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## Research Article

### A REVIEW ON AEROBIC AND ANEROBIC BIODEGRADATION OF BTEX COMPOUNDS

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#### ABSTRACT

Chemical and oil industries generate a large sort of extremely cyanogenetic organic pollutants, that have led to additive venturous effects on the atmosphere. The waste material comes out from chemical industries usually contain aromatic organic compounds that are not degraded naturally and so continue in the atmosphere. This makes these hazardous compounds for bioaccumulation in human and tissue. Organic pollutants represent a possible cluster of chemicals that may be seriously venturous to human health. Biological strategies for treatment of effluent containing organic micro pollutants are getting a lot of accepted over the globe. This review concentrate on the pathway for the biodegradation of benzene, toluene, ethylbenzene and xylenes (BTEX) underneath model conditions by microalgae and to grasp the anaerobic and anaerobic biodegradation pathways for BTEX compounds. These results favor the biomass when biodegradation method and create it enticing for additional use as an acceptable substrate for resultant processing into biofuels of third generation.

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#### INTRODUCTION

A measurable quantity of aromatic hydrocarbon enters the atmosphere due to the discharge from underground storage tanks, accidental spills, or improper waste disposal methods<sup>1</sup>. Once hydrocarbon is in-tuned with water, benzene, toluene, ethyl benzene, and xylene isomers (BTEX) account for the maximum amount as 90th of the hydrocarbon elements that are found within the soluble fraction<sup>2</sup>. Consequently, these chemicals are a number of the foremost common contaminants found in water. Benzene, toluene, ethyl benzene and xylene are mono-aromatic ring compounds with a 6-carbon benzene nucleus as their core structure. Because of their closed structures, these compounds, particularly benzene, are usually thought-about to be non-reactive species<sup>3</sup>; but, it's well-known that these compounds have the flexibility to bear chemical process and sure substitution reactions. At oil-spill sites, BTEX compounds will be transported through many meters underneath favorable oxidation-reduction conditions inflicting them to be persistent pollutants in each soil and water<sup>4, 5</sup>. Their ability to dissolve in water, relative to their poly-aromatic counterparts, is because of low octanol-water partition coefficient (Kow) values<sup>6-8</sup> that favors deliquescent dissolution, in spite of their hydrophobic nature. BTEX are virulent to

humans, and their removal from contaminated environments is of interest group<sup>9</sup>. BTEX compounds are a very important family of Organo pollutants that are elements of hydrocarbon and aviation fuels and are wide utilized in industrial syntheses<sup>10</sup>. The BTEX compounds are classified as priority pollutants regulated by the Environmental Protection Agency (U.S. Environmental Protection Agency. 1977). The negative health effects that result from the consumption of those compounds embrace cancer, liver lesions, somnolence and irritation of organs<sup>11,12</sup> additional reportable that human exposure to BTEX compounds over an extended amount of time ends up in skin and sensory irritation, adverse metabolic process health effects and central system irritation. In spite of the negative effects they cause to human health, BTEX compounds stay unmarked and untreated in municipal systems, thereby increasing the danger of water-related diseases through their body process. The persistent presence of BTEX compounds in air, and have reportable the transportation of those compounds from air into water bodies as a results of downfall<sup>13</sup>. As a result, it's imperative that the rectification of those compounds in water is prioritized in future water treatment systems. The power of natural microorganisms within the soil in BTEX degradation was initial incontestable<sup>14</sup>. Since then, many studies are applied so as to seek out

