Simple NanoBiohybrid For Catalytic Disintegration of Toxic Water Pollutants

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Abstract

World population is increasing day by day, which is calculated of about 80 million/year and total water demand of this huge population is almost 64 billion cubic meters/year [1, 2]. Moreover, industrialization and urbanization consistently polluted our existing water resources by adding notorious toxic pollutants, leading to simultaneously decrease in clean and safe water availability globally. Therefore, it is anticipating that about 1.8 billion people will compel to survive on Earth under water scarcity by 2025 [3].Conventional water purification technologies are time consuming, expensive, and have low affinity and efficiency to newly emerging anthropogenic water pollutants [4].The paradigm compelled scientific community to spot light the issue and develop novel technology for ensuring clean and safe water availability to all. Among the many promises of new water purification technology, here we propose a combination of nanomaterial (Carbon nanotube) and biomolecule (Enzyme) or simply 'NanoBiohybrid' catalyst can be a judicious choice for developing a novel water purification technology for disintegrating wide range of water pollutants. In addition, the potentiality of this NanoBiohybrid catalyst in both sensing and mitigating of organic water pollutants will be highlighted. The technology is a perfect example of multi-scale development and covers most of the challenges of existing water purification technology. We hope this "one pot" combination route can tackle a diverse range of water contaminants in near future.

Keywords: Carbon nanotube; Enzymes; NanoBiohybrid; Water purification.

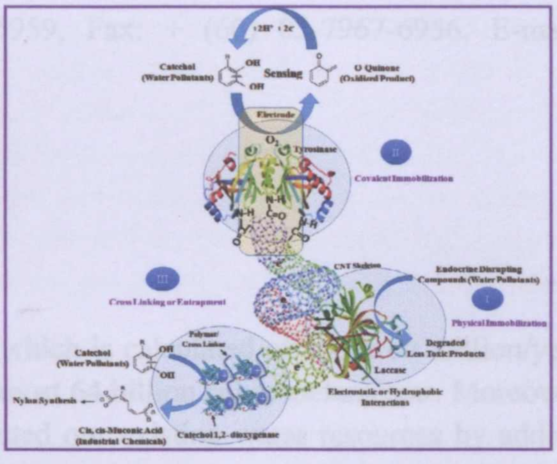

Fig. 1 Mechanisms of a potential NanoBiohybrid catalyst for water purification.

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World population is increasing day by day, which is calculated of about 80 million/year and total water demand of this huge population is almost 64 billion cubic meters/year. Moreover, industrialization and urbanization consistently polluted our existing water resources by adding notorious toxic pollutants, leading to simultaneously decrease in clean and safe water availability globally. Therefore, it is anticipating that about 1.8 billion people will compel to survive on Earth under water scarcity by 2025.Conventional water purification technologies are time consuming, expensive, and have low affinity and efficiency to newly emerging anthropogenic water pollutants.The paradigm compelled scientific community to spot light the issue and develop novel technology for ensuring clean and safe water availability to all. Among the many promises of new water purification technology, here we propose a combination of nanomaterial (Carbon nanotube) and biomolecule (Enzyme) or simply 'NanoBiohybrid' catalyst can be a judicious choice for developing a novel water purification technology for disintegrating wide range of water pollutants. In addition, the potentiality of this NanoBiohybrid catalyst in both sensing and mitigating of organic water pollutants will be highlighted. The technology is a perfect example of multi-scale development and covers most of the challenges of existing water purification technology. We hope this “one pot” combination route can tackle a diverse range of water contaminants in near future.

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1. Introduction

The world population has experienced to increase at a rate of 80 million/year, putting an additional demand of 64 billion cubic meters of potable water per annum (WWAP, 2009, 2012). In 2013, it has been observed that about 768 million people in the world has been suffered from improved fresh water facilities (WHO & UNICEF, 2013) of which Asia's populace counts 380 million (UNESCAP, 2013). The United Nations (UN) has claimed that almost 2.0 billion people could not use fresh, clean and safe water in 2013 (UN, 2013). It has been forecasted that by 2025 about 1.8 billion people will be forced to survive under absolute water scarcity (UN, 2014). On the other hand, the sea level can rise of about 10-15 inches by the 2025, and salt water would obtrude into the estuary ultimately increasing salinity (Oberrecht, 2014). These paint a clear picture of water scarcity, which is expensive, since it jeopardizes the industrial production, and diminishes the availability of hygienic foods, drinks and indirectly causes various epidemic diseases such as dengue, malaria, hepatitis *etc*. Thus an effective water purification technology is the need of the day, and its failure might further endanger the life processes and eco-friendly human existence.

