OPEN ACCESS
Scholars Bulletin
Abbreviated Key Title: Sch Bull
ISSN 2412-9771 (Print) |ISSN 2412-897X (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Subject Category: Physics

Potential approach, Novel Methods and Physiochemical Detection of Dyes through Nanoparticles

Sohail Manzoor[1], Muhammad Nasir Akram[2*], Javaid Riaz[1], Sanwal Piracha[3], Muhammad Mujahid Iqbal[1], Waseem Abbas[2], Muhammad Danish Qureshi[1], Muhammad Asif[2]

[1]Department of Physics, University of Agriculture Faisalabad Pakistan
[2]Centre of Excellence in Solid State Physics, University of the Punjab Lahore Pakistan
[3]Department of Chemistry, University of Agriculture Faisalabad Pakistan

DOI: 10.36348/sb.2021.v07i07.003 | **Received:** 02.06.2021 | **Accepted:** 29.06.2021 | **Published:** 08.07.2021

***Corresponding author:** Muhammad Nasir Akram

Abstract

Wastewater contains a variety of toxic dyes and heavy metals. Dyes are released by the different types of industries as environmental pollutants which has become a serious issue for the health of thousands of people. Azo dyes are released from the industries as environmental pollutants and are mixed to the drinking water of human due to their direct discharge into human inhibited areas. Many techniques are available for the degradation of dyes from wastewater such as reverse osmosis, coagulation, ion exchange, photo catalysis, and photo-Fenton etc. However, the traditional photo catalysis and photo-Fenton-like catalytic processes are active only under the irradiation of ultraviolet (UV) light. The photo catalysis involves the generation of electron (e^-)-hole (h^+) pairs under suitable light irradiation. There are many catalysts that have been used in photo catalysis such as ZnO, CdS, TiO_2. TiO_2 is used in the photo Fenton reaction that catalyzes the reaction between iron and hydrogen peroxide. There are many advantages of photofenton reaction such as reaction can be carried out with high performance and can be operated at the room temperature.

Keywords: Dyes, wastewater, photocatalysis, phtofentone reaction, hydroxyl radicals.

1. INTRODUCTION

Wastewater contains a variety of toxic dyes and heavy metals. Dyes that damages severe damage to changes in the environment and leads health problems. Dyes are released by the different types of industries as environmental pollution that has been a serious issue for the health of people and other habitats that affected due to pollution. Dyes in the wastewater are carcinogenic and causes the cancer once damage to cells of human body by interacting the DNA and causing severe mutations in structure of normal cells[1-3].

There is need to remove the toxic dyes from the wastewater that can possible through the creating the two medium as hydrophobic and hydrophilic for breaking the strong charge interaction in dyes. Many techniques are available for degradation of dyes from wastewater such as reverse osmosis is used for separation of ions, pollutants from the water through the membrane, coagulation that also remove the toxic dyes from wastewater, ion exchange that exchange the ions due large separation of dyes from the wastewater, photo catalysis, Fenton process, photo-Fenton are the most advanced methods for early degradation of dyes [4-6].