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economical microorganisms for BTEX degradation, in order that they may be utilized in environmental rectification for this mixture<sup>15</sup> developed and proprietary a method for the detoxification of liquid effluent streams<sup>16</sup>. Because of the virulent nature and resulting peril of organic compounds, the necessity to get rid of it from wastewaters and impure surroundings is incredibly preponderating and several other physical, chemical and biological removal or treatment technologies are utilized during this regard but, the physico-chemical removal or treatment technologies are found to own inherent disadvantage because of the tendency to make secondary virulent intermediates and additionally tried to be pricey. The main focus is on the event of technology that emphasizes detoxification and degradation of the waste product. Thus, biological removal or treatment technology has clad to be a good different because it produces no virulent finish merchandise and it's of low price. Biodegradation of those mixes by green growth has incontestable promising outcomes to defeat this issue. The bioremediation technology offers a promising tool to treat aerobically oil-contaminated shorelines a combination of thermophilic aerobic microorganism, comprising preponderantly bacteria genus spp., were accustomed degrade a good vary of aromatic hydrocarbons, such as phenols, toluene, aniline, benzothiazole, lindane (hexachlorocyclohexane), and their combination<sup>17</sup>. Recent rectification efforts have centered principally on biodegradation of BTEX compounds in marine atmosphere. The degradation of those compounds will be achieved by exploitation varied microorganisms like microorganism, fungi and alga. Each aerobic and anaerobic bacteria are shown to degrade BTEX compounds<sup>18</sup>. Currently a day's among the various organism algae embark to be most favorable. Algae not solely capable of bioaccumulation these pollutants, however they were additionally capable of biotransforming a number of these environmental pollutants. Algal species will additional tolerate these small pollutants and grow within the presence of those compounds and afterward degrade then and additional algal biomass is isolated and might be born-again to biofuel or third generation fuel<sup>19-21</sup>.

#### **Degradation Pathways for Btex Compounds**

In pure cultures of chemotropic organisms, reducing equivalents generated throughout transformation of hydrocarbons to metabolic intermediates, need to be transferred to an external electron acceptor with a additional positive oxidation-reduction potential so as to conserve energy for growth. Growth without an external electron acceptor isn't attainable<sup>22</sup>. Within the absence of oxygen, energy conservation are often accomplished by anaerobic respiration with different inorganic chemicals as electron acceptor. These reduction processes are usually cited as terminal electron accepting processes (TEAPs). Potential natural electron acceptors for anaerobic oxidization of organic matter to greenhouse gas in submersed environments are nitrate, Mn(IV), Fe(III) and sulphate. Greenhouse gas may also perform as an electronacceptor, yielding alkane series throughout methanogenesis. at the side of these electron acceptors, BTEX elements are often degraded anaerobically. The aerobic degradation of toluene yield via the initial addition of hydroxyl group groups by distinct mono- or dioxygenases<sup>23</sup>, looking forward to molecular oxygen as a co-substrate to destabilise the

aromatic ring. Underneath anoxic conditions, the initial catalyst attack of toluene is catalysed by the enzyme benzylsuccinate synthase (Bss), adding the methyl radical of toluene to fumarate (so-called "fumarate addition") forming benzylsuccinate<sup>24, 25</sup>. This catalyst step involves a glycy-radical mechanism, explaining however chemically stable aromatic compounds like toluene will be activated within the absence of molecular oxygen. Benzylsuccinate is then additional activated as a CoA-thioester, that is then remodeled, via many intermediates, to benzoyl-CoA. The latter is a vital central intermediate within the anaerobic dissimilation of aromatic compounds, funnelling metabolites from numerous peripheral degradation pathways into aromatic ring reduction, ring cleavage, and eventually a changed -oxidation to acetyl-CoA<sup>24,25</sup>.

