A study on the toxicity analysis and biodegradation of bisphenol A with the help of bacterial and fungal species

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ABSTRACT

Discarding of plastic is one of the acute predicaments confronted in the environment today, cause majority of plastics are resistant to bio degradation. In biosphere, some microorganisms are available which got the potential to atrophy large variety types of plastic under suitable conditions, but due to the intricate composition of these polymers along with their hydrophobic nature, biological decomposition is a time consuming process. This problem can be mitigated by the inception of polymers and its derivatives from biological origins or by the production of large number of plastic degrading microbes. Some microbial stains mainly bacteria which got the ability to produce and store biopolymers under a defined environmental conditions and utilizing these as carbon sources and produces biomaterials like polyhydroxyalkanoates (PHA) or biological polyester. Thus they are innocuous by not producing toxic by-products and can be degraded easily by microorganisms. In this study, we have discussed the toxicity of Bisphenol A, a potent compound of plastic and also its biodegradation pathways.

Keywords: biodegradation, synthetic plastic, natural plastic, PHA, biological polyesters, biodegradability tests, environmental conditions

INTRODUCTION

Since the origination of Bakelite, the popularity of plastic and its derivatives skyrocketed because of cost effectiveness and extremely malleability of that material.. However, plastic is causing a tremendous mutilation to the biosphere through various pathways and has got the potential to choke both abiotic and biotic systems. The effective remediation treatments by both government and private organisations are too exorbitant to run for a long time. However recent study on microbes have shown that majority of them posses a variety of enzyme which can catabolise the plastic to a simpler by products which are either biodegraded or they remain harmless inactive substances for the rest of their life. The fabrication large amount of synthetic polymer is possible with the help of advance sophisticated technologies mainly in the past decades. The chains of monomers are linked together by chemical bonds which then grow to a certain mark forming polymers. There are polymers that are naturally present in the environment like lignin, starch, chitin, etc. In modern world, synthetic polymers are used in various enterprises mainly in the utilization of packaging which alone covers 30% of plastic use throughout the world (Shah et al. 2008b; Dey et al. 2012; Kumar et al. 2011). In the nineteenth and twentieth century's, a breakthrough happened when synthetic plastics are used in the packaging industries which resulted a change in approaches to shifting with the advent of polyethylene carrying bags (Nerlandet al. 2014). Despite the popularity of synthetic polymers, they are facing a backlash owing to their resistance to different waste disposal processes and to their ability to choke the drainage system, mainly storm water drains (Song et al. 2009; Dey et al. 2012). Contamination of natural resources like water and soil is a major snag resulted from unauthorised and improper disposal of plastics (Bhatnagar and Kumari 2013; Ojo 2007; Arutchelviet al. 2008). By1990s, it was perceived that the total amount of plastic waste have tripled and is constantly in rise mainly in the marine ecosystem (Moore 2008). From 1990 to 1995 , Bird Island area of South Georgia saw the level of debris materials to be increasing markedly; twofold increase of plastic amount was seen in the

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coastal belts of the British Isles by a during 1994–1998 (Walker et al. 1997; Barnes 2002). It was estimated in Japan saw ten-fold increase of plastics between 1970 and 1980 (Moore 2008). The total demand for plastic increased from 107 million tons in 1993 to 146 million tons in 2000. The main contributors to these increase plastic problem are UK, China and India with a contribution of 1 million tons, 4.5 million tons and 16 million tons, respectively (Kumar et al. 2011). Presently, plastic has become a reliable substitute for traditionally used metal, leather and wood materials in the recent years because of their toughness, flexibility and physical properties (Sivan 2011; Singh and Sharma 2008). Plastic waste recycling till now has been largely a futile attempt because reports say that of over 1 trillion plastic bags that are dumped annually in the US, only 5% are recycled. In this situation it is seen that the bioremediation process is an effective way to mitigate plastic pollution (Shah et al. 2008b; Ojo 2007; Ali et al. 2014).

