

## Chapter 45

# Biodegradation of Phenol: Mechanisms and Applications

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### ABSTRACT

*Aromatic compounds are widely distributed in nature. Free phenols are frequently liberated as metabolic intermediates during the degradation of plant materials. In recent years the natural supply of phenolic substances has been greatly increased due to the release of industrial byproducts into the environment. Phenolic compounds are hazardous pollutants that are toxic at relatively low concentration. Effluents from petrochemical, textile and coal industries contain phenolic compounds in very high concentration; therefore there is a necessity to remove phenolic compounds from the environment. Microorganisms capable of degrading phenol are common and include both aerobes and anaerobes. The use of microbial catalysts in the biodegradation of organic compounds has advanced significantly during the past three decades. The efficiency of biodegradation of organic compounds is influenced by the type of the organic pollutant, the nature of the organism, the enzyme involved, the mechanism of degradation and the nature of the influencing factors.*

### INTRODUCTION

Phenol (hydroxy benzene) is an organic aromatic compound ( $C_6H_5OH$ ) consisting of a phenyl group ( $-C_6H_5$ ) bonded to a hydroxyl group ( $-OH$ ) Figure 1. It is a volatile, white crystalline solid with acidic nature. Phenol naturally occurs in decaying dead organic matters (rotting vegetables) and coal. At room temperature phenol is a translucent, colorless, crystalline mass, white powder or syrupy liquid when mixed with water. The crystals are hygroscopic and turn pink to red in air. Phenol has a sweet tar like odour and is soluble in alcohol, glycerol, petroleum and water to a lesser extent. Phenol nowadays is produced from petroleum on a large scale (about 7 billion kg/year). Generally phenol is synthesized from 1-methylethylbenzene (cumene), which can be used as an indication of the levels of phenol production.

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(Basha *et al.*, 2010). A german chemist, Runge in 1834, first isolated phenol from coal tar and named it as karbolsaure (coal-oil acid or carbolic acid), but its composition was not known until 1841. Phenol can be produced by synthetically and naturally. By fractional distillation of coal tar phenol is obtained naturally. Phenol was first used in the raw state, as creosote, to prevent the weathering of railway ties and ships timber. It was also used to reduce the odour of decomposition in sewage. It is frequently used in pharma Industries, synthetic resin, dyes, pesticides, etc. Phenol is very toxic and its increasing presence displays a significant environmental toxicity hazard. Acute exposure of phenol can result in myocardial depression and central nervous system disorders. A large number of microorganisms are capable of degrading phenol with bacteria as the major player. Characterization of bacteria that are capable of degrading phenol has resulted in bringing out the possible biological mechanism to remediate the phenol contaminant in the environment.

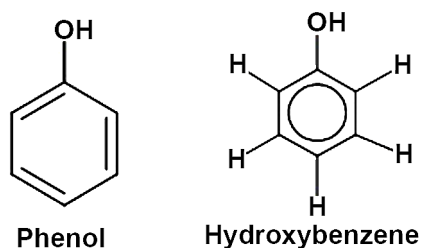
## Uses of Phenol

Phenol has been produced since 1860s. By the end of the 19<sup>th</sup> century, industrial scientists revealed many applications of phenol. It is widely used in the synthesis of dyes, aspirin, and one of the first high explosives, picric acid. As early as in 1872, it was found that phenol could be condensed with aldehydes (for example methanal) to make resinous compounds, a process still in use today. Phenolmethanal (formaldehyde) resins are the basis of the oldest plastics. It is still used to make low cost thermosetting plastics such as melamine and bakelite used in electrical equipment. Phenol is widely used to make pharmaceuticals, perfumes, pesticides, synthetic tanning agents, lubricating oils and solvents. Due to its wide application phenolic compounds are frequently found in effluent from coke-oven batteries, coal gasification refinery, petrochemical plants and other industries, such as herbicides, synthetic chemicals, pesticides, pulp-and-paper, photo developing chemicals, antioxidants, tannery and foundries (washing of the gas effluents) etc. (Basha *et al.*, 2010) (see Figure 1).

## Global Phenol Production

There was a decline in the global phenol during the recession, but they returned to normal in 2010. The world phenol production from 2010 to 2012, showed a positive annual growth (nearly 2.5%) Figure 2 (Global phenol production broken down by country, 2012) and figure 3 (Phenol capacity broken down by region, 2012). It increased from 8.34 million tonnes in 2010 to more than 8.9 million tonnes in 2012. APAC accounted for over 41% (above 3.7 million tonnes) of the overall output volume and became the

Figure 1.



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