Potential microbial decontamination (MD) for waste water purifications has historically been popular and studied in great details (Grady Jr, Daigger, Love, Filipe, & Leslie Grady, 2011; Wagner et al., 2002). Of particular interests are the biotransformations of notorious water pollutants that have been actually carried out by enzymes inside the microbial cells. It has been applied to treat complex waste water matrices where chemical treatments are typically inoperative. However, MD has been facing some shortcomings such as high costs, time consuming microbial growth processes, extreme sensitivity toward pH, temperatures, and stress, predators, toxic byproduct formations, dependence on nutrient growth mediums and generation of biomass, which make MD dormant to handle both the conventional priorities and newly emerging water pollutants (Khin et al., 2012).

In an attempt to prevail these shortcomings, water scientists have been budged to separate enzyme catalysts from their parent microorganisms and attenuated different waste water pollutants (Guzik et al., 2014; Mugdha & Usha). It has been popular because of its advantages such as mild reaction conditions, high effectiveness and specificity, high owing to low operating costs, and time, absence of secondary reactions, low or no energy consumption and finally eco-friendly than physical, chemical and biological counterparts (W. J. Goh et al., 2012; Khin et al., 2012; Subrizi et al., 2014). But, free enzyme has evinced poor stability and lifetime, high sensitivity to mechanical stresses and difficult to separate from its substrates and products (Brena et al., 2013; W. Feng & Ji, 2011; W. J. Goh et al., 2012). With the purposes of increasing their stability and recrudescence, immobilization of enzymes onto nanomaterials as supports to birth Nanobiohybrid (NBH) has been well documented (W. J. Goh et al., 2012; Subrizi et al., 2014; Xu, Chi, et al., 2013).

Comprehensive literature study has been confirmed that no analytical review has yet been published in order to show the potentiality of NBH in waste water purifications. In this study, we filled up the gap and showed that the utilization of useful nanomaterial properties (*e.g.* high surface area, greater chemical reactivity, lower costs and energy, and antimicrobial activity) as template for the development of an enzyme based Nanobio catalytic system for water purification. Therefore, it has appeals to register as a novel approach not only for water purifications, but to expand *Ab ovo* applications.

2. Shortcomings of Current Water Purification Technologies

In order to tackle wide range of pollutants, different water treatment technologies have been developed and applied at both experimental and field levels. The technologies are commonly classified as primary (screening, filtration, centrifugal, separation, sedimentation, coagulation, flocculation, *etc.*); secondary (aerobic and anaerobic treatments) and tertiary (distillation, crystallization, evaporation, solvent extraction, oxidation, precipitation, ion exchange, micro filtration (MF), ultra filtration (UF), nano filtration (NF) reverse osmosis (RO), adsorption, electrolysis, electrodialysis and so forth) (V. K. Gupta, Ali, Saleh, Nayak, & Agarwal, 2012). Out of these, only a few are capable of solving the water treatment issues. Some methods have found energy and operationally intensive and cannot be affordable at commercial level (R. Das, Ali, Abd Hamid, Ramakrishna, & Chowdhury, 2014). Adsorption techniques are easy and simple, yet their ability for water purification is not satisfactory (H. Y. Yang et al., 2013).

Figure 1 shows major drawbacks of current water purification technologies. It suggests that the water purification is a complex process and not even a single technique could be able to completely purify water. Upadhyayula et al. (2009) hypothesized that the classical techniques have become insensitive because of their dependence on influent water qualities such as turbidity, pH and temperature. Therefore, the technologies have compromised with water pollutants to pass through that leads to partially contaminated water effluents. In addition, industrializations and urbanizations have consistently added new anthropogenic water pollutants which are aliens to classical technologies and eventually appeared in water treatment plants. Finally, high operating costs shrink the availability of effective technologies especially in developing countries (Upadhyayula et al., 2009).

