ROLE OF FUNGI IN BIODEGRADATION OF XENOBIOTIC COMPOUNDS IN THE ENVIRONMENT

SUBHASH CHANDRA

P.G. Department of Botany, Sri Murli Manohar Town P G College Ballia (U. P.), India
Email: subhashcbsi1@gmail.com

ABSTRACT

The term biodegradation means transformation of a chemical compound from highly complicated form (organic) to simple (inorganic) form through biological process. If we say a compound is biodegradable, it means that it can be converted into various inorganic forms or can be mineralized i. e., possible to convert into carbon dioxide and water. Several species of fungi like Trichosporon cutaneum, Candida lipolytica, Candida tropicalis, Candida parapsilosis, Candida ernobii Candida boidinii Rhodotorula rubra, Aureobasidion (Trichosporon) pullulans. Rhodotorula aurantiaca, Saccharomyces cerevisiae Rhodotorula pilimanae, Yarrowiali polytica, Hansenula polymorpha Cladosporium, Aspergillus ustus, Aspergillus sydowii and Aspergillus destruens, whereas fungi belonging to Cunninghamella, Penicillium, Fusarium Cephalosporium Alternaria alternate, Mucor racemosus, Phoma glomerata, Trichoderma longibrachiatum and Trichoderma hamatum play a major role in the process of biodegradation of xenobiotic compounds in the environment.

Key-words: Fungi, xenobiotic compounds, biodegradation, environment

INTRODUCTION

Biodegradation is the process by which organic substances are broken down into simple compounds by living microorganisms (Marinescu, *et al.*, 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, *et al.*, 2002). The microbial organisms transform the substance through metabolic or enzymatic processes (Bhandari, et al., 2021). It is based on two process-growth and co metabolism. In growth, an organic pollutant is used as sole source of carbon and energy. This process results in a complete degradation 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 and Hofrichter, 2008). Several microorganisms like aerobic as well as anaerobic bacteria, algae and fungi are involved in biodegradation process (Das and Chandran, 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 (Mrozik, *et al.*, 2003; Fritsche and Hofrichter, 2008). The term biodegradation is often used in relation to ecology, waste management and mostly associated with environmental remediation. In the present review paper, the xenobiotic compounds are discussed and their biodegradation process in the environment are reviewed and summarized.

Type of Xenobiotic Compounds

The recalcitrant xenobiotic compounds can be grouped into the following types:

Halocarbons

These compounds contain different numbers of halogen (Cl, Be, F and I) atoms in the place of H atoms. They are used as solvents (Chloroform, CHCl3), as propellants in spray cans of cosmetics, paints etc., in condenser units of cooling systems (Freons, CCl3F, CCl2F2, CClF3, CF4) and as insecticides (DDT, BHC, lindane) and herbicides (2, 4-D, 2, 4, 5-T and dalapon) Brillas, et al., 2003). The C1-C2 haloalkanes like chloroform, freons etc. are volatile and escape into the atmosphere where they destroy the protective ozone (O3) layer leading to increased UV radiation. Pesticides like herbicides, fungicides and insecticides are applied to crops from where they leach into water bodies; many of them are subject to biomagnifications.

Polychlorinated Biphenyls (PCB's)

These compounds have two covalently linked benzene rings having halogens substituting for Polychlorinated biphenyls are used as plasticisers, insulator coolants in transformers and as heat exchange fluids (Taniguchi, *et al.*, 1997; Dhakal, et al., 2018). They are both biologically and chemically inert to various degrees, which increases with the number of chlorine atoms present in the molecules.

Synthetic Polymers

These compounds are produced as plastics e.g. Polyethylene, polystyrene, polyvinyl chloride etc. and nylons, which are used as garments, wrapping materials (Boehm and Farrington, 1984) etc. They are recalcitrant mainly due to their insolubility in water and molecular size.

Alkylbenzyl Sulphonates

These are surface-active detergents superior to soaps. The sulphonate group present at one end resists microbial degradation, while the other end (non-polar alkyl end) becomes recalcitrant if it is branched (Gordon, *et al.*, 2008).

