Int.J.Curr.Res.Aca.Rev.2020; 8(8): 38-47

International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 8 Number 8 (August-2020)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2020.808.006

Review on Biodegradation of Organic Compounds and Plastics

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Abstract

Biodegradation is defined as the biologically catalyzed reduction in complexity of chemical compounds. Indeed, biodegradation is the process by which organic substances are broken down into smaller compounds by living microbial organisms. The main aim of this review is to show how much microbial communities are important in waste removal biotechnologies. In this review recently published articles about biodegrading microbes were accessed and reviewed following necessary acknowledgement. When biodegradation is complete, the process is called "mineralization". However, in most cases the term biodegradation is generally used to describe almost any biologically mediated change in a substrate. So, understanding the process of biodegradation requires an understanding of the microorganisms that make the process work. The microbial organisms transform the substance through metabolic or enzymatic processes. It is based on two processes: growth and cometabolism. In growth, an organic pollutant is used as sole source of carbon and energy. This process results in a complete degradation (mineralization) of organic pollutants. Cometabolism is defined as the metabolism of an organic compound in the presence of a growth substrate that is used as the primary carbon and energy source. Several microorganisms, including fungi, bacteria and yeasts are involved in biodegradation process. Algae and protozoa reports are scanty regarding their involvement in biodegradation. Biodegradation processes vary greatly, but frequently the final product of the degradation is carbon dioxide. Organic material can be degraded aerobically, with oxygen, or anaerobically, without oxygen. Generally microorganisms with biodegrading ability are a promising phenomenon in waste removal technologies without harming life and wasting resources.

Article Info

Accepted: 08 July 2020
Available Online: 20 August 2020

Keywords

Organic compound, Chemical, Degradation, Aerobic, Anaerobic, Plastic.

Introduction

Microbial degradation is the major and ultimate natural mechanism by which one can clean up the petroleum hydrocarbon pollutants from the environment. The recognition of biodegraded petroleum-derived aromatic hydrocarbons in marine sediments was reported by Jones et al. They studied the extensive biodegradation of alkyl aromatics in marine sediments which occurred prior to detectable biodegradation of n-alkane profile of the crude oil and the microorganisms, namely, *Arthrobacter, Burkholderia, Mycobacterium, Pseudomonas, Sphingomonas, and Rhodococcus* were found to be involved for alkylaromatic degradation. Microbial degradation of petroleum hydrocarbons in a polluted tropical stream in Lagos, Nigeria was reported by

Adebusoye et al. Nine bacterial strains, namely, *Pseudomonas fluorescens, P. aeruginosa, Bacillus subtilis, Bacillus sp., Alcaligenes sp., Acinetobacter lwoffi, Flavobacterium sp., Micrococcus roseus, and Corynebacterium sp.* were isolated from the polluted stream which could degrade crude oil (Das and Chandran, 2011).

Plastics are polymers derived from petrochemicals which are further synthetically made from monomers by some chemical processes to produce these long chain polymers. Plastics are light weight, low cost, highly durable and are of high strength. In our daily life the plastics are available in various forms such as nylon, polycarbonate, polyethylene-terephthalate, polyvinylidene chloride, Urea formaldehyde, polyamides, polyethylene, polypropylene, polystyrene, polytetraflouro ethylene, polyurethane and polyvinyl chloride *et al.,* 2009). Widespread studies on the biodegradation of plastics have been carried out in order to overcome the environmental problems associated with synthetic plastic waste. Recent work has included studies of the distribution of synthetic polymer-degrading microorganisms in the environment, the isolation of new microorganisms for biodegradation, the discovery of new degradation enzymes, and the cloning of genes for synthetic polymer-degrading enzymes. Strains *Rhodococcus rhodochrous* ATCC 2967214 and *R. rhodochrous* NCIMP 13259 are capable of growing on styrene as a sole carbon and energy source while *R. rhodochrous* stains CTM use 2-methylaniline as sole carbon and energy source. 15 Steroids are also degraded by some strains of *R. Rhodochrous*. The microorganism’s role is very important for plastic degradation. The different types of microbes degrade different groups of plastics. The microbial biodegradation has been at accepted and process still underway for its enhanced efficiency (Shimao, 2001).