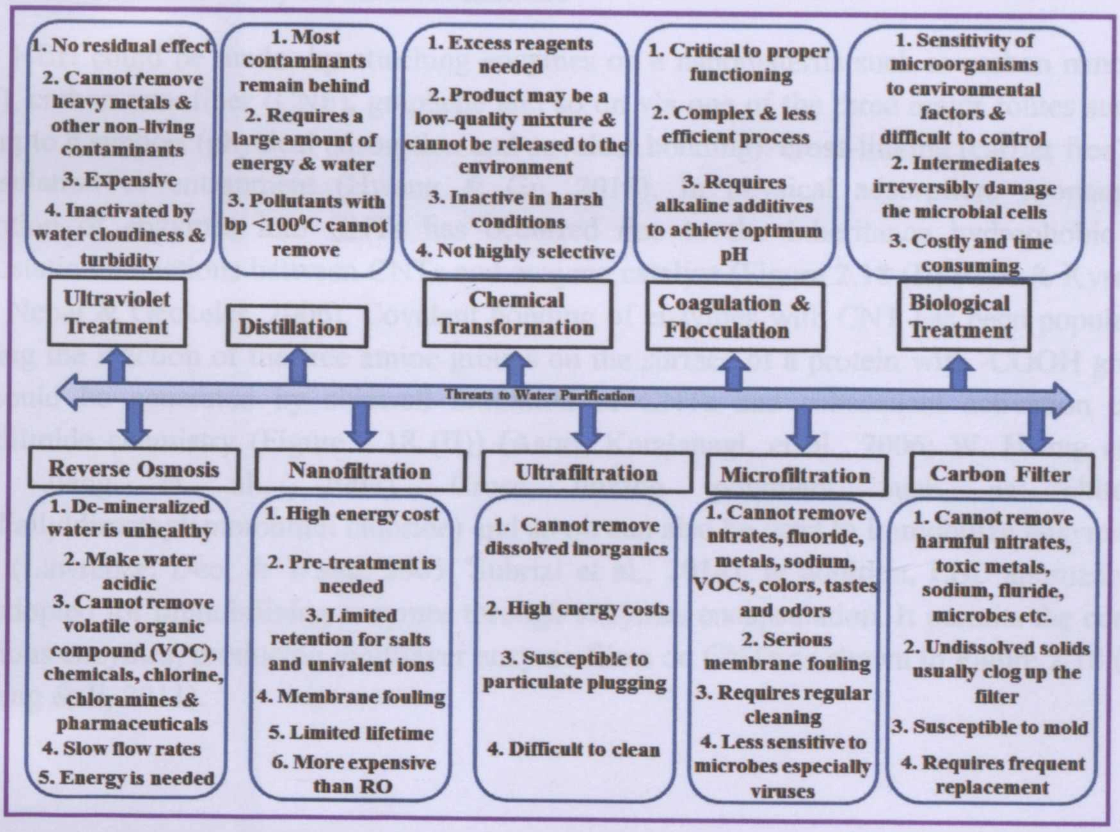

Figure 1: Some major threats to conventional water purification technologies.

3. Nanobiohybrid Catalyst as Novel Water Decontamination Platform

The advent of nanotechnology has given immeasurable opportunities to purify water. NBH has some advantages over conventional chemical oxidation of water pollutants (Asuri, Bale, et al., 2006; Brena et al., 2013; W. Feng & Ji, 2011). Firstly, it can be applied for water purifications where other chemical transformations of water pollutants are not possible. Secondly, the catalyst has greatest efficiency for disintegrating the electron resonance of benzene ring containing aromatic water pollutants in contrast to photocatalysis. Thirdly, recovered NBH catalyst could be used for multiple times (Subrizi et al., 2014), so the method can be economically viable. In fourth, it can be used in industry for yielding commercially important compounds, which have been produced by mitigating of organic waste water pollutants. Finally, the hybrid can play three major functions with high selectivity and sensitivity in water purifications: (i) binding and pre-concentrating the pollutants; (ii) removal and/or degradation of pollutants and (iii) sensing and monitoring the pollutants in water.

