PANCHAKOTesSAYS
ISSN : 0976-4968
Vol-12, No.-2, Nov 2021

Biocatalysts: A Green Technique to Minimize Water Pollution

Dr Sumitra Das [1*]

[1*] *Assistant Professor, Sreegopal Banerjee College, Bagati, Magra, Hooghly, West Bengal, India, email: sumitrasgb2022@gmail.com*

Abstract

In the modern age of industrializations, the growing amount of industrial waste in the water bodies highly demands a green sustainable bioremediation for their complete treatment and purifications of polluted water. Biocatalysis is the most advanced technique to handle the contaminants in the aquatic parts. The most beneficial aspect of biocatalyst lies in its low energy production and raw materials consumptions and also yields non-toxic by-products. It is considered to be a green techniques for the treatments of waste water systems. Despite of having several beneficial issues, its high production cost and low yields restrict it applications in a broader way. This article emphasizes on the previous development and application of the biocatalysts in the area of water purification and also give a brief insight on the scope of its future advancement and aspects which is a big challenge for the present research.

KEYWORDS: Biocatalysis, Bioremediation, Green techniques, Industrial waste, Waste water system

INTRODUCTION

The increasing amount of release of different types of colorants, pigments, phenolic compounds from the industrial effluents, hospital and household waste to the ground water and sea water is increasing day by day and crossing the security limit. This leads to the destruction of different good microorganisms and has bad impact on human health [1]. So it becomes a great challenge for the environmental scientist to develop new technologies for waste water treatment. Several conventional methods [2] are applying nowadays, but they are effective to remove the contaminants only partially. But report shows that this contaminants are very much effective towards human health and ecosystem at trace level also. In this critical condition, an advanced technology is urgently needed to treat this trace amount impurities. In the intervening time, thorough research is in progress to recycle the waste water rather than to consider it as loads. Research on biorefining of the contaminants of the waste water and development of new technologies are still going on to recycle the hazardous materials in an environmental friendly manner. In the recent times, various interesting research is made on the synthesis and development of biocatalysts [3] that are observed to be most effective and greener technique to degrade the organic contaminants of the wastewater. Biological methods mainly involve microorganisms [4] and different types of enzymes [5]. Specially, enzyme based processes have various advantages such as low energy requirement, low toxicity, ease of operation and production of less toxic by-products. Still its application in large scale is limited, because of the low stability of the enzymes and difficulty in their reusability, increase the operational cost. This problem can be shorted out by immobilizing the enzymes. Immobilization increases the stability of enzymes and also enhance the scope of their recyclability and reusability. This review article illustrates the recent progress and achievements in the field of biocatalytic water treatment. The scope and challenges to improve their efficiencies are also highlighted in this aspect.

BIOLOGICAL TREATMENT OF WASTE WATER

Several methods are now available for the control of contaminants in the waste water like adsorption [6], sedimentation [7], ozonation [8] and advanced chemical oxidation [9]. But these processes have numerous disadvantages like requirement of toxic chemical solvents, sophisticated instrumentations and production of hazardous by-products and even not capable for removal of some kind of contaminants. This increase the demand for developing new biological methods that are capable to satisfy the green environmental requirements. Biological process for water purification is classified into two categories – (1) handling with microorganisms and (2) dealing with enzymes in the free and immobilized form.

USING MICROORGANISMS

Literature shows that, a number of variety of bacteria like Stretomyces and Pseudomonous and fungi such as Trametes versicolor and Pleurotous ostreatus are widely applied. Depending on the nature of microorganisms, the degradation process can occur in aerobic, anaerobic and mixed aerobic-anaerobic condition.

USE OF ENZYMES

Enzymes are primarily of oxido-reductase group like laccases, peroxidases and tyrosinases [10] acquire an important role for the biodegradation of the contaminants specially phenolic and phenolic derivatives of the waste water. But the disadvantages of the free enzymes are their low stability and very poor reusability. In this aspect, it has been observed that immobilized oxido-reductase enzyme shows greater efficiency than its free form to remove the pollutants from the waste water. Immobilization increase the stability of the free enzyme and also open its scope for reusing in various bioreaction tools. It is also noteworthy in this regard to choose proper support materials for immobilization. Generally, inorganic, organic and hybrid materials are suitable for immobilization. These compounds should possess high stability, resist mechanical strain and have good compatibility with the biomolecules. Immobilized oxido-reductase enzymes exhibit 90% more efficiency than its free state.