What is biodegradation?

Biodegradation is the general term used to describe the biological conversion of organic contaminants to products that are generally lower in free energy. This term is often used loosely and interpreted in various ways (Han and Gu, 2010).

The term biodegradable plastics normally refer to an attack by microorganisms on nonwater-soluble polymer-based materials (plastics). This implies that the biodegradation of plastics is usually a heterogeneous process. Because of a lack of water-solubility and the size of the polymer molecules, microorganisms are unable to transport the polymeric material directly into the cells where most biochemical processes take place; rather, they must first excrete extracellular enzymes which depolymerize the polymers outside the cells. Biodegradation is defined as the biologically catalyzed reduction in complexity of chemical compounds(Alexander, 1994).Indeed, biodegradation is the process by which organic substances are broken down into smaller compounds by living microbial organisms (Marinescu and Dumitru, 2009). When biodegradation is complete, the process is called "mineralization". However, in most cases the term biodegradation is generally used to describe almost any biologically mediated change in a substrate (Bennet and Wunch, 2002).

So, understanding the process of biodegradation requires an understanding of the microorganisms that make the process work. The microbial organisms transform the substance through metabolic or enzymatic processes. It is based on two processes: growth and cometabolism.In growth, an organic pollutant is used as sole source of carbon and energy. This process results in a complete degradation (mineralization) of organic pollutants. Cometabolism is defined as the metabolism of an organic compound in the presence of a growth substrate that is used as the primary carbon and energy source (Fritsche, 2008). Several microorganisms, including fungi, bacteria and yeasts are involved in biodegradation process. Algae and protozoa reports are scanty regarding their involvement in biodegradation (Nilanjana Das, 2011). Biodegradation processes vary greatly, but frequently the final product of the degradation is carbon dioxide (Pramila *et al.,* 2012). Organic material can be degraded aerobically, with oxygen, or anaerobically, without oxygen (Fritsche, 2008; Mrozik *et al.,* 2003).

Biodegradation is the chemical dissolution of materials by bacteria or by other biological means. Recently biodegradable plastics are of great interest (Gnanavel *et al.,* 2015). Biodegradation takes place by the action of enzymes, chemical degradation with living organisms. This takes place in two steps. The first step is the fragmentation of the polymers into lower molecular mass species by means of abiotic reactions, like oxidation, photodegradation or hydrolysis, or biotic reactions, like degradations by microorganisms. This step is followed by the bioassimilation of polymer fragments by the microorganisms and their mineralisation. Biodegradability depends not only on the origin of the polymer, also on its chemical structure and the environmental degrading conditions. The factors, on which the mechanical nature of biodegradable materials depends on, are their chemical composition, production, storage and processing characteristics, their ageing and the application conditions (Isabelle Vroman, 2009). Degradable plastic is the one in which the degradation results from the action of naturally occurring microorganisms such as bacteria, fungi, and algae.

Significance of biodegradation

One of the major environmental problems today is hydrocarbon contamination resulting from the activities related to the petrochemical industry. Accidental releases of petroleum products are of particular concern in the environment. Hydrocarbon components have been known to belong to the family of carcinogens and neurotoxic organic pollutants. Currently accepted disposal methods of incineration or burial insecure landfills can become prohibitively expensive when amounts of contaminants are large. Mechanical and chemical methods generally used to remove hydrocarbons from contaminated sites have limited effectiveness and can be expensive. Bioremediation is the promising technology for the treatment of these contaminated sites since it is cost-effective and will lead to complete mineralization. Bioremediation functions basically on biodegradation, which may refer to complete mineralization of organic contaminants into carbon dioxide, water, inorganic compounds, and cell protein or transformation of complex organic contaminants to other simpler organic compounds by biological agents like microorganisms. Many indigenous microorganisms in water and soil are capable of degrading hydrocarbon contaminants (Nilanjana Das, 2011).

Biodegradation of organic compounds

Brief description on biodegradation of organic compounds

Petroleum hydrocarbons in crude oils, such as those released into marine ecosystems by the Exxon Valdez and BP Deepwater Horizon spills, are natural products derived from aquatic algae laid down between 180 and 85 million years ago.