Oil Mixtures

Oil is a natural product, has many components is biodegradable, the different components being degraded at different rates. Biodegradation is able to handle small oil seepages. But when large spills occur the problem of pollution becomes acute (Christensen, *et al.*, 2004; Hostettler, *et al.*, 2007). Oil is recalcitrant mainly because of its insolubility in water and due to toxicity of some of its components.

Other Xenobiotic Compounds

A number of pesticides are based on aliphatic, cyclic ring structures containing substitution of nitro-sulphonate, methoxy, amino and carbamyl groups; in addition, they also contain halogens. These substitutions make them recalcitrant.

Hazard of **Xenobiotic Compounds**

The xenobiotics present a number of potential hazards to human and the environment. These are following:

1. Many xenobiotics like halogenated and aromatic hydrocarbons are toxic to bacteria, lower eukaryotes and even humans. At low concentrations they may cause various skin problems and reduce reproductive potential.
2. Certain halogenated hydrocarbons have been shown to be carcinogenic.
3. Many xenobiotics are recalcitrant and persist in the environment so that there is a build up in their concentration with timer.
4. Many xenobiotics including DDT and PCB'^s^ are recalcitrant and lipophilic; as a consequence they show bioaccumulation or biomagnifications often by a factor of 10^{4-}-10^{6} (Biomagnifications occurs mainly because of the following reasons:
   (i) These compounds are continuously taken up from the environment and accumulation of DDT by phyto and zoo planktons from water.
   (ii) Such organisms are consumed by other organisms in a sequential manner constituting the food chain e.g. Planktons→Small fishes→Large fishes→Sea-eagles, the concentration of xenobiotics builds up as we move up in the food

chain (Iovdijova and Bencko, 2010; Godheja, *et al.,* 2016; Sall, *et al.*, 2022). In case of DDT a 10^5 fold increase occurs in Sea-eagles as compared to the concentration present in the aqueous environment as a result of which Sea-eagles laid fragile eggs. DDT and PCB'^s have been found in human tissues in high but sub lethal concentrations in those countries where they have been used, although humans were often not in direct contact with these chemicals (Cox and Surgan, 2006).

Degradation of Xenobiotic Compounds by Fungi

Fungi are an important part of degrading microbiota because, like bacteria, they metabolize dissolved organic matter; they are principal organisms responsible for the decomposition of carbon in the biosphere (Harms, *et al.*, 2017). But, fungi, unlike bacteria, can grow in low moisture areas and in low pH solutions, which aids them in the breakdown of organic matter (Spellman, 2008). Equipped with extracellular multienzyme complexes, fungi are most efficient, especially in breaking down the natural polymeric compounds. By means of their hyphal systems they are also able to colonize and penetrate substrates rapidly and to transport and redistribute nutrients within their mycelium (Matavuly and Molitoris, 2009). Several yeasts may utilize aromatic compounds as growth substrates, but more important is their ability to convert aromatic substances co metabolically. Some species such as the soil yeast *Trichosporon cutaneum* possess specific energy-dependent uptake systems for aromatic substances (e.g. phenol) (Mörtberg and Neujahr, 1985; Benmessaoud, *et al.*, 2022).

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 (Bartha, 1986). However, the biodegradation of n-alkanes having chain lengths upto n-C24 has also been demonstrated (Fritsche and Hofrichter, 2005). Typical representatives of alkane, utilizing yeasts include *Candida lipolytica*, *Candida tropicalis, Rhodotorula rubra* and *Aureobasidion* (*Trichosporon*) *pullulans*. *Rhodotorula aurantiaca* and *Candida ernobii* were found able to degrade diesel oil (De Ca`ssia Miranda, *et al.*, 2007). Yeasts are also reported for aniline biodegradation (Mucha, *et al.*, 2010). In addition to aromatic and aliphatic hydrocarbons compounds, fungi may transform numerous of other aromatic organopollutants co metabolically, including polycyclic aromatic hydrocarbons (PAHs) and biphenyls, dibenzofurans, nitroaromatics, various pesticides and plasticizers (Fritsche and Hofrichter, 2000; Atagana, 2009; Godoy, *et al.*, 2016; Zhang, *et al.*, 2017;

Wolf, *et al.*, 2020; Correa, *et al.*, 2021). There have also been studies of PCB metabolism by yeasts *Candida boidinii* and *Candida lipolytica* (Sasek, *et al.*, 1993) and *Saccharomyces cerevisiae* (Eaton, 1985; Benmessaoud, *et al.*, 2022). Insecticides and fungicides can also be adsorbed by *Saccharomyces cerevisiae* during aerobic fermentation (Cabras, *et al.*, 1988; Spina, *et al.*, 2018).

