Journal of Pollution Effects & Control
ISSN: 2375-4397
Caruso, J Pollut Eff Cont 2015, 3:3
DOI: 10.4172/2375-4397.1000e112

Ediotrial Open Access

Plastic Degrading Microorganisms as a Tool for Bioremediation of Plastic Contamination in Aquatic Environments

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Plastic contamination of aquatic environments from waste discharges, industrial raw materials, manufactured pellets or fragments of fishing nets, is becoming a future research priority, since it has been recognized to be an emerging global threat for its multiple (social and environmental) implications. Each year, approximately 140 million tonnes of synthetic polymers are estimated to be produced and several studies aim at investigating their global impact and interactions with organisms at several trophic levels [1-5]. Additional sources of plastic pollution in the ocean are given by secondary microplastics originating from the breakdown of larger plastic items. In fact, although plastics are extremely persistent in the marine environment, exposure to physical, chemical and biological processes results in their fragmentation down into smaller pieces. Plastics present in surface waters are more prone to degradation compared to those on the seafloor, for which decomposition is made longer because of the cold water temperature and reduced sunlight (UV) penetration [5]. The products of this fragmentation process are microplastics, i.e. plastic particles having a size lower than 5 mm in diameter, which are a global concern since these small particles can be ingested by many organisms including zooplankton, mussels, fish, seabirds and cetaceans. To solve this important environmental problem, many operational clean-up programs have started; for example, UNEP has engaged more than 40 million people from 120 Countries, setting educational measures to promote reduction of plastic use, waste recycling or disposal facilities. In November 2014, the European Union agreed binding targets for Member States to reduce the use of thin plastic bags by 2019, but other kind of plastic products may continue to be a threat for the sea. So, which actions could be performed? Apart from innovations in solid waste management and sewage treatment to trap smaller particles before discharging of effluents into the sea, an interesting approach could be provided by the use of microbes able to degrade plastics. Biodegradation is the capacity of one or more strains of microorganisms to utilize a synthetic polymer as the sole source of carbon and energy; some types of plastics such as polyhydroxyalkanoates (polyhydroxybutyrate PHB), and polylactic acid (PLA) are highly biodegradable, while synthetic polymers such as polyethylene (PE) polycaprolactone (PCL) and polystyrene (PS) have low biodegradability [6]. The degree of polymer biodegradation in natural ecosystems is affected by several factors, such as the nature of the substrate to be degraded and by environmental and microbiological factors [7].

The microbial degradation of plastics has been reviewed by some studies [8-10], which have addressed the abiotic and biotic (microbial) degradation of a wide array of synthetic polymers. The actinomycete *Rhodococcus ruber* [11] and the fungus *Penicillium simplicissimum* [12] were shown to produce extracellular enzymes able to degrade PE, but also thethermophylic bacterium *Brevibacillus borstelensis* [13] and *Streptomyces sp.* [14]. Polyhydroxyalkanoates (PHA), among which polyhydroxybutyrate (PHB), are metabolized by several microorganisms; PHA depolymerases have been detected in *Pseudomonas stutzeri*, *Alcaligenes faecalis* and *Streptomyces* sp. [8,10,15,16]. PHA-degrading fungi have been isolated from soil and marine environments and belong mostly to Basidiomycetes, Deuteromycetes (*Penicillium* and *Aspergillus*) and Ascomycetes [7]. Polycaprolactone (PCL) is a synthetic polyester easily degraded by microorganisms, among which the bacterium *Alcaligenes faecalis* [17] and *Clostridium botulinum* [10] and the fungus Fusarium [7,18]. Polylactic acid (PLA) is a polymer frequently used in biodegradable plastics; its degradation by a thermophilic bacterium (*Bacillus brevis*) was reported [19], as well as by only two fungal strains of *Fusarium moniliforme* and by *Penicillium roqueforti* [7,10]. Compared to other polymers, PLA degradation is slow and less susceptible to microbial attack [10].

Polyurethane is degraded by several fungal species, such as *Fusarium solani*, *Aureobasidium pullulans* sp., although its biodegradation is frequently incomplete [8,20]; a polyester PUR degrading enzyme produced by the bacterium *Pseudomonas chlororaphis* was isolated [21]. Polyvinyl chloride (PVC) is degraded by the bacterium *Pseudomonas putida* [22], polystyrene by the actinomycete *Rhodococcus ruber* [23].

In order to improve the process of plastic biodegradation, the mechanisms involved in the plastic degradation have also been explored [24]. There are two different processes: a direct action, in which the deterioration of plastics provides a trophic resource for microbial growth, or an indirect action, in which metabolic products of microorganisms affect the plastic structure. The main groups of microorganisms and the degradative pathways involved in polymer degradation often depend on the environmental conditions. At least two categories of enzymes are involved in biological degradation, the extracellular and the intracellular dehydrogenases. Enzymes secreted by microbes for biodegradation of plastics are mostly lipase, proteinase K, dehydrogenases [10].

