iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** VIII **Month of publication:** August 2022

DOI: https://doi.org/10.22214/ijraset.2022.46495

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

Review on Recent Technologies for Industrial Wastewater Treatment

Priya Vithalani[1], Ankita Murnal[2], Parthvi Akheja[3], Unnati Yagnik[4], Nikhil Bhatt[5]
[1, 2, 3]C.U. Shah Institute of Life science, C. U. Shah University, Wadhwan, Surendranagar, Gujarat, India
[4]Atmiya University, Rajkot, Gujarat, India
[5]Department of Biogas Research and Microbiology, Gujarat Vidyapith, Sadra, Gandhinagar, Gujarat, India

Abstract: Textile industry plays key role in any country for its basic needs and urbanization. Due to high demand in textile area, it generates massive amount of toxic wastewater. Generated wastewaters possess impurities and toxicity because of textile dyes containing complex organic chromophore groups. Direct release of wastewater creates lots of environmental issues. Treatments of textile effluent is not easily carried out by physical, chemical and biological methods without any affect. Nanoparticle mediated degradation trending presently but it contains metallic harmful effect so, further study cannot be focused on nanoparticles. However, biological methods are more reliable and environmental friendly for treatment. Various aerobic and anaerobic techniques were developed for treatment of textile effluent. In pilot scale study, researchers had established different types of bioreactors and tried to apply it on large scale in industries. Still, that methods are not that much efficient at large scale. So, advancement of treatment must be carried out by investigator such as microbial fuel cell reactors and biological integration with different physical and chemical processes.
Keywords: Textile effluent, Bioreactor, Microbial fuel cell, Toxic effect, nanoparticles

I. INTRODUCTION

After the Second World War, industrialization and globalization began worldwide. Due to the development of industries, many synthetic compounds are generated as per the requirements of various products for humans. Many industries such as textile, printing, chemical, and pharmaceutical industries had started the production of different chemicals and generated large amounts of wastewater [1]. The effluent of the industry has major issues due to its composition. The wastewater of the textile industry is having high color intensity, Total solids, Biological oxygen demand, chemical oxygen demand, metals, and salts [2]. Also, wastewater is enriched with nutrients such as carbohydrates and proteins, discharge could create eutrophication in the aquatic ecosystem. According to the world health organization, 30 % of human diseases and 40 % of illnesses arise due to the consumption of polluted water [3]. So, treatment of wastewater and reuse of water is obligatory. Treatment of wastewater is difficult due to compounds present in wastewater are complex in structure having recalcitrant property, it cannot degrade easily. Many conventional methods are utilized but methods have their advantages and disadvantages. Most advantages method included different biological methods for degradation, which is one of the environment friendly approach. Recently, major textile industries utilizing biological approaches rather than chemical and physical methods. The reason is after the treatments biological methods can create negligible end products.

II. TREATMENT STRATEGIES TO TREAT TEXTILE WASTEWATER

Textile industry plays important role to fulfil the need of basic requirement of humans. So, these days textile industry has their large contribution in globalization. But the waste come from this industry having serious environmental issue. Treatment of this waste is a one of the difficult tasks.

A. Physical Method

Adsorption is a one type of physical process on which molecule are adhere to surface of other molecule by the Van der waals attraction force. The process may be physical, chemical and biological. In ancient time carbon was utilized as an adsorbent. This process widely used in water purification. Now a days this process adapted by different industry to remove a toxic compound. [4] was experimented adsorption of Erythrosine B by fungus biomass of *Rhizopus arrhizus*. In their study they tested various parameters related to adsorption process. They had treated the waste with different treatment and maximum adsorption was found 355.9 mg/g and 363.6 mg/g in waste and acid treated waste biomass based on Langmuir adsorption isotherm.

Coagulation and flocculation are physical treatment for removal of large molecular weight compound from wastewater. Many metallic compounds are utilized for the treatment of textile wastewater. But the techniques are not beneficial for soluble compounds and low molecular weight compounds. [5] was carried out treatment of wastewater with ferrous sulphate as coagulant. The results showed that the technique was not much useful to remove dissolved organic compounds. [6] used aluminium sulphate and polyacrylamide as coagulant and flocculant, respectively for the treatment of wastewater.

