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Tannase Enzyme for Microbial Degradation of Industrial Effluents: A Review

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A B S T R A C T

Pollution is a pervasive phenomenon and inconvenient truth. Effluents from domestic and industrial sources are being released into the water bodies. They not only pollute the water bodies but also disturb the normal biological cycles of associated organisms. Industrial effluents are more polluting in nature as compared to domestic effluents. Industries utilize humongous quantities of water for cooling, cleaning, transportation and other tasks. In the process the water interacts with different chemicals, some are toxic while some may be neutral. It forms a harmful effluent and when it is disposed of in water bodies, causes water pollution. Wastewater from the brewery, tannery, paper pulp industries, food industries and textile industries are rich in organic contaminants. Removal of degradation of these contaminants is quite important before their disposal into water bodies. Various methods are available for effective removal of these contaminants from the effluents namely physical, chemical & biological. Biological treatment involves both aerobic & anaerobic treatment as well as degradation with microbes. Microbes contain several enzymes that can effectively degrade different organic compounds. Tannase isolated from some fungal and bacterial strains is effective in the degradation of tannin present in the effluent from the leather industry.

Introduction

Improper wastewater management is a major issue faced by many developing and developed countries around the globe. Major sources of waste generation are anthropogenic namely domestic and industrial waste water effluents. Disposal into rivers is a growing cause of concern. Their disposal into water bodies renders them unsuitable for primary or secondary consumption by humans or animals (Fakayode, 2005). Water bodies serve as the primary site for industrial effluent disposal. As per reports published by World Health Organization in 2004, about 17 % of the world is deprived of safe drinking water especially in countries like India, China, Middle East & Africa. By the year 2030, about 47 % of the world population will face a severe water crisis. About 2.1 billion people or 3 in 10 people lack access to clean drinking water worldwide (Akinloye and Olubanjo, 2014).

Industrial effluents are a complex mixture of inorganic, organic and synthetic compounds. The color of the wastewater depends on the age and concentration of impurities present in it (Abdel-Raouf *et al.,* 2012). Depending on the source of their origin effluents are rich in different kinds of pollutants. Industries require enormous amounts of water for processing raw materials and converting them into finished goods. Water is needed for washing, cooling, dyeing. Thus it gets mixed with a range of degradable and non-degradable pollutants. Textile, pulp and paper, leather, iron and steel, pharmaceutical, brewery and food industries are the major consumers of water and produce a high amount of industrial effluents. For treatment of effluent released from these industries several physical and chemical techniques are employed to reduce the contaminant load from effluent but these techniques also require the use of heavy chemicals and by-products of these processes are more harmful than the effluent itself. Researchers are focusing more on the development of remediation techniques that actively involves biological entities like plants and microbes as the procedure is less harmful and by-products are nontoxic. The leather industry consumes and produces a humongous amount of wastewater and the effluent often contains tannins which are known to inhibit the growth of several microbes thus interfering with the process of bioremediation of waste. Thus pretreatment of effluent with enzyme Tannase helps in reducing the concentration of tannins already present in the effluent.

Industrial Effluents and their Impacts on Water Bodies

Great civilizations have always flourished around the banks of some rivers. Water resources have played a crucial role in the development of great civilizations. With industrialization, these water bodies have now become a sink for all the effluents or wastewater that is being released from industries. Treatment facilities are unable to maintain their pace with industries that are constantly generating waste at an alarmingly high rate (Nwachukwu *et al.,* 1989). Different industries have different water requirements. The effluent generated by different industries thus contains different compounds.

Composition of Effluents From Different Sources

Effluents from different industries are rich in both degradable and non-degradable organic compounds, heavy metals, greases and oils, acids, bases and coloring compounds (Kosaric, 1992).

Textile Industry

For the cleaning and dyeing of work materials, a huge amount of water is required. For example Processing 1 kg of fabric requires 200 liters of water is required. Effluent released contains toxic aromatic amines, hazardous contaminants and heavy metals infused with aromatic media (Jin *et al.,* 2007). Effluent is rich in dyes so it adds color to water bodies and affects the penetration of sunlight into eater bodies. It adversely affects the BOD & COD of water (Pereira, 2012). Once released into breakdown into harmful products which are more damaging in nature because of their carcinogenic and mutagenic nature. It affects living entities by causing disorders like contact dermatitis, hypersensitive eye reaction, and respiratory disorders. They also cause soil pollution thereby affecting crops (Carmen and Daniel, 2012).