In conclusion, microbial degradation of plastic is a promising eco-friendly strategy which represents a great opportunity to manage waste plastic materials with no adverse impacts. Thanks to the progress in blue technologies, new plastic degrading microorganisms have recently been discovered, that have great biotechnological potential and could help the natural bioremediation processes, favoring the natural cleaning of natural ecosystems. Further advances in biochemistry and biotechnological fields could offer new perspectives the bioremediation of plastic contamination and should be encouraged to select the most active microbial consortia in the plastics degradation process.

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Received September 24, 2015; **Accepted** September 28, 2015; **Published** October 05, 2015

Citation: Caruso G (2015) Plastic Degrading Microorganisms as a Tool for Bioremediation of Plastic Contamination in Aquatic Environments. J Pollut Eff Cont 3: e112. doi:10.4172/2375-4397.1000e112

References

1. Andrady AL (2011) Microplastics in the marine environment. Mar Poll Bull 62: 1596-1605.
2. Cole M, Lindeque P, Halsband C, Galloway TS (2011) Microplastics as contaminants in the marine environment: a review. Mar Poll Bull 62: 2588-2597.
3. Eerkes-Medrano D, Thompson RC, Aldridge DC (2015) Microplastics in freshwater systems: a review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. Water Res 75: 63-82.
4. Caruso G (2015) Microplastics in marine environments: possible interactions with the microbial assemblage. J Pollut Eff Cont 3.
5. UNEP (2014) Plastic debris in the ocean. UNEP Year Book 2014 emerging issues update. Available at http://www.unep.org/yearbook/2014/PDF/UNEP_YearBook_2014.pdf
6. Sivan A (2011) New perspectives in plastic biodegradation. Curr Opin Biotechnol 22: 422-426.
7. Kim DY, Rhee YH (2003) Biodegradation of microbial and synthetic polyesters by fungi. Appl Microbiol Biotechnol 61: 300-308.
8. Shimao M (2001). Biodegradation of plastics. Curr. Opinion Biotechnol. 12: 242-247.
9. Shah AA, Hasan F, Hameed A, Ahmed S (2008) Biological degradation of plastics: a comprehensive review. Biotechnol Adv 26: 246-265.
10. Ghosh SK, Pal S, Ray S (2013) Study of microbes having potentiality for biodegradation of plastics. Environ Sci Pollut Res Int 20: 4339-4355.
11. Gilan O, Hadar Y, Sivan A (2004). Colonization, biofilm formation and biodegradation of polyethylene by a strain of Rhodococcus ruber. Appl Microbiol Biotechnol 65: 97-104.
12. Yamada-Onodera K, Mukumoto H, Katsuyaya Y, Saiganji A, Tani Y (2001) Degradation of polyethylene by a fungus Penicillus simplicissimus YK. Polym Degrad Stab 72: 323-327.
13. Hadad D, Geresh S, Sivan A (2005) Biodegradation of polyethylene by the thermophilic bacterium Brevibacillus borstelensis. J Appl Microbiol 98: 1093-1100.
14. Pometto AL, Lee B, Johnson KE (1992) Production of an extracellular polyethylene-degrading enzyme by Streptomyces sp. Appl Environ Microbiol 58: 731-733.
15. Mabrouk MM, Sabry SA (2001) Degradation of poly (3hydroxybutyrate) and its copolymer poly (3-hydroxybutyrate-co3-hydroxyvalerate) by a marine Streptomyces sp. SNG9. Microbiol Res 156: 323-335.
16. Kato N (1997) Cloning of poly (3-hydroxybutyrate) depolymerase from a marine bacterium, Alcaligenes faecalis AE122, and characterization of its gene product. Biochim Biophys Acta 1352: 113-122.
17. Oda Y, Oida N, Urakami T, Tonomura K (1997) Polycaprolactone depolymerase produced by the bacterium Alcaligenes faecalis. FEMS Microbiol Lett 152: 339-343.
18. Murphy CA, Cameron JA, Huang SJ, Vinopal RT (1996) Fusarium polycaprolactone depolymerase is cutinase. Appl Environ Microbiol 62: 456-460.
19. Tomita K, Kuroki Y, Nagai K (1999) Isolation of thermophiles degrading poly (L-lactic acid). J Biosci Bioeng 87: 752-755.
20. Nakajima-Kambe T, Shigeno-Akutsu Y, Nomura N, Onuma F, Nakahara T (1999) Microbial degradation of polyurethane, polyester polyurethanes and polyether polyurethanes. Appl Microbiol Biotechnol 51: 134-140.
21. Howard GT, Ruiz C, Hillard NP (1999) Growth of Pseudomonas chlororaphis on a polyester-polyurethane and the purification and characterization of a polyurethane-esterase enzyme. Int Biodeter Biodegrad 43: 7-12.
22. Anthony SD, Meizhong L, Christopher EB, Robin LB, David LF (2004) Involvement of linear plasmids in aerobic biodegradation of vinyl chloride. Appl Environ Microbiol 70: 6092-6097.
23. Mor R, Sivan A (2008) Biofilm formation and partial biodegradation of polystyrene by the actinomycete Rhodococcus ruber. Biodegradation 19: 851-858.
24. Singh B, Sharma N (2008) Mechanistic implications in plastic degradation. Polym Degrad Stab 93: 564-581.