Membrane process are utilized for the removal of dyestuff from textile wastewater. In this technique, membrane pressure is helpful to remove dyes from wastewater. Limitation of technique is cost, special equipment and fouling of membrane [7]. Polysulfon based membrane were utilised for removal of reactive dyes and salts in textile wastewater experiment performed by [8].

B. Electrochemical Process

Electrochemical process for the removal of Rhodamine B dye. They had used different electrolytes for the process and optimised process parameters.

The results were showed that complete degradation of Rhodamine obtained after 35 min, concentration of electrolyte 0.05 M, pH 7.0 and current density 10 mA/cm^2. Characterization of sludge was carried out by FTIR spectra and morphology was found with SEM analysis [9]. Similarly, studied electrochemical process for the removal of Disperse yellow 3 textile dye. They had used different electro catalytic materials. The optimised result found in boron dropped diamond used as an anode, Na_2SO_4 used as electrolyte, 50 % of color of dye removed by this process [10].

C. Nanoparticles Mediated Degradation

In recent trends nanoparticles are used in wastewater treatment for the removal of hazardous dye. The size of nanoparticle can be measured in nm so, high surface area is providing better chemical reaction. Four classes of functional nanoparticles were utilised for wastewater treatment namely is dendrimers, metal contain nanoparticles, zeolites and carbonaceous nanomaterials. Different combination of particles is synthesized by chemical method which have high efficiency for the removal of dyes [11].

D. Hybrid Techniques

Combination of two or more than two techniques are exploited for the treatment of textile wastewater. Combination of electrocoagulation and Nano filtration and the results of combination of methods showed positive impact on treatment of wastewater [12]. Combined methods were studied electrocoagulation followed by ozonation for removal of organic compound from textile effluent [13].

E. Biological Mediated Degradation

In the recent era of the research biological method are used for the degradation of textile dye effluent. It is a very reliable and eco-friendly approach for the treatment. The drawback of physicochemical treatment have high cost, high energy consumption, produce toxic sludge and having low reliability and efficiency. Microorganisms have their high efficiency for the removal of dye from textile effluent. Removal of dye by microorganisms having two different ways, one is adsorption on microbial biomass and second is degradation with the help of enzymes [14].

The degradation strategy of dye by bacteria, fungi, yeast and plant are different based on their growth pattern. In textile industry, Azo dye is one of the largest groups which have high impact in industry. For degradation of azo dye, reduction of chromophore (-N=N) group happen in both aerobic and anaerobic condition. For the degradation of azo dye majorly two classes of enzymes were reported, one is azo reductase and second is Laccases. Azo reductase is a reducing enzyme needs cofactor NADP, NADPH or both as an electron donor. The location of azo reductase is either cytoplasmic or membrane bound. Low molecular weight cofactor NADP or NADPH used as electron donor for redox reaction. Azo reductase can break bond (-N=N) and convert into amines which are colorless, though after the degradation the colored compound become colorless [15]**.** In aerobic and anaerobic condition working mechanism of azo reductase is different. Cytoplasmic and membrane bound azo reductase is exhibiting different mode of action. Azo reductase is sensitive to oxygen, so it can show higher activity in anaerobic condition compare to aerobic one. In aerobic condition, the oxygen is reduced redox mediator instead of azo dye. In anaerobic condition azo reductase can reduce azo dye easily. Laccase is a large group of enzymes majorly found in fungal mediated degradation. Laccase is copper contain multimeric glycoproteins. Laccase is used to oxidize aromatic compounds and generates free radicals which are useful in further degradation of compound**.**

III. LABORATORY SCALE RECTORS

In recent times biological reactors are widely used for the degradation of diverse textile dye effluent. To develop the reactor some basic things are taken such as, growth pattern of organism, oxygen requirement, operation cost, pH and temperature control, scale up and establishment cost. Various type of biological reactors were developed such as, aerobic, anaerobic, sequential, Hybrid, MFC and semi-continuous for treatment of high strength wastewater.