Iron and Steel Industry

China, Japan and India are the major producer of crude steel with an annual production of 808 MT, 105 MT and 96 MT respectively. For manufacturing 1 tonne of ingot steel about 250-500, m3/hr effluent is released from the factory (Geny and Dohen, 1972).

Pulp and Paper Industry

Growing human requirements and rapid industrial demands have led to a rise in demand for paper and pulp. Water usage is quite high due to the use of several dyes and chemicals which are used in the process. Per ton of product require 20,000-60,000 gallons of water during processing and production. Dyes which are used in the process are rich in both organic and inorganic pollutants. Recycling paper is thus recommended to reduce the water wastage and chemical load on nature (Pokhrel and Viraraghavan, 2004).

Pharmaceutical Industry

Effluent from pharmaceutical industries is rich in recalcitrant compounds as a result of which even microbes are unable to degrade. Antibiotics, lipid regulators, antiepileptics, tranquilizers are some of the substances that enhance the recalcitrant nature of effluent from these sources. Pre-treatment of these effluents can be useful in reducing their toxic nature to some extent so that they may become susceptible to biological degradation (Lateef, 2004).

Leather Industry

The leather industry is considered to be the most polluting sector causing pollution of both soil and water. About 90 % of industries use the chrome tanning process due to convenient procedures and excellent results but it is a wet process and utilizes enormous amounts of water (Chowdhury *et al.,* 2013). The soaking stage is considered most polluting as it contributes to 50-55 % of effluent produced in the entire tanning process. The effluent contains a mixture of chlorinated phenol, Cr(IV), sulfide, phenolic compounds, magnesium, sodium, potassium, azo-dyes, cobalt, cadmium compounds, antimony, lead, selenium, mercuric, arsenic, zinc, grease, oils and tannins (Tadese and Guya, 2017). Tannins are used for imparting color and to protect the skin from decomposition. They are highly soluble in water so when they are released into the water bodies with effluent they interfere in the microbial degradation process of activated sludge by inhibiting microbial growth in some strains (Natrajan, 2009). According to a study conducted in 2014 tannery effluent that is discharged into water, bodies is estimated to be around 300-400 million tonnes. This effluent is rich in all sorts of contaminants that can severely affect human health (Wosnie and Wondie, 2014).

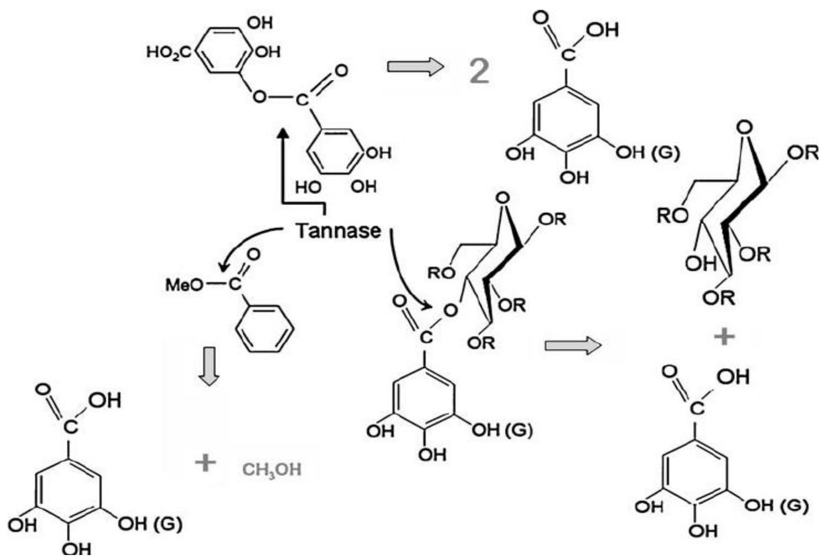
Bioremediation of Industrial Effluents

Physical and chemical techniques are doubtlessly effective but not ideal. Chemical precipitation, flotation, membrane filtration, reverse osmosis, nanofiltration, electrolytic recovery, etc are used for remediation of industrial effluents (Bilal *et al.,* 2013; Kurniawan *et al.,* 2006). Sludge and end products of such processes are quite toxic and more damaging in nature as compared to parental compounds. Biological methods have yielded far better results as compared to physio-chemical methods. For remediation purposes bacteria, fungi higher plants and algae are commonly deployed. Study of processes is also quite easy with these biological entities due to their short life span. Bioremediation can be categorized into Micro-remediation and Phytoremediation.