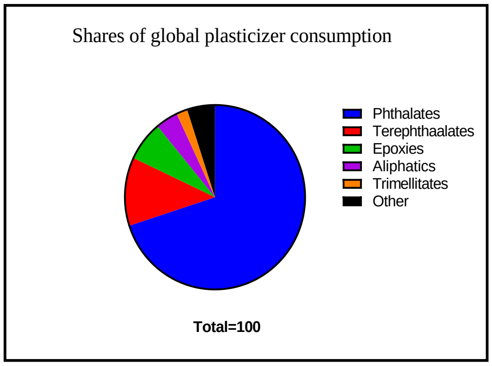


Fig 1: Shares of Global plasticizer consumption

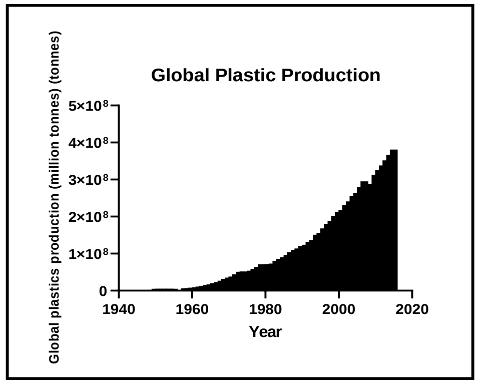


Fig 2: Global Plastic consumption per year

One of the major issue for the plastic decomposition is the resistance to biodegrading and even chemical degradation proves ineffective sometimes because of the excretion of toxic waste products and thermal degradation is also pathetic cause of the emission of dioxins and furans which are potential carcinogenic.

Toxicity Analysis of Bisphenol A

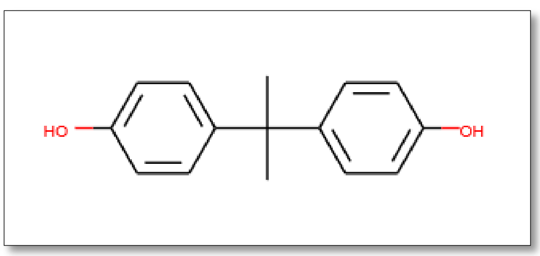


Fig 3: Chemical Structure of Bisphenol A

Bisphenol A is a potent toxic and carcinogenic compound known to cause a variety of effects on different signalling pathways by effecting the receptors.BPA is a binding agent to both the nuclearestrogen receptors (ERs), ERα and ERβ with a confidence of 1 in the endocrine system.(Wikipedia, n.d.). It is nearly 1000 to 2000 fold less dynamic than estradiol. BPA can mimic the activity of estrogen and antagonize estrogen thus showing that it is a selective estrogen receptor modulator (SERM). At increasing temperature, BPA binds and initiates an antagonistic action of the androgenic receptor.. It is also known to be an antagonist to the liver and immune system by affecting the antioxidant response element signalling pathway and the retinoid-related orphan receptor gamma signalling pathway respectively with a factor of .99

for both the cases. Mutagenicity study on bone marrow cells in mouse had showed that Bisohenol A when ingested orally can cause structural changes to the gene for a dose of 10mg/kg.

However a contradictory result was found in silico MouseTox prediction on NIH/3T3 cells showed low and unpredictive effect.(Fig. 4)