A. Aerobic reactors

To treat the textile effluent [16] carried out membrane bioreactor in their study. Microbial community IHK22 was utilized to treat the effluent in membrane bioreactor. Reactor performance was achieved 90 – 100 % degradation with dye concentration of 1.25 – 2.5 mg. g_{MLVSS}^{-1}. d^{-1} with 8 g_{MLVSS}^{-1}. d^{-1} biomass. Similarly aerobic reactor performed by [17] aerobic granular reactor was fed with reactive blue 59 with higher load upto 5 g/L. Effective removal of dye was obtained at 12 h.

B. Microaerophilic reactors

The reactive azo dye degradation under microaerophilic condition. They used down flow fixed film bioreactor for degradation of textile wastewater. Reactor was started with 7200 mg/L of COD with dye concentration of 300 mg/L. Performance analysis of rector found 97 % COD removal and 99 % color removal in 24 h of HRT with organic loading rate 7.2 kg COD m^3/d. Degradation of dye was confirmed with different analytical methods [18].

C. Anaerobic reactors

Laboratory scale anaerobic baffled reactor combined with down flow hanging sponge reactor with total volume 10 L and 4.14 L, respectively. Synthetic wastewater was containing 300 mg/L of COD. In performance of reactor 90 % of COD and 58 % decolorization was achieved [19]. Anaerobic dynamic membrane bioreactor. The performance of rector was good in terms of 98 % COD removal and 97 % color removal [20]. Sequential anaerobic reactor for degradation of reactive red 2, potent dye removal efficiency noted with methane gas production [21].

D. Sequential reactors

Performance of aerobic granular sludge batch reactors with aerobic and anaerobic treatment. Two reactors developed in batch, one was supplemented with dye and another was selected as control. Aerobic granular sludge was settled in both the reactors. More than 90 % of stable dye removed with anaerobic- aerobic reactor with azo bond reduction. More than 70 % degradation was achieved in anaerobic phase [22]. Similar study found in [23] performed sequential rector of anaerobic followed by microaerophilic condition. Operation of reactor was started with 10000 mg/L of COD and 3330 mg/L of BOD. Results was obtained as anaerobic phase 60 % of COD and BOD removed in minimum 2 days HRT and sequentially with Consortium BDN 97 % of COD was removed under microaerophilic condition in 12 h HRT. All over 99 % of color removed in 60 h HRT in combined process.

IV. ADVANCED TECHNOLOGY FOR TREATMENT OF TEXTILE WASTEWATER

Textile industry is a major source of environmental pollution the reason was producing large amount of wastewater per year. Due to that crisis of water is a major issue and toxic compound present in waste creating environmental issue. Generation of large amount of wastewater is a major concern for environmentalist. Modification in treatment is necessary to treat that huge amount of wastewater.

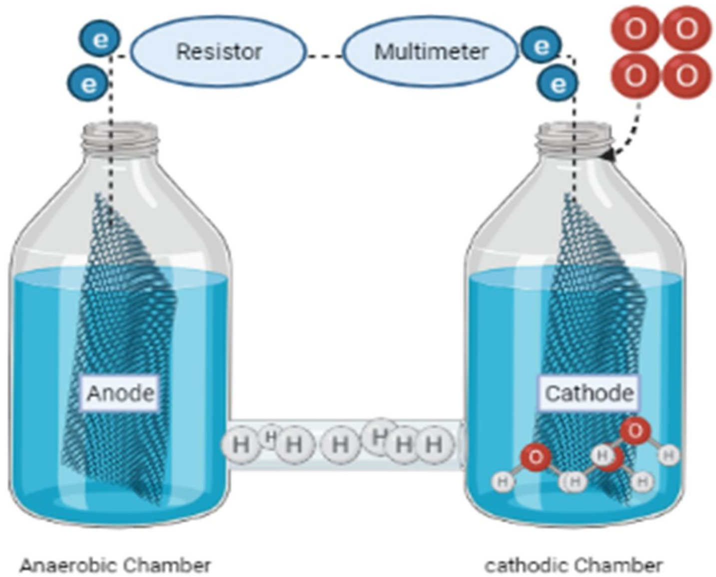
Now a days many integrated approaches are used such as microbial fuel cell. Microbial fuel cell integrated with some other physicochemical process which gives better results in terms of treatments.