Crude oils, composed mostly of diverse aliphatic and aromatic hydrocarbons, regularly escape into the environment from underground reservoirs. Because petroleumhydrocarbons occur naturally in all marine environments, there has been time for numerous diverse microorganisms to evolve the capability of utilizing hydrocarbons as sources of carbon and energy for growth. Oil-degrading microorganisms are ubiquitous, but may only be a small proportion of the prespill microbial community (Ronald M. Atlas, 2011) (Fig. 2).

There are hundreds of species of bacteria, archaea, and fungi that can degrade petroleum. Most petroleum hydrocarbons are biodegradable under aerobic conditions; though a few compounds found in crude oils, for example, resins, hopanes, polar molecules, and asphaltenes, have practically imperceptible biodegradation rates. Lighter crudes, such as the oil released from the BP Deepwater Horizon spill, contain a higher proportion of simpler lower molecular weight hydrocarbons that are more readily biodegraded than heavy crudes, such as the oil released from the Exxon Valdez. The polycyclic aromatic hydrocarbons (PAHs) are a minor constituent of crude oils; however, they are among the most toxic to plants and animals. Bacteria can convert PAHs completely to biomass, CO_2, and H_2O, but they usually require the initial insertion of O_2 via dioxygenase enzymes (Ronald M. Atlas, 2011).

Anaerobic degradation of petroleum hydrocarbons can also occur albeit at a much slower rates. Petroleum hydrocarbons can be biodegraded at temperatures below 0 ^{o}C to more than 80 ^{o}C. Microorganisms require elements other than carbon for growth. The concentrations of these elements in marine environments—primarily nitrates (NO3_), phosphates (PO43-), and iron (Fe)—can limit rates of oil biodegradation. Having an adequate supply of these rate limiting nutrients when large quantities of hydrocarbons are released into the marine environment is critical for controlling the rates of biodegradation and hence the persistence of potentially harmful environmental impacts. Bioremediation, which was used extensively in the Exxon Valdez spill, involved adding fertilizers containing nitrogen (N) nutrients to speed up the rates of oil biodegradation. Most petroleum hydrocarbons are highly insoluble in water. Hydrocarbon biodegradation takes place at the hydrocarbon_ water interface. Thus the surface area to volume ratio of the oil can significantly impact the biodegradation rate. Dispersants, such as Corexit 9500, which was used during the BP Deepwater Horizon spill, increase the available surface area and, thus, potentially increase the rates of biodegradation (Ronald M. Atlas, 2011).

Involved microorganisms in biodegradation of organic compounds

Microbial degradation is the major and ultimate natural mechanism by which one can clean up the petroleum hydrocarbon pollutants from the environment (Das and Chandran, 2011). The recognition of biodegraded petroleum-derived aromatic hydrocarbons in marine sediments was reported by scholars. They studied the extensive biodegradation of alkyl aromatics in marine sediments which occurred prior to detectable biodegradation of n-alkane profile of the crude oil and the microorganisms, namely, *Arthrobacter, Burkholderia, Mycobacterium, Pseudomonas, Sphingomonas, and Rhodococcus* were found to be involved for alkylaromatic degradation. Microbial degradation of petroleum hydrocarbons in a polluted tropical stream in Lagos, Nigeria was reported by Adebusoye *et al.,* 2007. Nine bacterial strains, namely, *Pseudomonas fluorescens, P. aeruginosa, Bacillus subtilis, Bacillus sp., Alcaligenes sp., Acinetobacter lwoffi, Flavobacterium sp., Micrococcus roseus, and Corynebacterium sp.* were isolated from the polluted stream which could degrade crude oil (Adebusoye *et al.,* 2007) (Fig. 3).