Microremediation

Microscopic entities like bacteria and fungi are used in the treatment of effluent. The process can both be aerobic and anaerobic. In the aerobic process, degradation takes place in the presence of oxygen and the toxic compounds are converted into carbon dioxide, water, and biomass by bacteria and fungi. In the anaerobic process and end, products are almost the same but the degradation takes place in absence of oxygen. Several species of fungi are bacteria are employed for the degradation of compounds present in the effluent (Kumar *et al.,* 2014). For example, Azodyes are degraded by *Phanerochaete chrysosporium* which is a fungus (Barr and Aust, 1994).

Fig.1 Mechanism of action of Tannase (Aguilar *et al.*, 2007)



Phytoremediation

Treatment of industrial effluent with indigenous or genetically engineered plants is more cost-effective and has fewer side effects as compared to physio-chemical methods (Lone *et al.*, 2008). Some genera like Brassica, Raphanus and Thalpsi are known to initiate binding interaction with heavy metals because of the presence of certain proteins on their surface. They can flourish around the sites with contaminated water and accumulate toxic substances. To treat sites contaminated with mercury pollution several genetically modified strains of Oryza, Nicotiana and Brassica are being used. Depending on the mechanism of action phytoremediation can be categorized as Phyto-filtration, Phyto-extraction, Phyto-stabilization and Phytovolatization (Abdel *et al.*, 2012).

Role of Novel Tannase Enzyme in Degradation of Effluents from Leather Industry

Chrome tanning is a widely accepted practice in many tanneries but due to its certain drawbacks efforts are being made to replace it. Tannin is widely used as a substitute as it prevents degradation of leather and also imparts color. Tannins are polyphenols and are usually classified as anti-nutritional factors. They are water-soluble and can precipitate protein from solutions. The molecular weight ranges from 500-3000 kDa (Aguilar *et al.*, 2007; Rodriguez *et al.*, 2008). They are quite resistant to degradation by microbes and are usually present in effluent released from food, leather, pulp and pharmaceutical industries. They are also secreted by plants in case of microbial attack thus are capable of retarding microbial growth and their presence in industrial effluent is quite problematic. They can retard the decomposition rate of effluent by inhibiting the enzymatic activity in microbes since they are antimicrobial in nature (Scalbert, 1991).

The abundance of phenolic hydroxyl groups in tannin allows them to form complexes with proteins quite easily providing them an industrial application (Mueller-Harvey *et al.*, 1987; Haslam, 1989). But effluents from these industries require special treatment and adopting physio-chemical methods is quite expensive and laborious. Thus biological treatments are adopted. It involves the treatment of tannin-containing effluent with enzyme Tannase that can be isolated from both fungal and bacterial strains (Bhat *et al.*, 1998; Field and Lettinga, 1992).

The concentration of tannins is effectively reduced by hydrolysis, glucose and gallic acid are produced as by-products which also serve as an energy source.

Gallic acid breaks down to simpler aliphatic acids which can enter the TCA cycle (Aithal and Belur, 2013; Bhat *et al.*, 1998). *Aspergillus fumigatus, A. versicolor, A. flavus, A. caespitosum, Penicillium charlesii, P. crustosum, P. resticulosum* are some of the fungal strains which serve as a potential source of novel tannase (Batra and Saxena 2005; Bradoo *et al.*, 1996; Sharma *et al.*, 2008; Bhardwaj *et al.*, 2003; Farias *et al.*, 1994; Kasieczka-Burnecka *et al.*, 2007; Rajakumar and Nandy, 1983).

Some thermophilic bacteria also serve as a potential source for the isolation of novel thermostable tannase enzymes (Beniwal *et al.*, 2014). *Bacillius, Lactobacillus, Klebsiella, Pantone, Staphylococcus* and *Pediococcus* are some bacterial strains that are capable of degrading gallotannins and ellagitannins (Deschamps *et al.*, 1980; Ayed and Hamdi, 2002; Noguchi *et al.*, 2007).

Tannase was discovered accidentally by Tieghem in 1867 and the fungal strains involved were *Penicillium glaucum* and *Aspergillus niger* (Lekha and Lonsane, 1997).

This review focuses on the adverse effects of industrial effluents on the environment and the role of microbes in breaking down the contaminants present in the effluent. The use of tannase in the treatment of tannin-rich effluent is quite effective in reducing the load of organic pollutants that are present in the effluent. Genetically engineered tannase enzyme can be a new approach for further improvement in treatment strategies.

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