A. Microbial Fuel Cell (MFC)

Microbial fuel cell is based on electrochemical systems which exploiting microorganisms to work as catalysts. Microbial fuel cell having two compartments, one is anaerobic and another is aerobic. It comprises device with anaerobic system based on redox reaction which generates electricity. In anaerobic condition the toxic compounds convert into aromatic amines which are reduced in aerobic condition. With the degradation of compounds electrons are generated which are measured by electronic device. The detail design of rector is given in Figure 1

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VIII Aug 2022- Available at www.ijraset.com

Figure 1 Design of Microbial Fuel Cell



Constructed MFC in parallel arrangement, series and individual. The treatment and electricity generation were studied. Parallel arrangement was shown maximum electricity generation as well as treatment. COD reduction was observed upto 82 % and removal of dye was observed upto 74 % with power density 7 mW/m^2 [24]. Similarly performed two chamber MFC for simulated textile wastewater embedded with Remazol Brilliant Blue R. The fungal strain *Pleurotus ostreatus*, Laccase producer showed higher decolourization 86 % and 60 % of total organic matter was reduced after 20 days of operation [25].

Sulfate reducing mixed communities for degradation of textile dye in MFC. The results of anodic chamber were revealed 85 % COD, dye and sulfate removal. Power density was shown 250 mW/m^2 with efficient treatment [26]. Similarly, study was carried out two chamber MFC. Anodic chamber was having anaerobic community and cathodic chamber they inoculated laccase producing *Ganoderma lucidum* fungus. Fungus used Acid orange 7 as carbon source and produced laccase and reached at maximum activity 20 U/L on 19^{th} day with 77 % degradation [27].

Different simulated and real wastewater are treated with MFC technique by [28], utilised starchy substrate produced by food processing industry. The substrate was having 22,000 mg/L COD, with this treatment 98 % COD reduction was achieved with power density of 500 mW/m^2. Textile dye effluent treated with MFC and the highest results were presented in 3 days HRT with 95 % COD removal and 1 mW/m^2 [29].

B. Photocatalytic Reactor

Novel rector incorporated with photocatalytic film. Photocatalytic film was synthesised by combination of graphite carbon nitride with titanium oxide immobilised with polystyrene film. The reactor was tested for the synthetic wastewater embedded with Remazol turquoise blue dye. The results were gained 92 % of total organic carbon reduction and 94 % decolourization within 140 min [30]. Constructed continuous flow photocatalytic packed bed reactor employed for two anionic textile dye one is eriochrome black T and methyl orange. TiO_2 was used as packing material in reactor. Under the influence of UV light Eriochrome black T and methyl orange were 99 % decolourised in contact time 6.6 min with flow of liquid were 0.5 mL/min [31]. Similarly, performed UV photoreactor. The combination of ZnO and metals were utilised for photocatalytic degradation of two reactive dyes. Physicochemical characterization was performed, results shown 90 % photocatalytic degradation of reactive dyes in contact time 6 h [32]. Membrane photocatalytic reactor and checked the effect of ZnO nanoparticles in presence of polyethylene glycol. Results of study was shown good efficiency of ZnO particles with ultrafiltration – polypipeazine amide (UF-PPA) membrane for degradation. Maximum results were shown in terms of industrial waste water degradation was 99 %, turbidity removal 100 %, COD removal 97 % with electric conductivity removal 90 % [33].