Several yeasts may utilize aromatic compounds as growth substrates, but more important is their ability to convert aromatic substances cometabolically. Some species such as the soil yeast *Trichosporon cutaneum* possess specific energy-dependent uptake systems for aromatic substrates (e.g., for phenol) (Pandey *et al.,* 2016). Furthermore, biodegradation of aliphatic hydrocarbons occurring in crude oil and petroleum products has been investigated well, especially for yeasts. The n-alkanes are the most widely and readily utilized hydrocarbons, with those between C10 and C20 being most suitable as substrates for microfungi (Rosenkranz *et al.,* 2013). However, the biodegradation of n-alkanes having chain lengths up to n-C24 has also been demonstrated. Typical representatives of alkane-utilizing yeasts include *Candida lipolytica, C. tropicalis, Rhodoturula rubra,* and *Aureobasidion* (*Trichosporon*) *pullulans*. *Rhodotorula aurantiaca* and *C. ernobii* were found able to degrade diesel oil. Yeasts are also reported for aniline biodegradation (a potential degradation product of the azo dye breakdown) it is the example of *C. methanosorbosa* BP-6. According to many authors, bacteria have been described as being more efficient hydrocarbon degraders than yeast, or at least that bacteria are more commonly used as a test microorganism. However, there is information that yeasts are better hydrocarbon degraders than bacteria (Gargouri *et al.,* 2015; Wang and Shao, 2013).

Process of organic compound biodegradation

Biodegradation, or the breakdown of chemical substances by living organisms, is one of the major processes that determine the fate of organic chemicals in the environment. Microorganisms, particularly bacteria and fungi, play a major role in biodegradation because of their abundance, species diversity, catabolic versatility, and ability to adapt to a wide variety of environmental conditions. Biodegradation can occur under both aerobic and anaerobic conditions. In the natural environment, the former occurs in soil or water where oxygen is present, whereas anaerobic degradation occurs in sediments or ground water where oxygen is generally absent. Biodegradation is important in wastewater treatment plants where both aerobic and anaerobic processes may be involved (Yu *et al.,* 2012).

Factors affect organic compounds biodegradation

A number of limiting factors have been recognized to affect the biodegradation of petroleum hydrocarbons. The composition and inherent biodegradability of the petroleum hydrocarbon pollutant is the first and foremost important consideration when the suitability of a remediation approach is to be assessed. Among physical factors, temperature plays an important role in biodegradation of hydrocarbons by directly affecting the chemistry of the pollutants as well as affecting the physiology and diversity of the microbial flora. (Anderson and Barnes, 1994) found that at low temperatures, the viscosity of the oil increased, while the volatility of the toxic low molecular weight hydrocarbons were reduced, delaying the onset of biodegradation (Das and Chandran, 2011).

Temperature also affects the solubility of hydrocarbons. Although hydrocarbon biodegradation can occur over a wide range of temperatures, the rate of biodegradation generally decreases with the decreasing temperature. Figure 1 shows that highest degradation rates that generally occur in the range 30–40◦C in soil environments, 20–30◦C in some freshwater environments and 15–20◦C in marine environments. (Venosa and Zhu, 2003) reported that ambient temperature of the environment affected both the properties of spilled oil and the activity of the microorganisms.

Significant biodegradation of hydrocarbons have been reported in psychrophilic environments in temperate regions. Nutrients are very important ingredients for successful biodegradation of hydrocarbon pollutants especially nitrogen, phosphorus, and in some cases iron. Some of these nutrients could become limiting factor thus affecting the biodegradation processes. Atlas reported that when a major oil spill occurred in marine and freshwater environments, the supply of carbon was significantly increased and the availability of nitrogen and phosphorus generally became the limiting factor for oil degradation. In marine environments, it was found to be more pronounced due to low levels of nitrogen and phosphorous in seawater (Nilanjana Das, 2011).

Freshwater wetlands are typically considered to be nutrient deficient due to heavy demands of nutrients by the plants. Therefore, additions of nutrients were necessary to enhance the biodegradation of oil pollutant. On the other hand, excessive nutrient concentrations can also inhibit the biodegradation activity. Several authors have reported the negative effects of high NPK levels on the biodegradation of hydrocarbons especially on aromatics. The effectiveness of fertilizers for the crude oil bioremediation in subarctic intertidal sediments was studied by Pelletier *et al.,* (2004 (Pelletier *et al.*, 2004). Use of poultry manure as organic fertilizer in contaminated soil was also reported, and biodegradation was found to be enhanced in the presence of poultry manure alone. (Maki *et al.*, 2006) reported that photo-oxidation increased the biodegradability of petroleum hydrocarbon by increasing its bioavailability and thus enhancing microbial activities (Maki *et al.,* 2006).