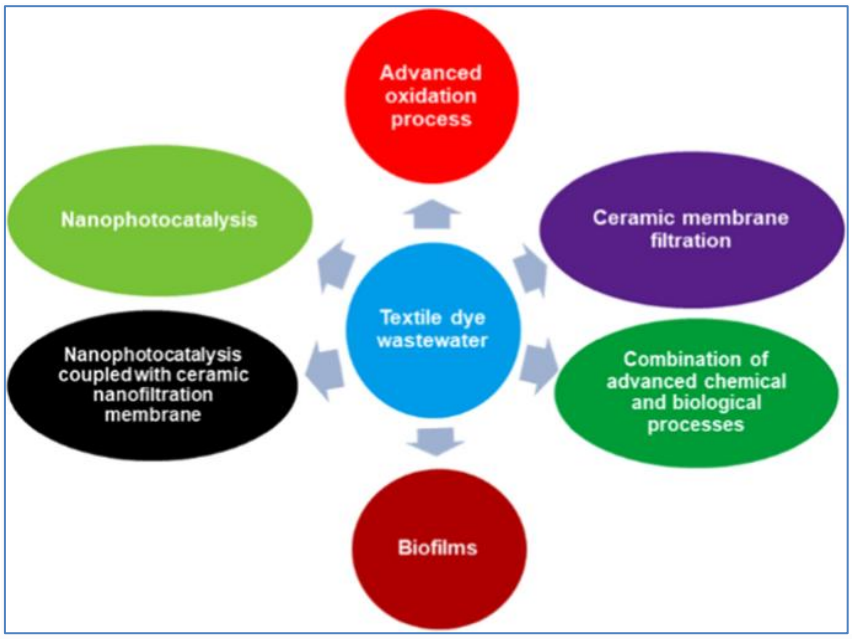

Fig-1: Shows the different methods of removal of toxic dyes from wastewater

Traditional methods are not reliable due to non-functionality under ultraviolet (UV) light and low rate of separation of dyes from the wastewater. However, the traditional photo catalysis and photo-Fenton-like catalytic processes are active only under the irradiation of ultraviolet (UV) light, which accounts for merely 5% of sunlight, and therefore their practical applications are limited. The development of visible light-driven photo catalysts and photo-Fenton-like catalysts is necessary for their applications in the wastewater treatment [5-9].

Although different methods are available for removal of dyes as pollutants from wastewater, among of all, photo catalytic and photo-Fenton-like catalytic processes have attracted remarkable attention for the decomposition of dyes, owing to their low cost, mild reaction conditions, and easy operation procedures. These are industrially suitable methods, environment friendly and less cost as compared to the traditional methods hence large separation rate of dyes from the wastewater due to advanced process in both processes [10].

2.1 Role of Photocatalysis in Degradation of Dyes

Photo catalysis process is used at the commercial and industrial level for the degradation of dyes from wastewater. It leads to decrease in the environmental pollution due to capturing of electrons and releases under the redox reaction. The most important spinel ferrites are developed due to their narrow band gap, magnetic property, and high stability. Many researchers have exploited ferrite photo catalysts for the photo catalytic degradation of organic pollutants. The function of $ZnFe_2O_4$ via a reduction-oxidation method, which showed decolorization of Orange II dye in visible light/catalyst/H_2O_2 system [11-13].

The photo catalysis process involves the generation of electron (e^-)-hole (h^+) pairs under suitable light irradiation, the transformation of photo excited charges to the surface of photo catalyst, redox reactions of the charges with chemical species to form active species, and the degradation of pollutants by the attack of active species [14-17].

Photo catalysis has many other advantages compared to the other traditional methods such as activation of the general catalysis in a way that during photo catalysis photons induce catalysis at the time of reaction. In the presence of photon (λ), oxygen acts as an electron acceptor and electrons are generated photo catalytically by the breakage of complex dyes. In response to visible light, polymeric nanomaterial's have been shown to degrade dye-containing wastewater photo catalytically within very short period. Photo catalysis is the most industrially used method due to low cost of materials utilized during degradation of dyes from wastewater and hence low cost [18-20].

There are many types of nanoparticles that have shown photocatalytic activity against dyes as pollutant materials Titanium dioxide and zinc oxide have shown excellent photo catalytic activity due to a positive band position that develops more electrons and holes under UV light. Recently, the photo catalytic capacity has been improved by modifying material surfaces using metal doped, non-metal doped and coupled systems. The other nanoparticle that have strong catalytic activity as zinc oxide have shown excellent photocatalytic activity due to a positive band position that develops more electrons and holes under UV light[21].