REMOVAL OF DYES

Nowadays the most important water pollutants are dyes. This goes on increasing due to the ingesting of different colouring materials like anthraquinone, azo and triarylmethane for dying in the textile industries. They are very much carcinogenic and cause various hazards to human health if it goes into the food chain. So it is vital, to develop a biocatalytic system that can release these pollutants effectively and results in comparatively pure water for better use. Recent reports show that immobilized oxido-reductase enzymes are very much efficient for this purpose. Laccase from Trametes versicolor immobilized onto glycidyl methacrylate (GMA)–functionalized polyacrylamide–alginate cryogel (PAG) [11] effectively decolorize the dyes containing different salts and other chemicals used for dying. In other work, bacterial laccase from Escherichia coli immobilized onto polyhydroxybutyrate beads (PHBs) [12] has been used for the degradation of Direct Red 105, Direct Yellow 106, and Direct Black 112 from real solution containing various inhibitors such as salts and other dispersants with 60% efficiency. Immobilized peroxidase on horseradish remove reactive black 5 and mallacite green. Manganese peroxidase (MnP) immobilized onto chitosan beads [13] by cross-linking with glutaraldehyde enables to inactive the dyes in textile effluents even up to 97% productivity. The above studies present that the immobilized enzymes satisfactorily compensate the harmful effects of dyes with better efficiency in presence of other chemicals.

PHARMACEUTICAL WASTES

The chemicals that are present in pharmaceutical wastes impose very detrimental effect on human and aquatic life. So it seems to be essential to remove them immediately. Several researchers investigate on various biological systems to solve this problem. Among them, covalently immobilized *laccase* onto Electrospun nanofibrous [14] textile successfully degrade chlortetracycline, carbamazepine, and diclofenac with 72%, 63% and 48% efficiency, respectively for 8 hrs reaction. Moreover, the resultant materials can be reused upto 10 cycles. Another report has revealed that *organophosphate hydrolase* immobilized on textile [15] designed into a column bioreactor can be able to degrade the pharmaceutical pollutants from the high flow rate of waste water upto 60 days of the reaction without losing the removal efficiency of the biocatalysts and it can be reused upto 7 catalytic cycles. *Horseradish peroxidase supported* on poly (vinyl alcohol) or poly (acrylic acid)/SiO_2 electrospun nanofibers [16] eliminates paracetamol from the waste water with 83% efficiency. Kinetic study of this reaction shows that it follows first order kinetics. Again, *laccase* *supported on* electrospun poly (L-lactic acid) or co-poly (ε-caprolactone) nanofibers textile [16] degrade effectively the chemicals generally present in the anti-inflammatory drugs like, naproxen, and diclofenac from the waste water with remarkable efficiency.

REMOVAL OF PHENOL

Owing to its low solubility in water and high solubility in fat makes it feasible to accumulate in various organisms of plants and animals. It has very much adverse effects on human health due to its high toxicity, corrosivity and carcinogenicity. Literature shows that Horseradish peroxidase enzyme immobilized on cashew polysaccharide [17], a natural polymer shows effectivity to degrade different types of phenolic contaminants like catechol, bromophenol, nitrophenol with higher efficiency. Due to its better recyclability this system can be employed in different industrial and medicinal sectors. Immobilizing laccase on silica [18] results in its high temperature compatibility and can degrade chlorophenol and catechol with an 80% average efficiency. Tyrosinase immobilized on magnetic iron nanoparticle [19] can effectively remove phenol contaminants with ~100% efficiency. Research has been going on to further improve the catalytic activity of the immobilized enzymes by considering the kinetic, thermal and other physicochemical parameters.

REMOVAL OF PHENOLIC DERIVATIVES

Phenolic derivatives like phenolic endocrine-disrupting chemicals (PEDCs) have been gaining much more importance nowadays because of their adverse effect on human health as well as it also deteriorates the quality of soil and water. Several research has been done on immobilized biocatalysts to control PEDCS from polluted water. Contemporary research on treatment of waste water has revealed that better results may be obtained by the aggregation effect of adsorption and biodegradation. Changing the supporting materials results in to degrade different derivatives with an enhanced efficiency. As for example, *laccase supported on* polyacrylonitrile/polyvinylidene fluoride nanofibrous textile [20] successfully remove 2,4,6-trichlorophenol for about 270 mins reaction with 95.4% efficiency. This also produce the reusability of the biocatalyst upto 7 cycles. Further report has shown that *laccase* immobilized on mesoporous nanofibers textile can be used to remove triclosan [21]. Catechol from wastewater has been reported to remove through the collective effect of biocatalysis and adsorption using commercial *laccase* immobilized on polyacrylonitrile/montmorillonite/graphene oxide composite nanofibers textile. Dai, Yao, Song [22] have made another attempt to develop new biocatalyst by encapsulating *laccase* on electrospun nanofibrous membrane via emulsion electrospinning. This resultant material has the ability to remove bisphenol A with 90%