#### **Aerobic Condition for Btex Compounds**

Under aerobic conditions, numerous substrate cooperations have been seen amid biodegradation of BTEX combinations<sup>26</sup> observed that the inhibition effect of toluene on benzene was higher than the restraint impact of benzene on toluene. Moreover, the inhibitory impacts of p-xylene on toluene and ethylbenzene corruption were much more articulated than on other BTEX mixes. One conceivable reason might be expected to the aggressive digestion in which p-xylene restrained the use of toluene and ethylbenzene due to rivalry for the dynamic restricting site of a catalyst. Aerobic life forms perform cell breath to get vitality using Vigorous creatures doing cell breath, use oxygen to oxidize substrates (for instance sugars and fats) so as to acquire vitality. This prompts fast and supreme corruption of most of toxins. Blended microbial networks have the most dominant biodegradative potential attributable to hereditary data of more than one life form is important to corrupt the mind boggling blends of natural mixes present in sullied territories. The underlying assault of aliphatic and cycloaliphatic hydrocarbons require sub-atomic oxygen. Oxidation of hydrocarbons is delegated being terminal or diterminal. The mono-terminal oxidation is the key pathway. These early responses, viz. hydroxylation and dehydrogenation, are additionally regular to pathways of corruption of other fragrant hydrocarbons. It advances by means of the development of the resultant alcohol, aldehyde, and unsaturated fat. B-Oxidation of the unsaturated fats results in the arrangement of acetyl-CoA. n-Alkanes with an uneven number of carbon particles are debased to propionyl-CoA, which is later carboxylated to methyl malonyl-CoA and further changed over to succinyl-CoA. Unsaturated fats of a physiological chain length might be legitimately consolidated into layer lipids; however most of corruption items are brought into the tricarboxylic corrosive (TCA) cycle. Fanning present in hydrocarbons diminishes the rate of biodegradation. Methyl side gatherings don't profoundly diminish the biodegradability, while complex stretching chains, e.g., the tertiary butyl gathering, meddle with the activity of the degradative catalysts. The essential advance of benzene oxidation is a hydroxylation catalyzed by a dioxygenase (as seen in Fig). The item, a diol, is then changed over to catechol by a dehydrogenase. The expansion of a substituent bunch onto the benzene ring renders elective systems conceivable to assault side chains or to oxidize the sweet-smelling ring. The primary response engaged with the oxidation of toluene is the methyl bunch hydroxylation. The

methyl gathering of toluene is oxidized bit by bit to the comparing liquor, aldehyde, and carboxylic gathering. Benzoate shaped or its alkylated subordinators are then oxidized by toluate dioxygenase and decarboxylated to catechol. The oxygenolytic cleavage of the aromatic ring happens by means of o- or m-cleavage<sup>27</sup>.

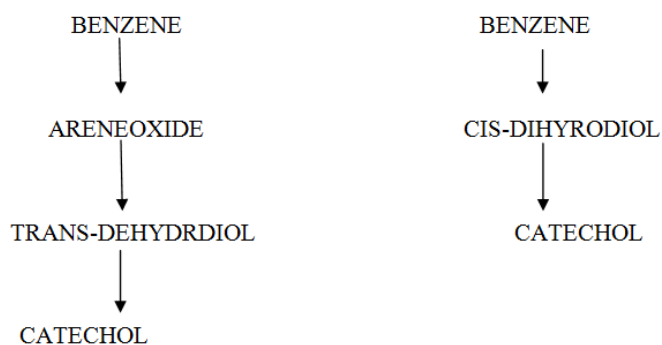


Fig 1 Dioxygenase Reaction for Initial Cleavage of Benzene and catechol formation.

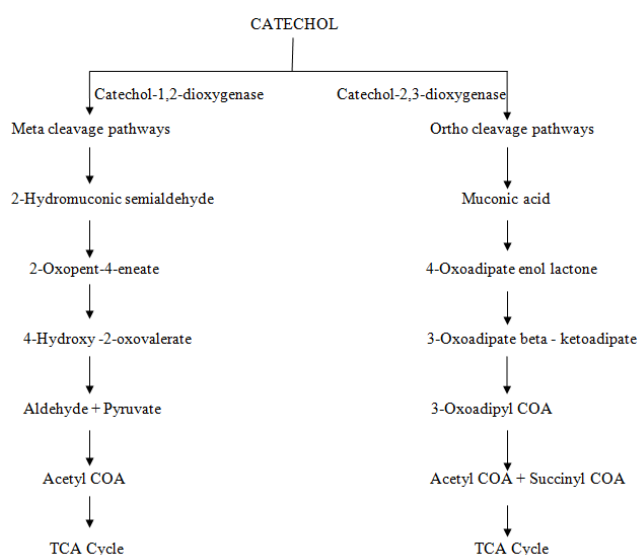


Fig 2 Catabolism of Catechol by ortho and meta-cleavage pathways during aerobic process.