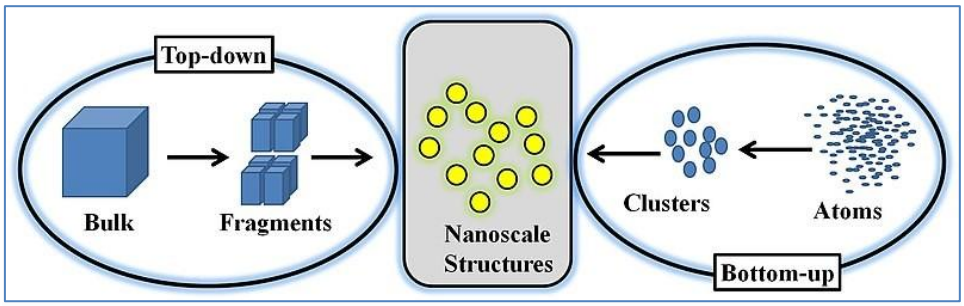

Fig-2: Shows the designing mechanism of photo catalysis and action of nanoparticles

Other types of nanoparticles are used in photo catalysts due to supporting materials ease reaction and fast removal of dyes. Nanoparticles such as chitosan act as support material of metallic photo catalysts. Owing to strong adsorption and high surface area, chitosan reduces the amount of intermediates during photo catalytic reactions. In addition, chitosan allows quick and trouble-free recovery of the photo catalyst, which can be recycled with or without any regeneration [22, 23].

There are many catalysts that have been used in photo catalysis such as ZnO, CdS, TiO2. Different factors are playing important role in photocatalysis process such as band gap and surface area. Most of them have band gap in the UV (ultraviolet) region, i.e., equal to or greater than 3.36 eV (λ = 388 nm). Thus, these catalysts promote photo catalytic reactions under the illumination of UV radiations. Nanowires as well as Nanorods are used in degradation of dyes from the wastewater as indictors of pollutants under photocatalysis thus assisting their removal. These nanowires as well as nanorods optical properties and more surface volume thus employed in all degradation Industrial processes [24].

Azo dyes are released from the industrials as environmental pollutants and mixed to the daring water of human due to their direct intact into human pollution. Combinations of nanomaterial's are used for their removal such as oxides of metal as well as biopolymers performing degradation of active bands of azo dyes by making deforming in structure of azo dyes that containing the stabile structure off lots of amines, carbon and hydrogen. Combinations of oxides of metal as well as biopolymers in different polymeric structures improves the photo catalytic activity against nitrogen containing toxic dyes [25].

2.2 Role of Photofenton Reaction in Degradation of Dyes

This reaction produced the free radicals under oxidation of iron. The stable free radicals are formed in this reactions are source of hydrogen peroxide. During this reaction, Fe (II) that potentially react with H_2O_2. It resulted he production of large number of hydroxyl radical ($OH^{\bullet}$) that could be an important source of $OH^{\bullet}$ in sunlit natural waters. It also depends upon on light irradiation that utilized during phtotofeton reaction. The introduction of lighter irradiation leads to the production of more hydroxyl radical while on the other hand, introduction of less light irradiation leads to the production of less hydroxyl radical [26-27].

Most of nanomaterials are designed in order to remove the dyes from waste water using advanced engineering technologies. TiO_2 is used in the photo Fenton reaction that catalyzed the reaction between iron and hydrogen peroxide. Since, this reaction is dependent on the light, production of free radicals also indicted by light source. This reaction under the production of free radicals can be utilized for degradation of dyes. More of the free radicals generated during the reaction, more of the light irradiation and more degradation of dyes. While of the less free radicals generated during the reaction, less of the light irradiation and less degradation of dyes [26-27].

There are many advantages of photofenton reaction such as reaction can be carried out with high performance and can be operated at the room temperature and it catalyzed the reaction of hydrogen peroxide by breakdown them into the water and oxygen that acting as environment friendly. There are many disadvantages of photofenton reaction such as reaction can be carried out at limit pH such as pH 3, also due to large volume of iron utilized that finally produced d the large quantities of slug. It also leads to environmental pollution [28-30].