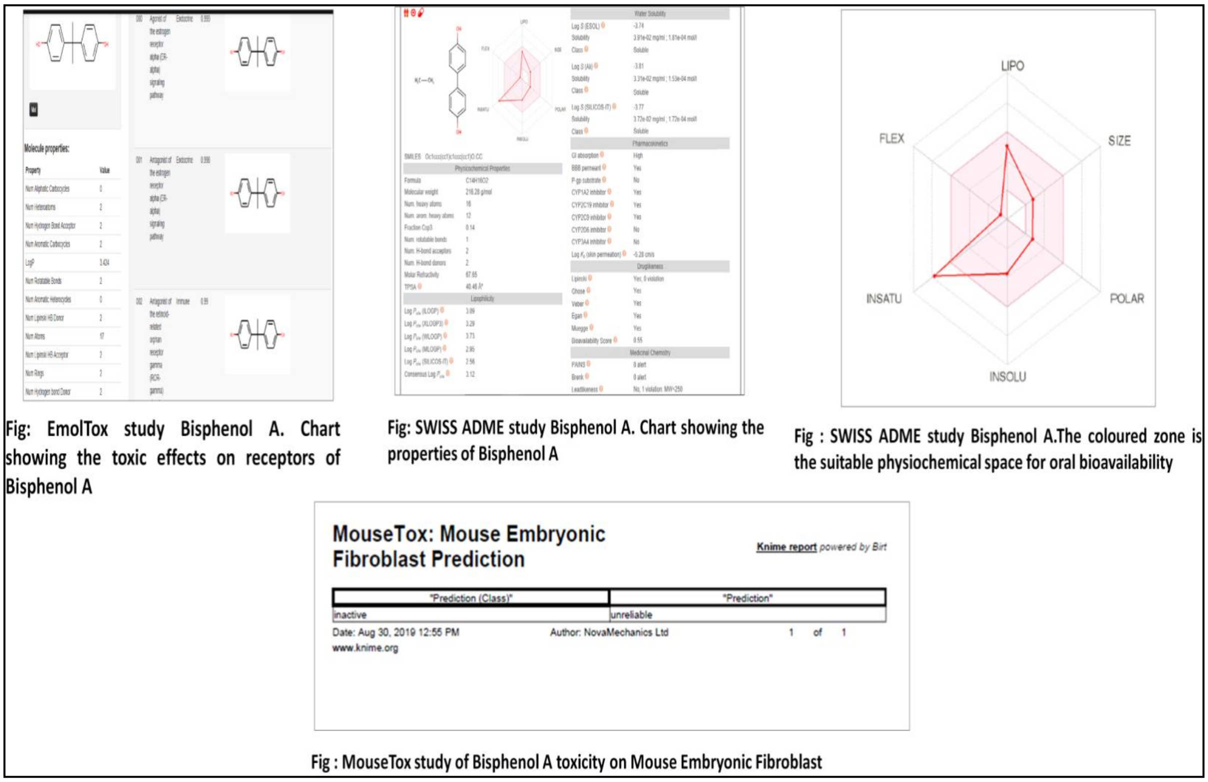


Fig: EmolTox study Bisphenol A. Chart showing the toxic effects on receptors of Bisphenol A

Fig: SWISS ADME study Bisphenol A. Chart showing the properties of Bisphenol A

Fig : SWISS ADME study Bisphenol A.The coloured zone is the suitable physiochemical space for oral bioavailability

Fig : MouseTox study of Bisphenol A toxicity on Mouse Embryonic Fibroblast

Fig 4: Different Toxic Database and Modelling software results showing the toxic effects of Bisphenol A

SWISS ADME analysis revealed that Bisphenol can highly penetrate gastrointestinal tract and can inhibit Cytochrome P450(Fig.4)(Fig.5)(Fig.6)

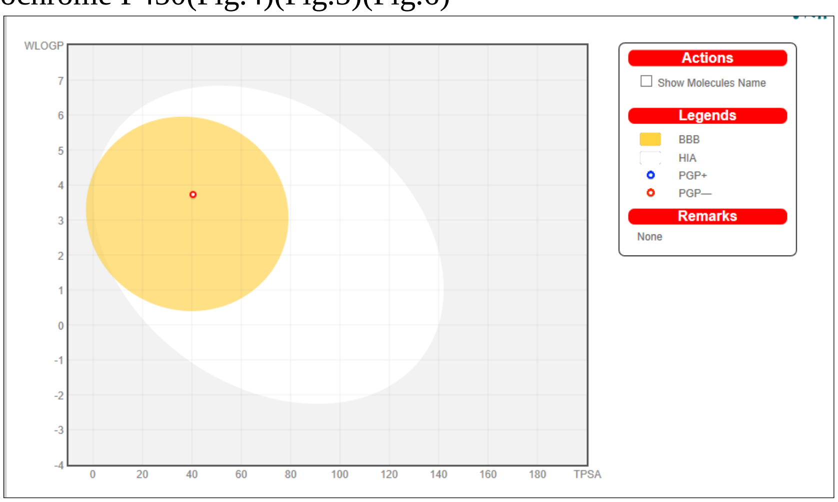
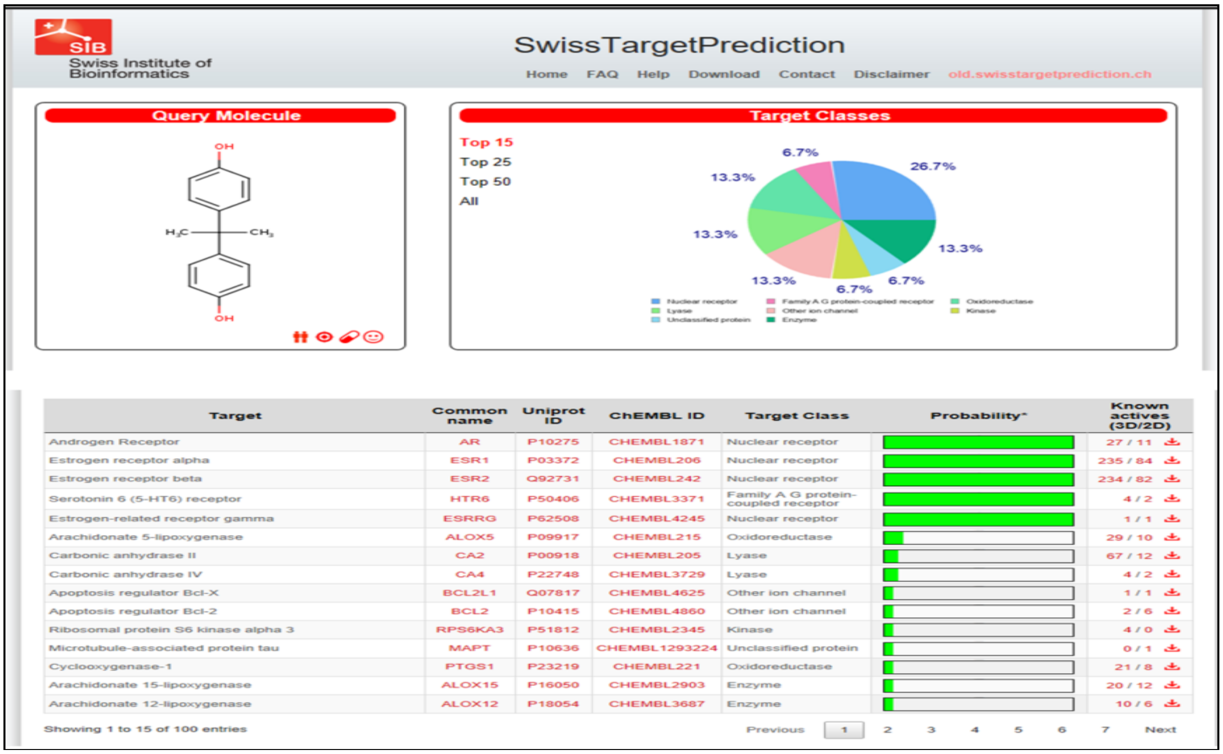