Biodegradation of plastics

Based on their chemical properties the plastics are differentiated into degradable and nondegradable polymers. Normally nonbiodegradable plastics are synthetic plastics and they have a usual repeat of small monomer with very high molecular weight. But the degradable plastics are made up of starch and they have less molecular weight (Raziyafathima *et al.*, 2015).

Brief description plastic biodegradation

Plastics are polymers derived from petrochemicals which are further synthetically made from monomers by some chemical processes to produce these long chain polymers (Shimao, 2001). Plastics are light weight, low cost, highly durable and are of high strength. In our daily life the plastics are available in various forms such as nylon, polycarbonate, polyethylene-terephthalate, polyvinylidene chloride, Urea formaldehyde, polyamides, polyethylene, polypropylene, polystyrene, polytetraflouro ethylene, polyurethane and polyvinyl chloride. Widespread studies on the biodegradation of plastics have been carried out in order to overcome the environmental problems associated with synthetic plastic waste. Recent work has included studies of the distribution of synthetic polymer-degrading microorganisms in the environment, the isolation of new microorganisms for biodegradation, the discovery of new degradation enzymes, and the cloning of genes for synthetic polymer-degrading enzymes (Shimao, 2001).

Involved microorganisms in plastic biodegradation

Strains *Rhodococcus rhodochrous* ATCC 2967214 and *R. rhodochrous* NCIMP 13259 are capable of growing on styrene as a sole carbon and energy source while *R. rhodochrous* stains CTM use 2-methylaniline as sole carbon and energy source. Steroids are also degraded by some strains of *R. rhodochrous* (Muthukumar and Veerappapillai, 2015). The microorganism's role is very important for plastic degradation. The different types of microbes degrade different groups of plastics. The microbial biodegradation has been at accepted and process still underway for its enhanced efficiency (Raziyafathima *et al.*, 2015).

Process of biodegradation

The process of biodegradation happens naturally over time. Depending on the material, the timeline to complete full degradation can vary. With plastics, this process usually takes hundreds to thousands of years to complete, if ever, because of the strong polymers that makes up its chemical structure. However, with biotec environmental, llc's organic plastic additive, ecopure, the process is significantly accelerated. Ecopure plastics complete the biodegradation process at much higher rates, which includes (Bio-Tech Environmental, 2017):

Aerobic phase

In this phase, the enzymes and decomposition chemicals act as a catalyst to the biofilm coating the plastic. During this time, aerobic microbes are becoming established and moisture is building up in the refuse. Standard plastic moisture absorption capability is relatively small, but the additive causes further swelling, weakening the polymer bonds. This creates molecular spaces for microbial growth, which begins the aerobic degradation process in which oxygen is converted to CO_2.

Anaerobic, non-methanogenic phase

After oxygen concentrations have declined sufficiently, the anaerobic processes begin. During the initial stage (hydrolysis), the microbe colonies eat the particulates, and through an enzymatic process, reduce large polymers into simpler monomers. The organic additive causes additional swelling and opening of the polymer chain and increased quorum sensing. This further excites the microbes to increase their colonization and consumption of the polymer chain. As time progresses, acidogenesis occurs where the simple monomers are converted into fatty acids. CO_2 production occurs rapidly at this stage.

Anaerobic, methanogenic unsteady phase

The microbe colonies continue to grow, eating away at the polymer chain and creating increasingly larger molecular spaces. During this phase acetogenesis occurs, converting fatty acids into acetic acid, carbon dioxide and hydrogen. As this process continues, CO_2 rates decline and hydrogen production eventually ceases.

Anaerobic, methanogenic steady phase

The final stage of decomposition involves methanogensis. As colonies of microbes continue to eat away at the remaining surface of the polymer, acetates are converted into methane and carbon dioxide, and hydrogen is consumed. The process continues until the remaining element is humus. This highly nutritional soil creates and improved environment for the microbes and enhances the final stage of decomposition.