CONCLUSION

Due to disadvantages of photofenton reaction, combination of nanoparticles such as pyrite and Nano zero-valent iron called hetero-/homo-geneous Fenton-like processes. These nanomaterial's can be increased the efficiency of overall reaction by reducing the slug due to iron atoms hence less toxic wastes are produced. It ultimately leads to degradation of large amount of dyes in water and hence environment friendly.

REFERENCES

1. Natarajan, S., Bajaj, H. C., & Tayade, R. J. (2018). Recent advances based on the synergetic effect of adsorption for removal of dyes from waste water

using photocatalytic process. Journal of Environmental Sciences, 65, 201-222.
2. Jain, R., & Shrivastava, M. (2008). Photocatalytic removal of hazardous dye cyanosine from industrial waste using titanium dioxide. Journal of Hazardous materials, 152(1), 216-220.
3. Yola, M. L., Eren, T., Atar, N., & Wang, S. (2014). Adsorptive and photocatalytic removal of reactive dyes by silver nanoparticle-colemanite ore waste. Chemical Engineering Journal, 242, 333-340.
4. Agnihotri, S., Sillu, D., Sharma, G., & Arya, R. K. (2018). Photocatalytic and antibacterial potential of silver nanoparticles derived from pineapple waste: process optimization and modeling kinetics for dye removal. Applied Nanoscience, 8(8), 2077-2092.
5. Yola, M. L., Eren, T., & Atar, N. (2014). A novel efficient photocatalyst based on TiO2 nanoparticles involved boron enrichment waste for photocatalytic degradation of atrazine. Chemical Engineering Journal, 250, 288-294.
6. El-Sharkawy, E. A., Soliman, A. Y., & Al-Amer, K. M. (2007). Comparative study for the removal of methylene blue via adsorption and photocatalytic degradation. Journal of colloid and interface science, 310(2), 498-508.
7. Chatterjee, D., Ruj, B., & Mahata, A. (2001). Adsorption and photocatalysis of colour removal from waste water using flyash and sunlight. Catalysis Communications, 2(3-4), 113-117.
8. Gupta, V. K., Saleh, T. A., Pathania, D., Rathore, B. S., & Sharma, G. (2015). A cellulose acetate based nanocomposite for photocatalytic degradation of methylene blue dye under solar light. Ionics, 21(6), 1787-1793.
9. Karthikeyan, K. T., Nithya, A., & Jothivenkatachalam, K. (2017). Photocatalytic and antimicrobial activities of chitosan-TiO2 nanocomposite. International journal of biological macromolecules, 104, 1762-1773.
10. Sun, J. H., Dong, S. Y., Wang, Y. K., & Sun, S. P. (2009). Preparation and photocatalytic property of a novel dumbbell-shaped ZnO microcrystal photocatalyst. Journal of Hazardous Materials, 172(2-3), 1520-1526.
11. Marimuthu, S., Antonisamy, A. J., Malayandi, S., Rajendran, K., Tsai, P. C., Pugazhendhi, A., & Ponnusamy, V. K. (2020). Silver nanoparticles in dye effluent treatment: A review on synthesis, treatment methods, mechanisms, photocatalytic degradation, toxic effects and mitigation of toxicity. Journal of Photochemistry and Photobiology B: Biology, 205, 111823.
12. Shanthi, M., & Kuzhalosai, V. (2012). Photocatalytic degradation of an azo dye, Acid Red 27, in aqueous solution using nano ZnO.
13. Katsumata, H., Kawabe, S., Kaneco, S., Suzuki, T., & Ohta, K. (2004). Degradation of bisphenol A in water by the photo-Fenton reaction. Journal of Photochemistry and Photobiology A: Chemistry, 162(2-3), 297-305.
14. Huston, P. L., & Pignatello, J. J. (1999). Degradation of selected pesticide active ingredients and commercial formulations in water by the photo-assisted Fenton reaction. Water Research, 33(5), 1238-1246.
15. Mendez-Arriaga, F., Esplugas, S., & Gimenez, J. (2010). Degradation of the emerging contaminant ibuprofen in water by photo-Fenton. Water research, 44(2), 589-595.
16. Bai, H., Jiang, W., Kotchey, G. P., Saidi, W. A., Bythell, B. J., Jarvis, J. M., ... & Star, A. (2014). Insight into the mechanism of graphene oxide degradation via the photo-Fenton reaction. The Journal of Physical Chemistry C, 118(19), 10519-10529.
17. Chacón, J. M., Leal, M. T., Sánchez, M., & Bandala, E. R. (2006). Solar photocatalytic degradation of azo-dyes by photo-Fenton process. Dyes and pigments, 69(3), 144-150.
18. Katsumata, Hideyuki, Maki Sada, Satoshi Kaneco, Tohru Suzuki, Kiyohisa Ohta, and Yoshihiro Yobiko. "Humic acid degradation in aqueous solution by the photo-Fenton process." Chemical Engineering Journal 137, no. 2 (2008): 225-230.
19. Kavitha, V., & Palanivelu, K. (2005). Degradation of nitrophenols by Fenton and photo-Fenton processes. Journal of Photochemistry and Photobiology A: Chemistry, 170(1), 83-95.
20. Katsumata, H., Kaneco, S., Suzuki, T., Ohta, K., & Yobiko, Y. (2006). Photo-Fenton degradation of alachlor in the presence of citrate solution. Journal of Photochemistry and Photobiology A: Chemistry, 180(1-2), 38-45.
21. Spacek, W., Bauer, R., & Heisler, G. (1995). Heterogeneous and homogeneous wastewater treatment—comparison between photodegradation with TiO2 and the photo-Fenton reaction. Chemosphere, 30(3), 477-484.
22. Evgenidou, E., Konstantinou, I., Fytianos, K., & Poulios, I. (2007). Oxidation of two organophosphorous insecticides by the photo-assisted Fenton reaction. Water Research, 41(9), 2015-2027.
23. Arana, J., Rendón, E. T., Rodríguez, J. D., Melián, J. H., Díaz, O. G., & Peña, J. P. (2001). Highly concentrated phenolic wastewater treatment by the Photo-Fenton reaction, mechanism study by FTIR-ATR. Chemosphere, 44(5), 1017-1023.
24. Sarrai, A. E., Hanini, S., Merzouk, N. K., Tassalit, D., Szabó, T., Hernádi, K., & Nagy, L. (2016). Using central composite experimental design to optimize the degradation of tylosin from aqueous solution by photo-fenton reaction. Materials, 9(6), 428.
25. Amat, A. M., Arques, A., Miranda, M. A., & Seguí, S. (2004). Photo-Fenton reaction for the abatement

