Study of Degradation of BTEX Aromatic Compounds Using Peroxidase Enzymes

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Abstract
Today, water resources conservation is considered as the most vital human resource by various international communities. The water stream is mainly contaminated by the various applications. Due to the low efficiency and issues of conventional treatment methods, newer methods of treatment of industrial wastewater are being introduced. One of the new methods is the use of peroxidase enzymes in the treatment of industrial and urban wastewater. In this paper, four different peroxidase enzymes have been studied to remove BTEX compounds (Benzene, Toluene, Ethylbenzene, and Xylene) in wastewater effluent. The best peroxidase enzymes have been chosen to decrease BTEX compounds after evaluating the four enzymes via the hierarchical analysis process (AHP). The cost, efficiency, environmental requirements, and industrialization have been selected as criteria in the AHP method. Also, peroxidase from mustard, peroxidase from horseradish, peroxidase from lignin and oxidase from polyphenol were proposed for this study. Expert choice software has been applied to evaluate the AHP process. The analyze of various criteria indicated that the cost parameter with 31.3% preference was chosen as the main criteria, as well as the oxidase from polyphenol was selected as the proposed alternative with 28.1% of priority.

Keywords: Peroxidase Enzymes, AHP, BTEX removal.

Introduction
In the past two decades, numerous researches have been performed on the ability of enzymes to degrade aromatic compounds. These studies are based on a variety of criteria, such as the increasing volume of environmentally compatible and incompatible pollutants, evaluation of the use of peroxidase enzymes for the removal of various pollutants as well as new methods for more efficient enzyme [1]. The wastewater treatment processes can be classified into three categories: physical, chemical and biological. The elimination of aromatic compounds via the use of enzymes in chemical and biological treatment processes (the catalysts of processes are a type of biological catalyst) is very common. The advantages of enzyme treatment method compared to the application of bio-catalysts are the following items: application in bio-resistant compounds, applicability at low and high concentrations of pollutants, applicability in wide pH range and convenience control of the treatment process[1]. The strict regulations have been introduced in some countries for aromatic compounds (BTEX) due to many

environmental issues [1]. These pollutants are found in the effluent of many industries such as refineries and petrochemical complex, metal plating, paint, and chemical and textile industries. Most of the polycyclic aromatic hydrocarbons (PAHs) compounds are toxic and must be separated from the wastewater stream before the sewage enter the environment [2]. The enzymatic treatment has been proposed as one of the potential methods rather than the conventional methods by many scientists [1-2].

One of the new methods is the use of peroxidase enzymes, these enzymes have a selective performance and also carry out well at low pollutant concentrations. Many peroxidase enzymes have been implemented to remove environmental pollutants, but some peroxidase enzymes have been employed more than another peroxidase enzymes to decrease aromatic compounds (BTEX).

The peroxidase from horseradish enzyme has been widely applied to eliminate phenolic compounds [3]. The peroxidase from horseradish effectively removes phenolic compounds from wastewater and its ability is in a wide range of pH, temperature and different concentrations of aromatics [1]. Kris S.freeman was reported that peroxidase from horseradish enzyme can be removed 95% phenolic compounds in a batch reactor under optimal conditions. This enzyme was employed in both urban and industrial wastewater streams [1]. In industrial effluent from an olive oil factory with a concentration of phenol 1221 mg/l, COD[1] and BOD[2] amount decreased by 58% and 78%, respectively [4].

Peroxidase enzyme from mustard is one of the enzymes that has been studied in the removal of aromatic compounds more recently. Upon activation of the mustard enzyme, it can enhance the oxidation of many toxic aromatic compounds, including phenols, anilines, ethers and aromatic compounds [5]. Peroxidase enzyme from mustard is suitable for wastewater treatment because it can to maintain its activity in a wide range of pH and temperature.

Peroxidase from lignin (Lip), also known as ligninase or diarylpropane oxygen, it was reported for the first time in 1983 [6]. This enzyme is part of the extracellular system of the white-rot fungus called phanerochaete chrysosporium [7-8]. Peroxidase from lignin can be employed to degrade a number of inconsistency aromatic compounds and to oxidize a number of polycyclic aromatic and phenolic compounds [6-9]. The role of peroxidase from lignin in lignin re-polarization has also been established [7-9-10]. The stability of lignin peroxidase in waste treatment has been studied by Erwin and et al [7]. Researches have shown that lignin peroxidase is easily deactivated at low pH.

Oxidase from polyphenol are another family of oxidoreductases that are able to enhance the oxidation reactions of phenolic compounds. These enzymes are divided into two groups [11]. Tyrosinases, also known as polyphenol oxidase, phenolase, or catechase, improve two successive reactions.With non-enzymatic polymerization, they become insoluble in water and are easily eliminated by straightening [12-13].