Factors affecting biodegradation of plastics

The degradation of plastics can be said to begin as soon as the polymer is synthesised, and is increased by residual stresses left by moulding processes. This can be followed by exposure to light (especially UV), humidity, oxygen, heat, bacteria and stress. Plastics can also be contaminated by other materials, including other plastics. A polystyrene camera body, for example, can be attacked by plasticiser migrating from a PVC strap. Ideally the conservator needs information about the history of an object before prescribing treatment, but even before this, the plastics ‘doctor’ must jump another hurdle. Specific conservation action cannot be taken until the polymer has been identified, and this is a technical area full of pitfalls. A 1920s black brooch could be made of at least six different plastics materials, or simply painted as was common practice in the 19th century. Even a patent number, one of the few ‘hallmarks’ found on plastics and an obvious aid to identification, may refer to a fixing mechanism and not to the moulding.

Temperature affecting biodegradable plastic

Rates of plastic biodegradation generally decrease at lower temperatures. This is believed to be a result primarily of decrease in enzymatic activity, however, increased solubility and bioavailability of less soluble hydrophobic substances also play an important role. Higher temperatures enhance the rates of hydrocarbon metabolism with general optimum in the range of 30°C to 40°C, most Landfills operate above these temperatures. Cold-adapted, psychrophilic and psychrotrophic microorganisms (for example, *Rhodococcus* sp.) are able to grow at temperatures around 0°C. They are widely distributed in nature because a large part of the Earth’s biosphere is at temperatures below 5°C (Delille *et al.*, 2009).

Oxygen affecting biodegradable plastic

The initial steps in the catabolism of aliphatic, cyclic, and aromatic hydrocarbons by bacteria and fungi involve the oxidation of the substrate by oxygenases for which molecular oxygen is required. Conditions of oxygen limitation normally exist in aquatic sediments and soils. Oxygen depletion can occur in the presence of easily utilizable substrates that increase microbial oxygen consumption (Margesin and Schinner, 2001).

Nitrogen and phosphorus

Along with carbon, five other elements – hydrogen, nitrogen, oxygen, phosphorus, and sulfur – play a major role in life on Earth. The release of hydrocarbons into environments often produces excess of carbon over nitrogen and phosphorus which quickly become exhausted. It is well established that deprivation of nitrogen and phosphorus inhibits microbial plastic degradation in such ecosystems as estuaries, seawater and marine sediments, freshwater lakes, groundwater, and soils (Margesin and Schinner, 2001).

Salinity affecting biodegradation

Biodegradation rates of plastic in fresh and marine water are comparable and depend on tolerance/adaptation of resident oil-degrading microorganisms to the specific salinity. Because abundance of microorganisms in highly halophilic conditions is greatly reduced, so is plastic biodegradation. It was shown that rates of hydrocarbon utilization start to decrease noticeably in the salinity range 3.3 to 28.4%. Nonetheless, there are several reports about microorganisms able to oxidize petroleum hydrocarbons even in the presence of 30% w/v NaCl. Among such microorganisms are crude oil-degrading Streptomyces albiaxialis, and an n-alkane (C10-C30)-degrading member of the Halobacterium group (Margesin and Schinner, 2001).

Pressure affecting plastic biodegradation

The importance of pressure as a variable in the biodegradation of hydrocarbons is most probably confined to the deep-sea environment where temperature factor is also at play. Barophiles (piezophiles) are microorganisms that require high pressure for growth, or grow better at pressures higher than atmospheric pressure. Little is known about ability of deep-sea microorganisms to cope with hydrocarbons. In general, plastic which reaches the deep-ocean environment is degraded very slowly by resident microorganisms and some fractions persist for decades (Margesin and Schinner, 2001).

Water availability

Water availability or water activity (also water potential) ranges from 0.0 to 0.99. Hydrocarbon biodegradation in terrestrial ecosystems may be limited by the available water. Optimal rates of biodegradation in sludge are observed at 30% to 90% of water saturation. The presence of moisture (unsaturated conditions) in a landfill increases gas production because it encourages bacterial decomposition. Moisture may also promote chemical reactions that produce gases which are captured and used for heating of homes or powering businesses. A typical value of L o in most MSW landfills in the United States is about 25% on wet basis. (wt of water/wt of water + dry solids), the ASTM D5511-12 is tested with 40% solids.

pH affecting biodegradable materials

In contrast to most aquatic biosystems, soil pH can be highly variable ranging from 2.5 in mine refuse to 11.0 in alkaline deserts. Most heterotrophic bacteria and fungi favor a near neutral pH, with fungi being more tolerant to acidic conditions.