of commercial surfactants in a solar pilot plant. Solar Energy, 77(5), 559-566.
26. Macías-Sánchez, J., Hinojosa-Reyes, L., Guzmán-Mar, J. L., Peralta-Hernández, J. M., & Hernández-Ramírez, A. (2011). Performance of the photo-Fenton process in the degradation of a model azo dye mixture. Photochemical & Photobiological Sciences, 10(3), 332-337.
27. Parida, K. M., & Pradhan, A. C. (2010). Fe/meso-Al2O3: An efficient photo-Fenton catalyst for the adsorptive degradation of phenol. Industrial & engineering chemistry research, 49(18), 8310-8318.
28. Fukushima, M., Tatsumi, K., & Morimoto, K. (2000). The fate of aniline after a photo-Fenton reaction in an aqueous system containing iron (III), humic acid, and hydrogen peroxide. Environmental science & technology, 34(10), 2006-2013.
29. Chen, F., He, J., Zhao, J., & Jimmy, C. Y. (2002). Photo-Fenton degradation of malachite green catalyzed by aromatic compounds under visible light irradiation. New Journal of Chemistry, 26(3), 336-341.
30. Nogueira, R. F. P., Silva, M. R. A. D., & Trovó, A. G. (2005). Influence of the iron source on the solar photo-Fenton degradation of different classes of organic compounds. Solar Energy, 79(4), 384-392.