Laccase, produced by several fungi, can reduce the toxicity of phenolic compounds from the polymerization process [14]. Laccase can also bind pollutant phenols to natural phenols because of their relative lack of specificity [14]. In fact, laccase is able to oxidize phenolic compounds to their free anionic radicals [11]

In this study, the bio-degradation of BTEX compound was surveyed via AHP[3] method to facilitate decision from among mustard peroxidase, horseradish peroxidase, lignin Peroxidase and polyphenol peroxidase. The suitable peroxidase enzymes for removing of BTEX compounds were chosen by Expert Choice software.

[1] Chemical Oxygen Demand
[2] Biological Oxyen Demand
[3] Analytic Hierarchy Process

Experimental

The analytic hierarchy process was used for the degradation of BTEX process. The AHP is one of the most comprehensive systems designed for decision making with multiple criteria. This method is based on pairwise comparisons that facilitate judgment and calculations and show the degree of consistency and inconsistency of the decision [15]. Expert Choice software which is a powerful tool for multi-criteria decision making based on hierarchical analysis has been used for this purpose. In this software, the preferences are based on the calculation of the final weight and the sensitivity of the decision-making. The cost of the aromatic compounds treatment process, its technical feasibility, treatment efficiency and environmental requirements in the industry are the four criteria chosen for this study. The relationship between criteria and treatment process alternatives was illustrated in Fig.1.

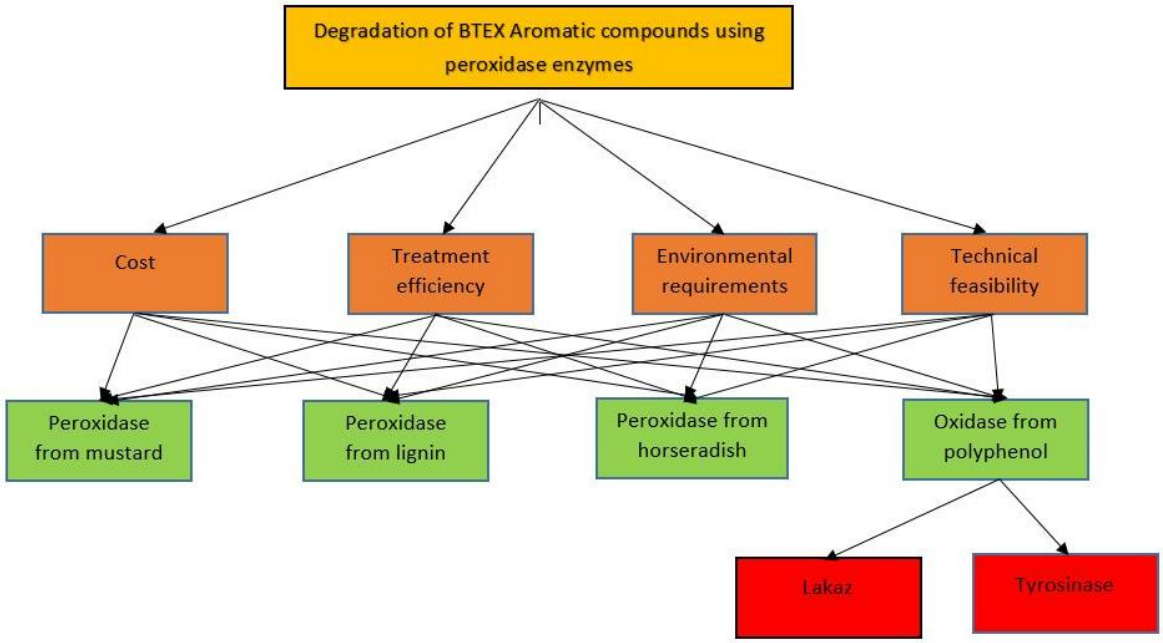

Fig. 1. Folwchart of AHP method for BTEX removal

According to previous studies, four peroxidase enzymes were selected for the treatment of aromatic compounds.

Results and discussion

Pairwise comparisons between the cost of the aromatic compounds treatment process, its technical feasibility, treatment efficiency and environmental requirements were conducted as criteria mean. Then, this paired comparison was computed in Expert Choice software. The software environment is very friendly and it can do a pair comparison easily. Pairwise comparisons implemented based on various parameters such as numerical, graphical, and alphanumeric which the numerical comparison is selected due to the easier concept. These parameters are presented in Table (1) [16].

Table 1. Preference qualitative for pair wise comparison method [16-17]

Amount	Importance
1	With a similar preference criterion
3	Somewhat preferable
5	Highly preferred
7	Very preferable
9	Extremely preferable
2, 4, 6 and 8	Importance between the above values

A pairwise comparison matrix of criteria is shown in Table (3). Inconsistency for pairwise comparisons of criteria was computed by the expert choice software.

