorganisms. This essentially leads to its environmental accumulation and pollution. In recent times, the prospect of biodegradation of LDPE and the employment of microbes to degrade them have earned significant importance owing to the lack of efficiency of the physical and chemical methods of its disposal. Biodegradation of LDPE films can be broadly classified into abiotic and biotic measures.