Figure.1 Steps in Biodegradation(Claire Dussud, 2015)

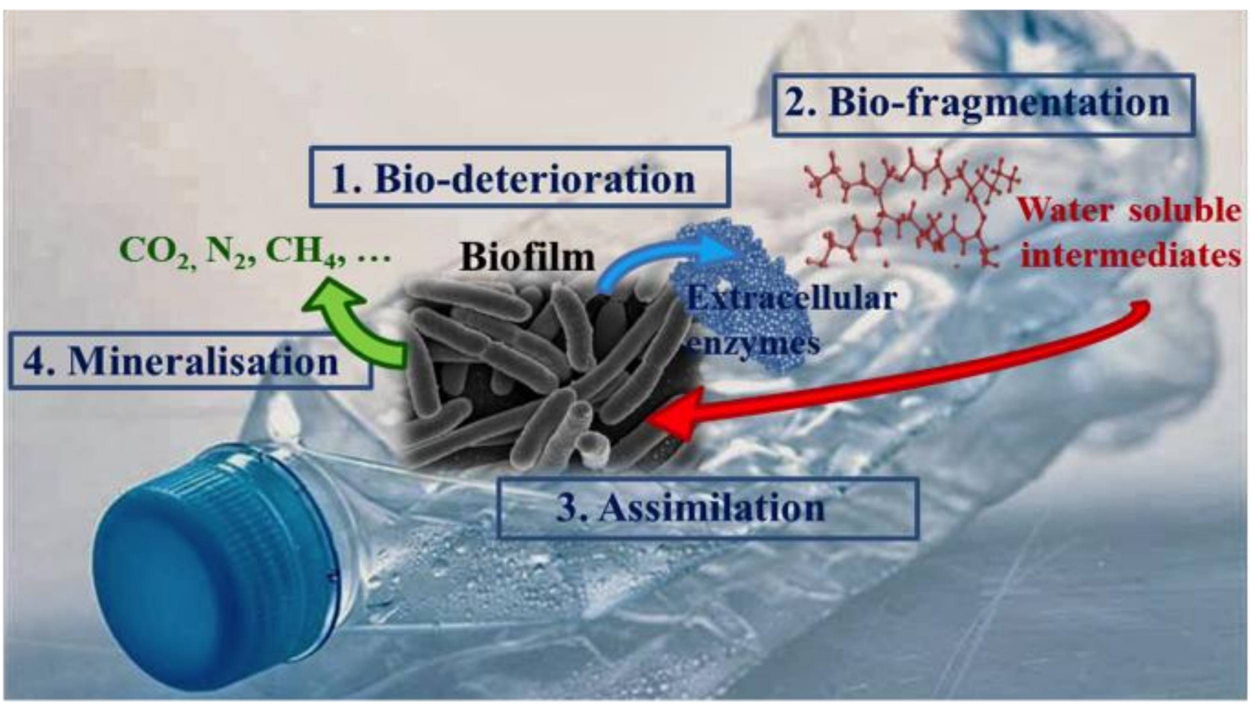


Figure.2 Oil Degrading Bacteria (Ronald M. Atlas, 2011)