Table 2. Pairwise comparsion Matrix

	Cost	**Efficiency**	**T**echnical **F**easibility	**E**nvironmental **R**equirements
Cost	1	5	3	3
Efficiency		1	2	1/4
Technical **F**easibility			1	1/2
Environmental **R**equirements				1
Inconsistency index:	**8%**			

Consistency Ratio (CR) is one of the most significant evaluations in the hierarchical analysis process, which should be less than 10%. As can be seen from Table (2), the inconsistency for the proposed criteria is less than 10%. This means that possible errors in judgments are less remarkable. It should be noted that the inconsistency of the AHP (Criteria and Alternative) process is 9%.

Each of the four alternatives has advantages and disadvantages that should be carefully studied in order to evaluate the pairwise comparison. Fig. 2 and Fig. 3 indicated the outcome of a pairwise comparison of the criteria and alternatives respectively. The cost criteria presented the most influence between criteria parameters by 31.3 percent priority.

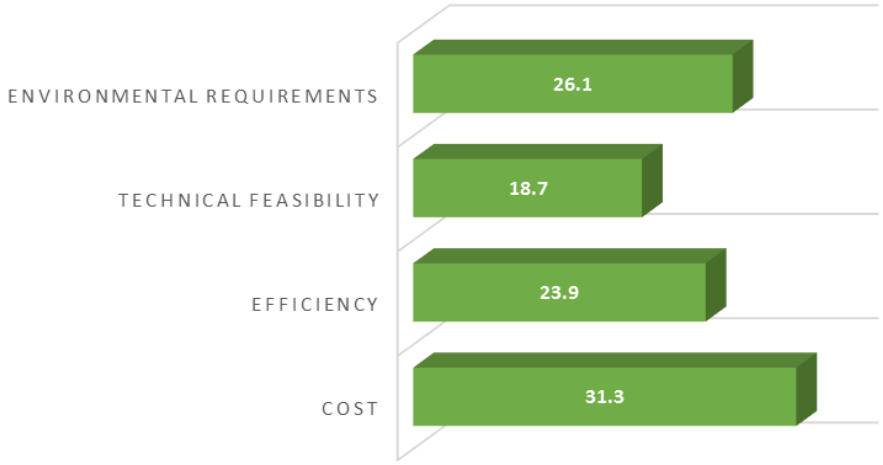

Fig. 2. The result of the pairwise comparison for the Criteria

Due to the reasons mentioned in the introduction section, pairwise comparisons of the alternatives were performed in the software. The results show that the oxidase from polyphenol alternative having the highest preference of 28.1% over the other alternatives. According to the consequences, the alternatives are not much preferable to each other. This outcome is probably because these enzymes are not yet industrial applications.

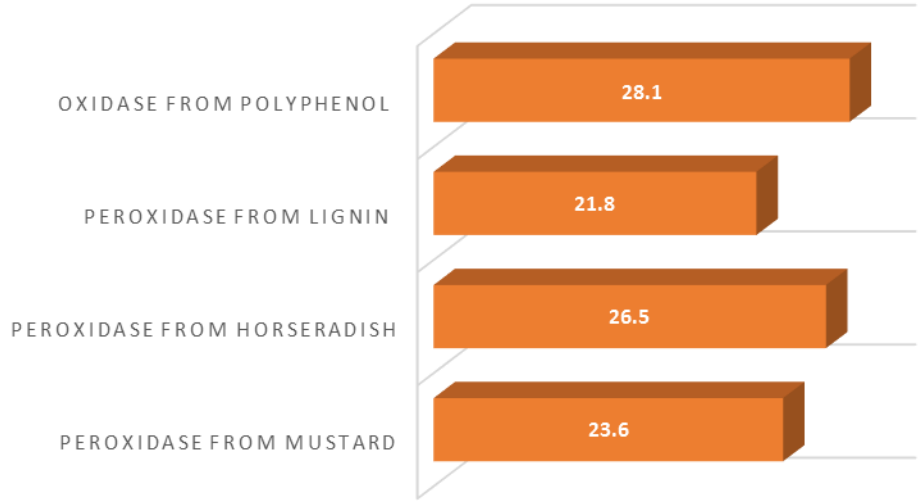

Fig. 3. The result of the pairwise comparison for the Alternative

Conclusions

Aromatic compounds (BTEX) must be removed from sewage streams for hazardous environmental issues. For this purpose, the hierarchical analysis process was employed to achieve a rational choice of the aromatic compounds treatment method. The consequences of expert choice software indicate that the cost criteria is the most preferred (43%). Also, the oxidase from polyphenol alternative with the highest percentage 35.8% has the highest priority over the other alternatives.

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