Fig 5: SWISS ADME study Bisphenol A. Boiled egg model



Target	Common name	Uniprot ID	ChEMBL ID	Target Class	Probability*	Known actives (3D/2D)
Androgen Receptor	AR	P10275	CHEMBL1871	Nuclear receptor		27 / 11
Estrogen receptor alpha	ESR1	P03372	CHEMBL206	Nuclear receptor		235 / 84
Estrogen receptor beta	ESR2	Q92731	CHEMBL242	Nuclear receptor		234 / 82
Serotonin 6 (5-HT6) receptor	HTR6	P50406	CHEMBL3371	Family A G protein-coupled receptor		4 / 2
Estrogen-related receptor gamma	ESRRG	P62508	CHEMBL4245	Nuclear receptor		1 / 1
Arachidonate 5-lipoxygenase	ALOX5	P09917	CHEMBL215	Oxidoreductase		29 / 10
Carbonic anhydrase II	CA2	P00918	CHEMBL205	Lyase		67 / 12
Carbonic anhydrase IV	CA4	P22748	CHEMBL3729	Lyase		4 / 2
Apoptosis regulator Bcl-X	BCL2L1	Q07817	CHEMBL4625	Other ion channel		1 / 1
Apoptosis regulator Bcl-2	BCL2	P10415	CHEMBL4860	Other ion channel		2 / 6
Ribosomal protein S6 kinase alpha 3	RPS6KA3	P51812	CHEMBL2345	Kinase		4 / 0
Microtubule-associated protein tau	MAPT	P10636	CHEMBL1293224	Unclassified protein		0 / 1
Cyclooxygenase-1	PTGS1	P23219	CHEMBL221	Oxidoreductase		21 / 8
Arachidonate 15-lipoxygenase	ALOX15	P16050	CHEMBL2903	Enzyme		20 / 12
Arachidonate 12-lipoxygenase	ALOX12	P18054	CHEMBL3687	Enzyme		10 / 6