**Anaerobic** Condition for BTEX Compounds

Anaerobic biological process of aromatic compounds begins with the oxidation or reduction of substituent groups, carbon-carbon cleavage of the substituent from the ring, decarboxylations, the removal of O-methyl, sulfur, nitrogen, or halogens from the ring<sup>28, 29</sup>. Generally, these transformations cause the conversion of various aromatic compounds to benzoate or its coenzyme A (CoA) thio-ester before ring reduction and cleavage. The reduction of benzoyl-CoA represents a substantial energy barrier for anaerobic microorganisms. The thiogroup present in coenzyme A considerably lowers the mid-point potential of the primary electron transfer<sup>30-32</sup> yet; the reduction of benzoyl-CoA represents a key energy barrier<sup>31</sup> which might overcome by adenosine triphosphate reaction<sup>33</sup>. Many pathways are acknowledged for anaerobic cleavage of the benzene nucleus of aromatic compounds with functional groups like carboxyl or hydroxyl radical groups. The anaerobic metabolism of aromatic hydrocarbon poses a hurdle because of the massive topological

resource energy<sup>34</sup>. Anaerobic degradation of aromatic organic compounds could be a multistep method within which microorganisms break down hydrocarbon within the absence of oxygen. Benzene, toluene, xylene and ethyl benzene compounds are ascertained to be mineralized beneath anaerobic conditions (as seen in Table) underneath a good sort of electron accepting conditions starting from methanogenic, sulphate reducing, iron reducing, manganese reducing to denitrification<sup>28, 35, 36</sup>. Anaerobic BTEX degrading activities and microorganisms are usually related to sites that have shown to be long run contaminated with crude oil hydrocarbons<sup>37</sup>. Anaerobic biodegradation of aromatic hydrocarbon was found to be comparatively slow administered using laboratory enrichment cultures needed nearly 2 years to mineralize aromatic hydrocarbon underneath methanogenic conditions<sup>35</sup>. Within the similar context, anaerobic toluene degradation is ascertained to be at intervals as less as 6 hrs using denitrifying microorganism<sup>28</sup>.

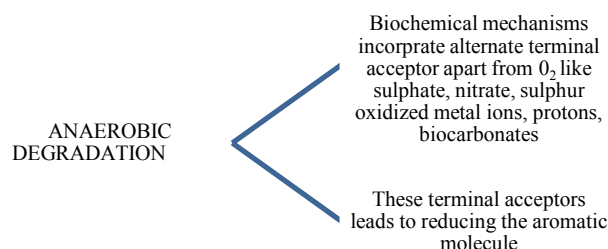


Fig 3 Biodegradation of Aromatic Hydrocarbons by Anaerobic process

Table 1 Biodegradation Under Anoxic (Anaerobic Conditions)

Anaerobic Process for Biodegradation under	Compound	Reference
Nitrate Reduction Condition	Benzene	J.D. Coates <i>et al</i> <sup>38</sup> . 2001
	Benzene	D.R. Lovley <i>et al</i> <sup>39</sup> . 2000
Sulphate Reducing Condition	Benzene in Mixtures of BTX	H.U. Pfeffer <i>et al</i> <sup>40</sup> . 1995
	Petroleum contaminated harbor sediments	J.D. Coates <i>et al</i> <sup>41</sup> . 2002
	Benzene	H.R. Beller <i>et al</i> <sup>42</sup> . 1992
	Toluene	H.R. Beller <i>et al</i> <sup>43</sup> . 1992
Sulphate Reducing Condition	Toluene	E.A. Edwards <i>et al</i> <sup>44</sup> . 1992
	Hydrocarbons	P. Rueter <i>et al</i> <sup>45</sup> . 1994
	Toluene, Xylene	G. Harms <i>et al</i> <sup>46</sup> . 1999
	o-Xylene, m-Xylene and Homologous Alkyl benzene	D.R. Lovley <i>et al</i> <sup>47</sup> . 1995
	Benzene	D.R. Lovley <i>et al</i> <sup>48</sup> . 1994
	Toluene	E.K. Marr <i>et al</i> <sup>49</sup> . 1961