efficiency from wastewater. In an another endeavour, Dai et al reported the production of multi-walled carbon nanotube modified *laccase*-carrying electrospun fibrous membranes which can remove phenolic derivatives from water, including bisphenol A, triclosan and 2,4-dichlorophenol with acceptable range of efficiency. These biocatalysts can be reused upto 10 cycles without hampering its original activity. Apart from laccase, *horseradish peroxidase* covalently supported on electrospun poly (vinyl alcohol)–polyacrylamide blend nanofibrous textile also seems suitable to remove phenol within 180 min reaction and yields reusability upto 25-cycles and retaining 54% of initial activity [23]. Encapsulated *horseradish peroxidase* into the nanofibrous textile by emulsion electrospinning is able to remove pentachlorophenol (83% removal efficiency) at room temperature [24]. *A supported tyrosinase* through response surface methodology is used to bio-catalytic removal of bisphenol A over 90 mins reaction at 25 °C. The enzyme regains its 90% activity after 30 days of storage.

The above discussion summarizes the fact that, the supported enzymes on suitable materials show greater potential to remove the pollutants from waste water. But some limitations have been faced by the researchers that include vulnerability of the surrounding environment, pre-treatment of the waste water and poor performance in a system dealing with a mixture of pollutants. Extensive research has been going on to overcome these limitations.

CHALLENGES AND FUTURE PERSPECTIVES

Biocatalysts are highly demanding to initiate many reactions under mild condition. It is one of the environment friendly green techniques to control the water pollutants. This review highlights the use of different microorganisms and immobilized enzymes as biocatalysts for the water purification in a wide range of reactions at low energy consumption, less hazardness and at low cost. Moreover, immobilizing the enzymes on suitably chosen support increase their stability and recyclability for few cycles. These are the advantages of this technique. But still there are some limitations of this procedure, such as (i) loss of enzymes occur during immobilization (ii) active sites of the enzymes get blocked or disoriented during immobilization (iii) some of the immobilization process requires high temperature that leads to denaturation of the enzymes (iv) biocatalysts stored for few years may lose its activity so it becomes difficult to use it for large scale though applying optimal condition. Besides these limitations, efforts have been made to overcome the obstacles by decreasing its waste during immobilization, improve the supporting materials to optimize the extreme reaction conditions. Nowadays plasma treatment or biocrosslinkers are introduced in the field of biocatalysts that seems to be more efficient and effective to carry out a number of reactions in an eco-friendly method.

CONCLUSIONS

It can be concluded in short that, biocatalysis based on microorganism and enzymatic degradation of pharmaceuticals, industrial and municipal effluents in waste water specially phenols and phenol derivatives, estrogens, dyes, pesticides etc show a huge success in the recent years. Among the several predictable methods, biocatalytic degradation of the contaminants of waste water has proved to be more effective because of its low energy requirement, cost effectiveness and production of low toxic by products. Despites of its large advantages, it cannot be used in large scale because of scarcity of availability of suitable enzymes necessary for biodegradation. Further research is needed to develop new enzyme, multi enzymatic system for the better treatment of waste water.

REFERENCES:

i. Madhav S., Ahamad A., Singh A. K. et al, (2020). Water Pollutants: Sources and Impact on the Environment and Human Health, Advanced Functional Materials and Sensors. Springer: 43-72.
ii. Mohiyaden H.A., Sidek L.M., Salih G. H. A. *et al* (2016). Conventional Methods and Emerging Technologies for Urban River Water Purification Plant: A Short review. J. Eng. Appl. Sci. **11**(4): 2547-2556.
iii. Barbhuiya N.M., Misra U., Singh S. P. (2022). Biocatalytic membranes for combating the challenges of membrane fouling and micropollutants in water purification: A review. *Chemosphere*. **286(2)**: 131757.
iv. Zhu Y., Wang W., Ni J., Hu B. (2020). Cultivation of granules containing anaerobic decolorization and aerobic degradation cultures for the complete mineralization of azo dyes in wastewater. *Chemosphere*. **246**: 125753.
v. Zdarta J., Jankowska K., Bachosz K. *et al*. (2021). Enhanced Wastewater Treatment by Immobilized Enzymes. *Curr. Pollut. Rep.,* **7**: 167-179.
vi. Rashid R., Shafiq I., Akhter P., Iqbal M. J., Hussain M. (2021). A state-of-the-art review on wastewater treatment techniques: the effectiveness of adsorption method. *Environ. Sci. Pollut. Res.* **28**, 9050-9066.
vii. Abdal-Fatah M. A., Hawash S. I., Abd El Maguid A. (2020). Treatment of metal processing waste water using coagulation and sedimentation techniques. *J. Eng. Appl. Sci.* **15(23)**: 2812-2819.
viii. Mehrjouei M., Muller S., Moller D. (2015). A review on photocatalytic ozonation used for the treatment of water and wastewater. *Chem. Eng. J.* **263**: 209-219.
ix. Tony A. M., El-Geuindi M. S. A., Hussein S. M., Elwahab. (2016). Degradation of an organophosphorus insecticide (chlorpyrifos) in simulated wastewater using advanced oxidation processes and chemical oxidation. *App. Sci. Report*. **15(2)**: 63-73.
x. Pandey K., Singh B., Pandey A. K. *et al*. (2017). Application of Microbial Enzymes in Industrial Waste Water Treatment. *Int. J. Curr. Microbiol. App. Sci.* **6(8)**: 1243-1254.
xi. Yavaser R., Karagozler A. A. (2021). Laccase immobilized polyacrylamidealginate cryogel: A candidate for treatment of effluents. *Process Biochem.* **101**: 137-146.
xii. Jankowska K., Zdarta J., Grzywaczyk A., Degórska O., Kijeńska-Gawrońska E., Pinelo M. et al. (2021). Horseradish peroxidase immobilised onto electrospun fibres and its application in decolourisation of dyes from model sea water. *Process Biochem*.**102**:10–21.