C. Integrated Technology

Integrated technology for the degradation of wastewater embedded with methyl orange. The two-chamber MFC was coupled with three-dimensional electro Fenton technique. Cathodic chamber was showed high COD reduction up to 80 % in 72 h. The integrated system was shown great efficiency of treatment [33]. Integrated approach for the removal of Remazol navy blue dye with 100 ppm dye solution complete degradation of dye was found in anodic chamber. Degradation of dyes was followed first order kinetics. Intermediated of dye was produced in anaerobic chamber was further degraded with integrated aerobic system. Modified constructed wetlands microbial fuel cell (CWMFC) for the treatment of textile wastewater. Two different CWMFC was constructed, one with reactive oxygen loss dependent (CWMFC+ROL) and another with intermittent aeration (CWMFC+IA). The results were gained as COD reduction 70 % in both the system. The maximum power density 30 and 19 mW/m^2 in CWMFC+IA and CWMFC+ROL, respectively [34].

V. CONCLUSION

Textile industry is having average 50 % role in globalisation, due to increment in textile area it generates huge amount of toxic wastewater. So, treatment of produced wastewater is a difficult task as the waste is contain several toxic dyes. Therefore, removal of that compound is needed for all industrialist. To overcome this problem different technologies are available such as physical, chemical and biological. Now a day's researcher is preferring biological method rather than physical and chemical because of it is less harmful to environment. Various research institutes are developing such technique which are efficient at larger scale. High number of research projects are running by different researcher in this area.

REFERENCES

[1] Vithalani, P., Mahla, P., Bhatt, N. (2022). Treatment of Textile Wastewater by Nanoparticles. In: Muthu, S.S., Khadir, A. (eds) Textile Wastewater Treatment. Sustainable Textiles: Production, Processing, Manufacturing & Chemistry. Springer, Singapore. https://doi.org/10.1007/978-981-19-2852-9_1

[2] Yaseen, D. A., & Scholz, M. (2018). Treatment of synthetic textile wastewater containing dye mixtures with microcosms. Environmental Science and Pollution Research, **25**(2), 1980–1997. https://doi.org/10.1007/s11356-017-0633-7

[3] Machineni L. (2019). Review on biological wastewater treatment and resources recovery : attached and suspended growth systems. water science and technology 2013–2026. https://doi.org/10.2166/wst.2020.034

[4] Salvi, N. A. (2018). Decolorization of Erythrosine B by Rhizopus arrhizus biomass. Applied Water Science, **8**(7), 1–11. https://doi.org/10.1007/s13201-018-0800-0

[5] Rodrigues, C. S. D., Madeira M. L., Boaventura R. A. (2014). Treatment of textile dye wastewaters using ferrous sulphate in a chemical coagulation / flocculation process. Environmnetal technology January **2014**, 37–41. https://doi.org/10.1080/09593330.2012.715679

[6] Sher, F., Malik, A., & Liu, H. (2013). Journal of Environmental Chemical Engineering Industrial polymer effluent treatment by chemical coagulation and flocculation. Biochemical Pharmacology, **1**(4), 684–689. https://doi.org/10.1016/j.jece.2013.07.003

[7] Kiran, S., Adeel, S., Nosheen, S., & Hassan, A. (n.d.). Recent Trends in Textile Effluent Treatments : A Review. 29–49.

[8] Mondal, M., & De, S. (2016). Treatment of textile plant effluent by hollow fiber nanofiltration membrane and multi-component steady state modeling. Chemical engineering journal, **285**, 304–318. https://doi.org/10.1016/j.cej.2015.10.005

[9] Vijayakumar, K., Geetha, S., & Govindaraj, M. (2019). Degradation of rhodamine B dye solution by photoelectrocoagulation treatment techniques. Asian Journal of Chemistry, **31**(5), 1095–1099. https://doi.org/10.14233/ajchem.2019.21803

[10] Salazar, R., Ureta-zañartu, M. S., González-vargas, C., Nascimento, C., & Martinez-huitle, C. A. (2017). Electrochemical Degradation of Industrial Textile Dye Disperse Yellow 3 : Role of electrocatalytic material and experimental conditions on the catalytic production of oxidants and oxidation pathway. https://doi.org/10.1016/j.chemosphere.2017.12.092