3.1 Nanomaterial and Enzyme Immobilizations

NBH could be made by attaching enzymes on a nanomaterils such as carbon nanotube (CNT), carbon nanofiber (CNF), graphene and so on via one of the three major routes such as binding to a support (physical adsorption and covalent bonding), cross-linking (carrier free) and encapsulation or entrapment (Hwang & Gu, 2013). In physical adsorption, spontaneous adsorption of enzymes into CNTs has occurred due to the inheritance hydrophobic and electrostatic interactions between CNTs and enzyme catalyst (Figure 2.18 (I)) (Gao & Kyratzis, 2008; Nepal & Geckeler, 2006). Covalent bonding of enzymes with CNT has been popular by inducing the reaction of the free amine groups on the surface of a protein with -COOH groups that could be generated by sidewall oxidation of CNTs and subsequent activation using carbodiimide chemistry (Figure 2.18 (II)) (Asuri, Karajanagi, et al., 2006; W. Huang et al., 2002; Jiang et al., 2004). Cross linking polymers such as chitosan, poly(diallyldimethylammonium chloride) and so on can also be used to immobilize enzymes on CNTs (Lawrence, Deo, & Wang, 2005; Subrizi et al., 2014). In addition, LBL approach has been adopted for immobilizing enzymes through enzymes encapsulation. It permits the coating of various enzymes, producing multilayer enzyme films on CNTs as shown in Figure 2.18 (III)) (W. Feng & Ji, 2011).

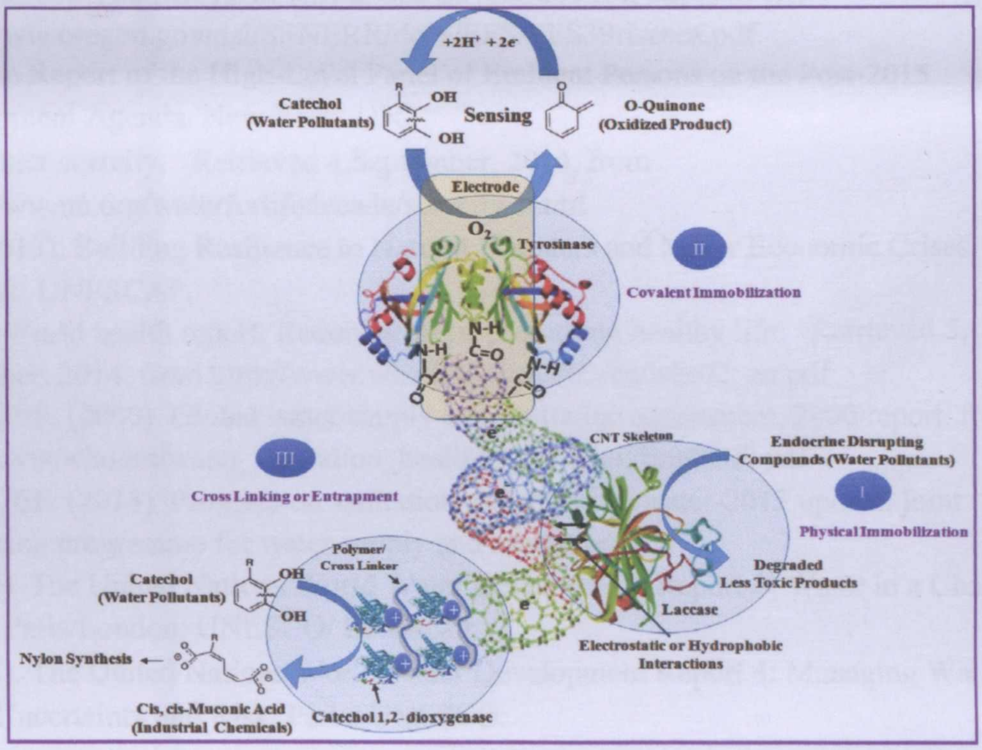

Figure 2.18: Mechanisms of a potential Nanobiohybrid catalyst for water purifications.

4. Conclusions

Fresh and clean water are important to human health. Unfortunately, current world is now facing clean and safe water crises, which are expected to increase day by day. In order to overcome this scarcity, CNT based *nanobiohybrid* catalysis for disintegrating organic water pollutants sowed the seeds of novel innovative waste water purification technologies. Enzymes immobilized on CNTs would be more effective for purifying waste water because of its broader pH, temperature, thermo, and storage stabilities, reusability. Although, many literatures have been published on enzyme immobilizations on CNTs, most of these spotlighted on monitoring purpose only, i.e. as sensor technology. But, scientific community has overlooked the use of this catalyst for eliminating the pollutants from waste water matrices. Therefore, more study is necessary to mature this potential tool, which might give potable water instantly. Let us think a best future of improving and novel CNT based waste water purification technologies and bring a sustainable world for all in the near future.

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