xiii. Bilal M., Asgher M., Iqbal M., Hu H., Zhang X. (2016). Chitosan beads immobilized manganese peroxidase catalytic potential for detoxification and decolorization of textile effluent. *Int. J. Biol. Macromol*. **89**:181–189.

xiv. Taheran M., Naghdi M., Brar S. K., Knystautas E. J., Verma, M., Surampalli, R. Y., (2017). Degradation of chlortetracycline using immobilized laccase on Polyacrylonitrile-biochar composite nanofibrous membrane. *Sci. Total Environ.* **605**: 315-321.

xv. Xu, R., Si, Y., Li, F., Zhang, B. (2015). Enzymatic removal of paracetamol from aqueous phase: horseradish peroxidase immobilized on nanofibrous membranes. *Environ. Sci. Pollut. Control Ser.* **22 (5)**, 3838-3846.

xvi. Zdarta, J., Jankowska, K., Wyszowska, M. *et al.* (2019). Robust biodegradation of naproxen and diclofenac by laccase immobilized using electrospun nanofibers with enhanced stability and reusability. *Mater. Sci. Eng. C.* **103**: 109789.

xvii. Silva T., Borges L. L., Barboza e Souza E. R., Caramori S. S. (2019). Synthesis of immobilized biocatalysts for wastewater decontamination. *Polímeros*. **29(4)**:1-8.

xviii. Mohammadi M., Ashabi M. A., Salehi P., Yousefi M., Nazari M., Brask J. (2018). Immobilization of laccase on epoxy-functionalized silica and its application in biodegradation of phenolic compounds. *Int. J. Biol. Macromol.* **109**:443–447.

xix. Abdollahi K., Yazdani F., Panahi R., Mokhtarani B. (2018). Biotransformation of phenol in synthetic waste water using the functionalized magnetic nano-biocatalyst particles carrying tyrosinase. *3 Biotech.* **419(8)**: 1-8.

xx. Xu R., Chi C., Li F., Zhang B., (2013). Laccase polyacrylonitrile nanofibrous membrane: highly immobilized, stable, reusable, and efficacious for 2, 4, 6-trichlorophenol removal. *ACS Appl. Mater. Interfaces*. **5(23)**: 12554-12560.

xxi. Wang Q., Cui J., Li G., Zhang J., Li D., Huang F., Wei Q. (2014). Laccase immobilized on a PAN/adsorbents composite nanofibrous membrane for catechol treatment by a biocatalysis/adsorption process. *Molecules.* **19(3)**: 3376-3388.

xxii. Dai Y., Yao J., Song Y., Wang S., Yuan Y. (2016). Enhanced adsorption and degradation of phenolic pollutants in water by carbon nanotube modified laccase-carrying electrospun fibrous membranes. *Environ. Sci. Nano* **3(4)**: 857-868.

xxiii. Niu J., Xu J., Dai Y., Xu J., Guo H., Sun K., Liu R. (2013). Immobilization of horseradish peroxidase by electrospun fibrous membranes for adsorption and degradation of pentachlorophenol in water. *J. Hazard Mater.* **246**: 119-125.

xxiv. Zdarta J., Staszak M., Jankowska K. (2020). The response surface methodology for optimization of tyrosinase immobilization onto electrospun polycaprolactoneechitosan fibers for use in bisphenol A removal. *Int. J. Biol. Macromol.* **165**: 2049-2059.