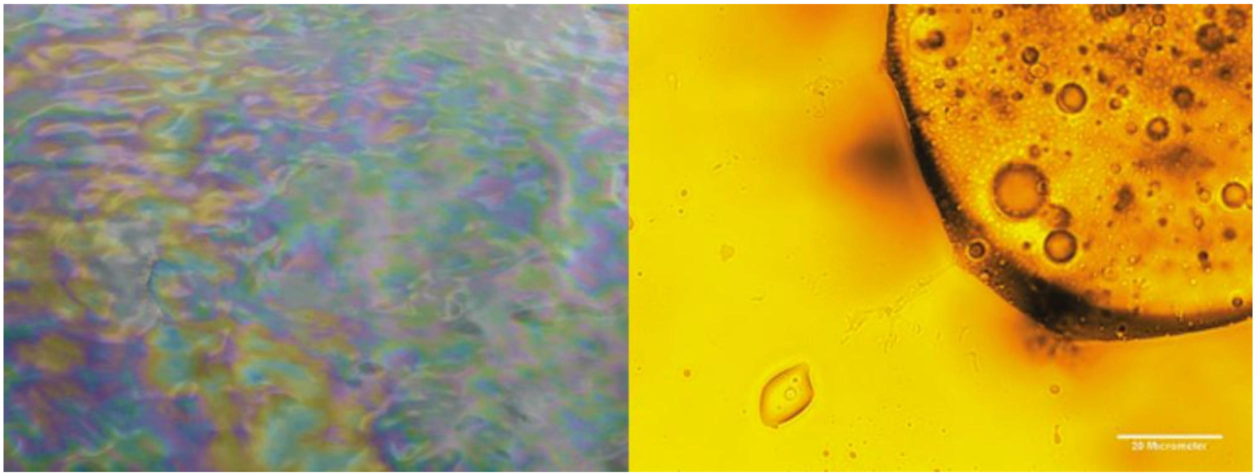
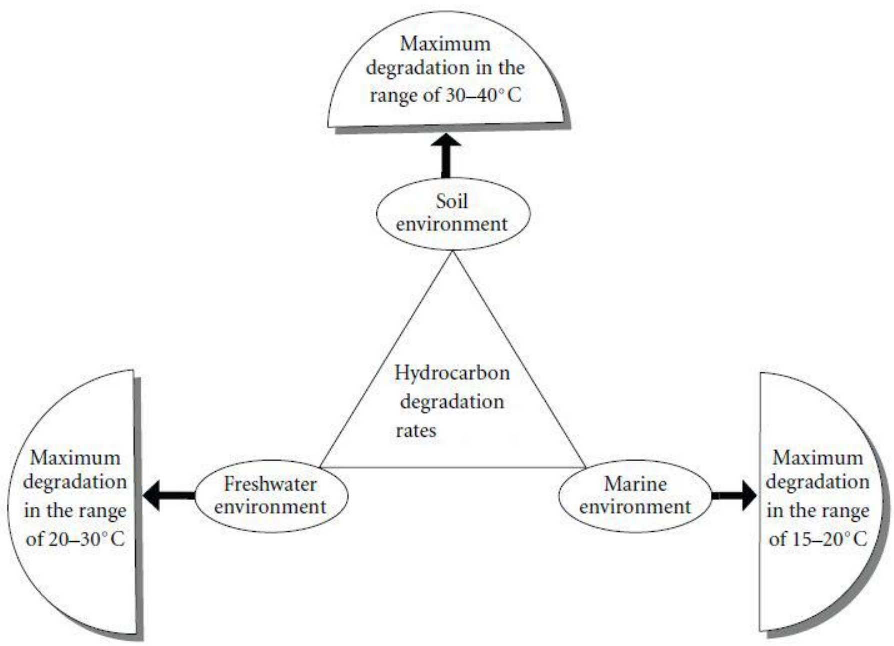


Figure.3 Hydrocarbon degradation rates in soil, fresh water, and marine environments (Das and Chandran, 2011)



Biotic factors affecting biodegradation of plastic

Hydrocarbons in the environment are biodegraded primarily by bacteria and fungi. Algae and protozoa are important members of the microbial community in both aquatic and terrestrial ecosystems, but the extent of their involvement in hydrocarbon biodegradation is largely unknown and most likely is minor.

There are three mechanisms for adaptation of microbial communities to chemical contaminants: (1) induction and depression of enzymes, (2) genetic changes (mutations, horizontal gene transfer), and (3) selective enrichment (Margesin and Schinner, 2001).

It is conclusion, in this article "Review on Biodegradation of Organic Compounds and Plastics" diversity of microorganisms with biodegrading ability was reviewed in detail with respect to type microbes substance that degraded by those species of microorganisms. Using biodegradation to remove waste is the most promising and environmentally friend. Therefore, the science community should give concerns to this science to solve the current World headache specially which related with industrial toxic wastes.

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How to cite this article:

Chala Dandessa and Abiru Neme. 2020. Review on Biodegradation of Organic Compounds and Plastics. *Int.J.Curr.Res.Aca.Rev*. 8(8), 38-47. doi: https://doi.org/10.20546/ijcrar.2020.808.006