Yeasts are known for playing an important role in the removal of toxic heavy metals. There are many reports on biosorption of heavy metals by yeasts (Sharaf and Alharbi, 2013). Several investigations demonstrated that yeasts are capable of accumulating heavy metals such as Cu (II), Ni (II), Co (II) and Cd (II) and are superior metal accumulators compared to certain bacteria (Wang and Chen, 2006; Atagana, 2009; Gururajan and Belur, 2018). Several yeast strains like *Saccharomyces cerevisiae*, *Rhodotorula pilimanae, Yarrowiali polytica, and Hansenula polymorpha* have been reported to reduce Cr (III) (Ksheminska, *et al.*, 2006). Most studies have reported the efficiency of immobilized cells of yeasts in metals removal.

The majority of filamentous fungi are unable to totally mineralize aromatic hydrocarbons; they only transform them into indirect products of decreased toxicity and increased susceptibility to decomposition with the use of bacteria suggesting that the interaction among fungi and bacteria is profitable for the process of petroleum hydrocarbon mineralization. Among the filamentous fungi participating in aliphatic hydrocarbon are *Cladosporium* and *Aspergillus*, whereas fungi belonging to *Cunninghamella*, *Penicillium*, *Fusarium* and *Aspergillus* can take part in aromatic hydrocarbon decomposition (Steliga, 2012). Fungal genera, like *Amorphoteca*, *Neosartorya* and *Talaromyces* were isolated from petroleum contaminated soil and proved to be the potential organisms for hydrocarbon degradation (Chaillan and Bury, 2004). A group of fungi like *Aspergillus*, *Cephalosporium* and *Penicillium* was also found to be potential degrader of crude oil hydrocarbons (Singh, 2006). Fungal potentiality in PCBs degradation has been rarely explored. Several studies revealed that filamentous fungi can degrade PCBs. Among the filamentous fungi, the ligninolytic ones have been specifically investigated because of their extracellular, a specific oxido-reductive enzymes that have been already successfully exploited in the degradation of many aromatic pollutants. Fungi are known to tolerate and detoxify metals by several mechanisms including valence transformation, extra and intracellular precipitation and active uptake (Gadd, 1993; 2016). The most widely researched fungi in regard to dye degradation are the ligninolytic fungi (Bumpus, 2004). Nine strains of filamentous fungi were isolated by Abrusia, et, al., (2007) from cinematographic film consisted of three species of *Aspergillus* i.e. *Aspergillus* *ustus*, *Aspergillus nidulans*, *Aspergillus versicolor* as well as *Penicillium chrysogenum*, *Cladosporium* cladosporioides, *Alternaria alternate*, *Mucor racemosus*, *Phoma glomerata* and *Trichoderma longibrachiatum* were able to biodegrade the gelatine emulsion with different rates of metabolic carbon dioxide production.

Conclusion

In conclusion, xenobiotics include many compounds that are involved in both industrial and agricultural activities. Synthetic organic pesticides are a class of xenobiotics that are commonly used in agriculture and are added to the soil in large amount each year. Chemicals with pesticide activity were designed primarily to control insect, weed, fungi and nematode pests like DDT, BHC, 2, 4-D, 2, 4, 5-T, dalapon and carbomyl. The environmental conditions such as water content, salinity, pH and temperature must be suitable for the degrading microorganisms to proliferate and the enzyme to operate. If the xenobiotic compounds are toxic and the rate of biodegradation is very slow, adverse impact on humans, animals, fishes, birds and on ecological health are possible. It is describable to maintain xenobiotic concentrations in the environment at as low a level as possible. Because of these concerns, considerable research effort has been spent in trying to understand the metabolic degradation pathways of xenobiotic compounds in the environment. Several species of fungi play a major role for degradation of xenobiotic compounds in the environment. So, fungal activities are very important for the renewal of our environment and maintenance of the global carbon cycle.

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