Fig 6: SWISS ADME study Bisphenol A. Target prediction

Degradation of Bisphenol A

Series of molecules were discovered with the ability to degrade bisphenol. In one such mention, biodegration was done with the help of a Strain BP-7 of *Sphingomonassp* and BP-11R of *Spingomonasyanoikuyae* with the utilization of activated carbon(AC). It is found that the bacteria species are breaking down Bisphenol A without forming the by-product 4-hydroxyacetophenone (Yamanakaet al., 2008).In river water system, presence of numerous bacterial species were found which can lower the spiked Bisphenol A level in river water at aerobic condition .Half- life for Bisphenol A was degraded within 2 to 3 days and it was almost below the perceive level (<0.005 mg / L) on the 10^{th} day. The rate for Bisphenol A degradation usually ranges from 18 to 91% with the most efficient ones detected as *Pseudomonas putida strain.* (Kang et al., 2004).Bacteria isolated from the effluent of thermal paper industry *Pseudomonas aeruginosa* can grow on bisphenol A , which it utilizes as a carbon source(Vijayalaskmi et al., 2003).The procedure for extraction and analysis is discussed below(Fig 7)

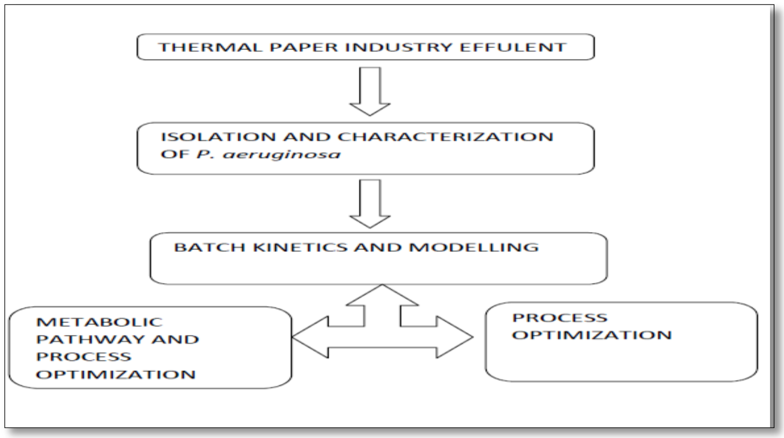


Fig 7: Isolation of *P. aeroginosa* from thermal paper industry.

Bisphenol A can also be efficiently degraded with the help of fungal species. Numerous fungal laccases are used as biocatalyst for its degradation. Tartaric acid and pyroglutamic acid were detected as by-products from the degradation reaction when BPA is treated with *Coriolopsisgallica* lacase in the availability of mediator 1-hydroxybenzotriazole and in absence of it, β-hydroxybutaric acid is formed.(Daassiet al., 2017) (Fig. 8)

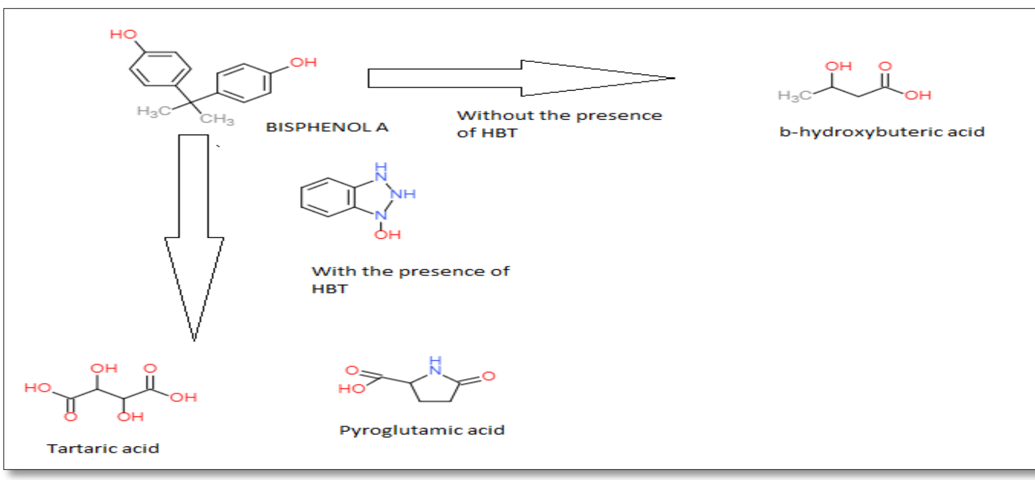


Fig 8: Degradation of Bisphenol A with the help of fungal laccases

CONCLUSION:

Bisphenol A is a potent toxic agent and its toxicity study is still largely untraced. However with the advent of new discovery of Bacterial and Fungal degrading enzymes , it is hopeful that Bisphenol A will be easily degraded in a cost effective way on a long term scale. New synthesis of bacteria and fungus from soil and sewage are undergoing for further and better decomposition of Bisphenol A.

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