



## Review

# Peroxidases-assisted removal of environmentally-related hazardous pollutants with reference to the reaction mechanisms of industrial dyes



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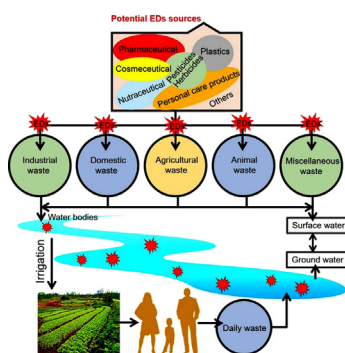
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## HIGHLIGHTS

- This manuscript highlights the catalytic role of peroxidases in removing emerging pollutants.
- Peroxidases can decontaminate an array of toxic compounds.
- Degradation pathways of various hazardous dyes are shown.
- Enzyme-catalyzed reactions are potential alternatives to classical chemical methods.

## GRAPHICAL ABSTRACT



## ARTICLE INFO

## Article history:

Received 10 May 2018

Received in revised form 7 June 2018

Accepted 22 June 2018

Available online xxx

Editor: Paola Verlicchi

## Keywords:

Peroxidases

Hazardous contaminants

Emerging pollutants

Industrial dyes

Emerging pollutants

Catalytic pathways

Environmental protection

## ABSTRACT

Environmental protection is one of the most important challenges for the humankind. Increasing number of emerging pollutants resulting from industrial/human-made activities represents a serious menace to the ecological and environmental equilibrium. Industrial dyes, endocrine disruptors, pesticides, phenols and halogenated phenols, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and other xenobiotics are among the top priority environmental pollutants. Some classical remediation approaches including physical, chemical and biological are being employed, but are ineffective in cleaning the environment. Enzyme-catalyzed transformation reactions are gearing accelerating attention in this context as potential alternatives to classical chemical methods. Peroxidases are catalysts able to decontaminate an array of toxic compounds by a free radical mechanism resulting in oxidized or depolymerized products along with a significant toxicity reduction. Admittedly, enzymatic catalysis offers the hallmark of high chemo-, regio-, and enantioselectivity and superior catalytic efficiency under given reaction environment. Moreover, enzymes are considered more benign, socially acceptable and greener production routes since derived from the renewable and sustainable feedstock. Regardless of their versatility and potential use in environmental processes, several limitations, such as heterologous production, catalytic stability, and redox potential should be overcome to implement peroxidases at large-scale transformation and bio-elimination of recalcitrant pollutants. In this article, a critical review of the transformation of different types of hazardous pollutants by peroxidases, with special reference to the proposed reaction mechanisms of several dyes is presented. Following that major challenges for industrial and environmental applications of peroxidases are also discussed. Towards the end, the information is also given on miscellaneous applications of peroxidases, concluding remarks and outlook.

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1. Introduction

Environmentally-related emerging pollutants (EPs) represent a broad range of human-made chemicals (cosmetics, pesticides, pharmaceuticals, personal and household care products and toxic heavy elements) which are widely used and indispensable for modern society, around the globe (Bilal et al., 2018a; Rasheed et al., 2018a). These pollutants are extremely toxic, carcinogenic, and mutagenic and their

accumulation poses severe threats to all key spheres including the hydrosphere, lithosphere, and biosphere, among others (Ahmed et al., 2017; Bilal et al., 2018b; Rasheed et al., 2018b). Effective degradation and removal of these pollutants have emerged as a major concern for biotechnologists and environmental scientists. Fig. 1 illustrates an overview of the routes by which some emerging contaminants/pollutants so-called endocrine disrupting chemicals (EDs) enter various receptors, i.e., surface water, groundwater, and consumers. Intensive recent

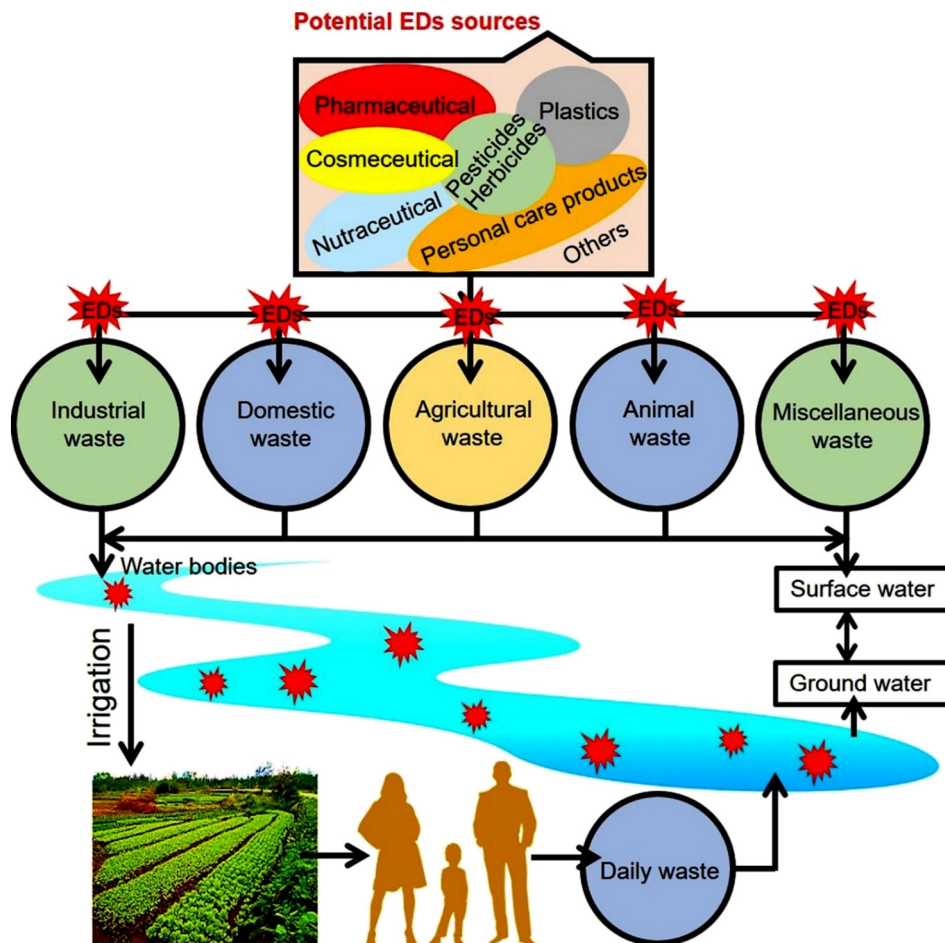


Fig. 1. Schematic pathways of some emerging EDs from sources to receptors.

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