[11] Das, J., & Dhar, S. S. (2020). Camellia sinensis mediated synthesis of zero valent iron nanoparticles and study of their efficacy in dye degradation and antibacterial activity. International Journal of Environmental Analytical Chemistry, 1–14. https://doi.org/10.1080/03067319.2020.1828388

[12] Aouni, A., Fersi, C., Ben, M., Ali, S., & Dhahbi, M. (2009). Treatment of textile wastewater by a hybrid electrocoagulation / nanofiltration process. **168**, 868–874. https://doi.org/10.1016/j.jhazmat.2009.02.112

[13] Bilińska, L., Blus, K., Gmurek, M., & Ledakowicz, S. (2018). Coupling of electrocoagulation and ozone treatment for textile wastewater reuse. Chemical Engineering Journal. https://doi.org/10.1016/j.cej.2018.10.093

[14] Jamee, R., & Siddique, R. (2019). Biodegradation of synthetic dyes of textile effluent by microorganisms: an environmentally and economically sustainable approach. European Journal of Microbiology and Immunology, **9**(4), 114–118. https://doi.org/10.1556/1886.2019.00018

[15] Khouni, I., Louhichi, G., & Ghrabi, A. (2020). Assessing the performances of an aerobic membrane bioreactor for textile wastewater treatment: Influence of dye mass loading rate and biomass concentration. Process Safety and Environmental Protection, **135**, 364–382. https://doi.org/10.1016/j.psep.2020.01.011

[16] Kolekar, Y. M., Nemade, H. N., Markad, V. L., Adav, S. S., Patole, M. S., & Kodam, K. M. (2012). Decolorization and biodegradation of azo dye, reactive blue 59 by aerobic granules. Bioresource Technology, **104**, 818–822. https://doi.org/10.1016/j.biortech.2011.11.046

[17] Balapure, K., Bhatt, N., & Madamwar, D. (2015). Mineralization of reactive azo dyes present in simulated textile waste water using down flow microaerophilic fixed film bioreactor. Bioresource Technology, **175**, 1–7. https://doi.org/10.1016/j.biortech.2014.10.040

[18] Nguyen, T. H., Watari, T., Hatamoto, M., Sutani, D., Setiadi, T., & Yamaguchi, T. (2020). Evaluation of a combined anaerobic baffled reactor–downflow hanging sponge biosystem for treatment of synthetic dyeing wastewater. Environmental Technology and Innovation, **19**, 100913. https://doi.org/10.1016/j.eti.2020.100913

[19] Berkessa, Y. W., Yan, B., Li, T., Jegatheesan, V., & Zhang, Y. (2020). Treatment of anthraquinone dye textile wastewater using anaerobic dynamic membrane

bioreactor: Performance and microbial dynamics. Chemosphere, **238**, 124539. https://doi.org/10.1016/j.chemosphere.2019.124539

[20] Wang, Z., Yin, Q., Gu, M., He, K., & Wu, G. (2018). Enhanced azo dye Reactive Red 2 degradation in anaerobic reactors by dosing conductive material of ferroferric oxide. Journal of Hazardous Materials, **357**, 226–234. https://doi.org/10.1016/j.jhazmat.2018.06.005

[21] Franca, R. D. G., Vieira, A., Mata, A. M. T., Carvalho, G. S., Pinheiro, H. M., & Lourenço, N. D. (2015). Effect of an azo dye on the performance of an aerobic granular sludge sequencing batch reactor treating a simulated textile wastewater. Water Research, **85**, 327–336. https://doi.org/10.1016/j.watres.2015.08.043

[22] Balapure, K., Jain, K., Bhatt, N., & Madamwar, D. (2016). Exploring bioremediation strategies to enhance the mineralization of textile industrial wastewater through sequential anaerobic-microaerophilic process. International Biodeterioration and Biodegradation, **106**, 97–105. https://doi.org/10.1016/j.ibiod.2015.10.008

[23] Sonu, K., Syed, Z., & Sogani, M. (2020). Up-scaling microbial fuel cell systems for the treatment of real textile dye wastewater and bioelectricity recovery. International Journal of Environmental Studies, **77**(4), 692–702. https://doi.org/10.1080/00207233.2020.1736438