Iron Reducing Conditions	Aromatic Hydrocarbons	D.R. Lovley <i>et al</i> <sup>50</sup> . 1996
	Benzene	D.R. Lovley <i>et al</i> <sup>51</sup> . 1990
	Toluene, Phenol and p-cresol	T. Vogel <i>et al</i> <sup>52</sup> . 1987
Transformation by Methanogens (Cultures and Sediments) Complete	Toluene	E.A. Edwards <i>et al</i> <sup>53</sup> . 1992
	Benzene	B. Schink <i>et al</i> <sup>54</sup> . 2000
Mineralization of Compound in Anoxic conditions		

**Various Microorganisms Involved in Phenol Degradation**

In recent years, a number of microbic ecologists have identified numerous microorganism species that are effective degraders of hydrocarbons in natural environments. Microorganisms are mainly used for bioremediation of those pollutants and promptly eliminate these pollutants from the marine atmosphere. BTEX compounds are degraded by many microorganisms, (shown in Table), that uses these micropollutants mixture as a result of the sole carbon hotspot for cultivation of the organisms. Microorganisms have important role in process of rectification. The microorganisms that have the physiological and metabolic capability for waste removal are additional typically microorganism (aerobic likewise as anaerobic), however fungi may also play a major role. However, the physico-chemical removal or treatment technologies are found to possess inherent downside as a result of the tendency to make secondary cytotoxic intermediates and additionally evidenced to be expensive. Thus, biological removal or treatment technology has had to be a good alternative as a result of it produces no cytotoxic end product and it's of low value.

**Table 2** Some Bacterial Species for Degradation of Aromatic Compounds

Bacterial Species	Aromatic hydrocarbon	Reference
<i>Rhodococcus rhodochrous</i>	Benzene	R.A. Deeb <i>et al</i> <sup>55</sup> . 1999
	Toluene	
	Ethylbenzene	
<i>Pseudomonas spp.</i>	Xylene	L.D. Collins <i>et al</i> <sup>56</sup> . 1999
	Benzene	
	Toluene	
<i>Rhodococcus sp.</i>	p Xylene	R.A. Deeb <i>et al</i> <sup>57</sup> . 2000
	Benzene	
	Toluene	
<i>Pseudomonas putida</i>	m- and p- Xylene	R.E. Parales <i>et al</i> <sup>58</sup> . 2000
	Benzene	
	Toluene	
<i>Acinetobacter calcoaceticus</i>	Ethylbenzene	A.C. Frazer <i>et al</i> <sup>59</sup> . 1995
	Benzene	
	Toluene	
	Xylene	

**Table 3** Some Fungal Species for Degradation Of Aromatic Compounds

Fungal Species	Aromatic Compound	Percent Degrade	Reference
<i>Cladophialophora sp.</i> Strain T1	BTEX	Toulene-90%	F.X. Prenafeta <i>et al</i> <sup>60</sup> . 2002
		Ethyl-benzene-90% Xylene-60%	
<i>Trametes versicolor</i>	BTEX	71%	S. Barathi <i>et al</i> <sup>61</sup> . 2001
<i>Phaenerochete chrysosporium</i>	BTEX	Toulene-40%-50%	E. Aranda <i>et al</i> <sup>62</sup> . 2010
		Ethyl-benzene-98%	

**CONCLUSION**

The aromatic hydrocarbons may it be monoaromatic or polyaromatic, has a widespread use in petrochemical industry and also has many applications which leads to their accumulation in the environment making them priority pollutants due to their ecotoxicity and health hazards. Microorganisms have been an important tool in the biodegradation approaches may it be in-situ or ex-situ methods. Aerobic-anaerobic catabolic pathways have been studied in bacterial, fungal and fungal populations. For the degradation of phenol many physical and chemical methods have been in use at present. An alternative method for degradation is biological process or "Bioremediation". Relatively cheaper and effective process and releases lesser harmful products. Biological treatment is environmental friendly, very efficient, cost effective and has gained increasing attention in pollution prevention. These applications techniques in the laboratory, large pilot plants and industrial scale opens the doors for future research and explorations and offers new frontiers for developing new and efficient technologies. Although many approaches are available for BTEX removal, the search continues for the development and improvement in the future works.

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