[24] Simões, M. F., Maiorano, A. E., dos Santos, J. G., Peixoto, L., de Souza, R. F. B., Neto, A. O., Brito, A. G., & Ottoni, C. A. (2019). Microbial fuel cell-induced production of fungal laccase to degrade the anthraquinone dye Remazol Brilliant Blue R. Environmental Chemistry Letters, **17**(3), 1413–1420. https://doi.org/10.1007/s10311-019-00876-y

[25] Miran, W., Jang, J., Nawaz, M., Shahzad, A., & Lee, D. S. (2018). Sulfate-reducing mixed communities with the ability to generate bioelectricity and degrade textile diazo dye in microbial fuel cells. Journal of Hazardous Materials, **352**, 70–79. https://doi.org/10.1016/j.jhazmat.2018.03.027

[26] Lai, X., Guo, R., Xiao, H., Lan, J., Jiang, S., Cui, C., & Ren, E. (2019). Rapid microwave-assisted bio-synthesized silver/Dandelion catalyst with superior catalytic performance for dyes degradation. Journal of Hazardous Materials, **371**, 506–512. https://doi.org/10.1016/j.jhazmat.2019.03.039

[27] Pandey, P., Shinde, V. N., Deopurkar, R. L., Kale, S. P., Patil, S. A., & Pant, D. (2016). Recent advances in the use of different substrates in microbial fuel cells toward wastewater treatment and simultaneous energy recovery. Applied Energy, **168**, 706–723. https://doi.org/10.1016/j.apenergy.2016.01.056

[28] Fang, Z., Song, H. L., Cang, N., & Li, X. N. (2015). Electricity production from Azo dye wastewater using a microbial fuel cell coupled constructed wetland operating under different operating conditions. Biosensors and Bioelectronics, **68**, 135–141. https://doi.org/10.1016/j.bios.2014.12.047

[29] Das, S., & Mahalingam, H. (2020). Novel immobilized ternary photocatalytic polymer film based airlift reactor for efficient degradation of complex phthalocyanine dye wastewater. Journal of Hazardous Materials, **383**(September 2019), 121219. https://doi.org/10.1016/j.jhazmat.2019.121219

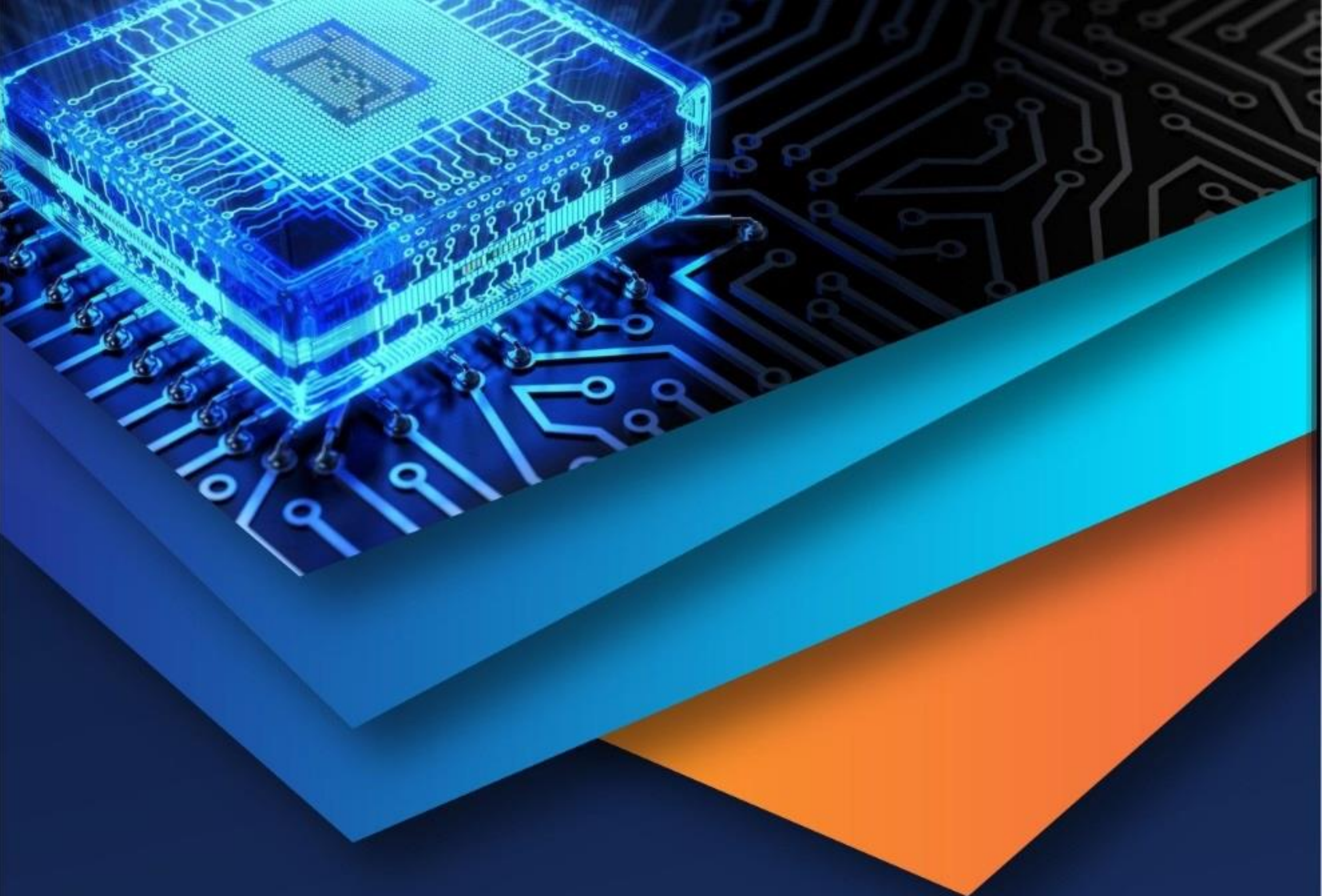
[30] Vaiano, V., Sacco, O., Libralato, G., Lofrano, G., Siciliano, A., Carraturo, F., & Guida, M. (2020). Degradation of anionic azo dyes in aqueous solution using a continuous flow photocatalytic packed-bed reactor: influence of water matrix and toxicity evaluation. Biochemical Pharmacology, September, 104549. https://doi.org/10.1016/j.jece.2020.104549

[31] Rodrigues, J., Hatami, T., Rosa, J. M., Tambourgi, B., Helena, L., & Mei, I. (2019). . Chemical Engineering Research and Design. https://doi.org/10.1016/j.cherd.2019.10.021

[32] Liyana, A., Hanis, N., Hairom, H., Abu, D., Sidik, B., Misdan, N., Yusof, N., Khairul, M., & Wahab, A. (2019). Journal of Environmental Chemical Engineering A comparative study of ZnO-PVP and ZnO-PEG nanoparticles activity in membrane photocatalytic reactor (MPR) for industrial dye wastewater treatment under di ff erent membranes. Journal of Environmental Chemical Engineering, **7**(3), 103143. https://doi.org/10.1016/j.jece.2019.103143

[33] Huang, T., Liu, L., Tao, J., Zhou, L., & Zhang, S. (2018). Microbial fuel cells coupling with the three-dimensional electro-Fenton technique enhances the degradation of methyl orange in the wastewater. Environmental Science and Pollution Research, **25**(18), 17989–18000. https://doi.org/10.1007/s11356-018-1976-4

[34] Srivastava, P., Dwivedi, S., Kumar, N., Abbassi, R., Garaniya, V., & Yadav, A. K. (2017). Performance assessment of aeration and radial oxygen loss assisted cathodes based integrated constructed wetland-microbial fuel cell systems. Bioresource Technology. https://doi.org/10.1016/j.biortech.2017.08.026



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)