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Electrochemical oxidation of textile effluents and further treatment by coupled system electrooxidation using *Prosopis cineraria*

Poonam Ojha*[,1] & Rupali Shrivastava[2]

[1]Department of Chemistry, Swami Keshvanand Institute of Technology, Management & Gramothan, Jaipur, India

[2]Department of Chemistry, Vivekanand Global University, Jaipur, India

E-mail: pnmojha@gmail.com

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This paper deals with study of physico-chemical analysis of waste water contaminated by effluents discharge from textile industries of Sanganer town, Jaipur and their treatment using electrochemical method of oxidation using boron-doped diamond electrodes and coupled system of electrooxidation *with Prosopis cineraria*. The degradation of pollutants has been confirmed by estimation of removal efficiencies of various parameters like turbidity, colour, chemical oxygen demand (COD) and biological oxygen demand (BOD) before and after treatment of textile effluents contaminated water.

Keyword: Biological oxygen demand, Boron-doped diamond electrodes, Chemical oxygen demand (COD), Electrochemical method, Physico-chemical analysis, *Prosopis cineraria*, Textile industry, Turbidity

Textile Industry is associated with highest pollutant discharge as it releases most toxic effluents and is responsible to most wide increase in water pollution whole world. Textile waste water contains high concentration of organic and inorganic compound and polymers that gives large amount of suspended solids, strong color varying *p*H. Moreover many of these pollutants are not biodegradable[1]. They are stable in light and high temperature. Thus they deteriorate environment and causes severe health issues. It textile waste water is not properly treated before dumping, they can cause septic conditions, reduces concentration of O_2 in water ecosystem thus affects survival of aquatic life. And when transported to food chain also cause serious effects to humans. Nowadays, there is increasing awareness in development of new techniques or environmental friendly techniques for treatment of textile waste water which were not completely treated by traditional methods.

In recent years, treatment of textile effluents using electrochemical technique is becoming a popular technique. Electrooxidation using electron (clean reagent) removes organic matter by oxidising them using electrical energy completely without generating any secondary pollutants[2]. Electrochemical oxidation process is very simple and cost effective technology for textile waste treatment and environmental decontamination.

Electrochemical oxidation process involves direct and indirect techniques to destroy organic and inorganic pollutants present in dyes. Advanced oxidation process (AOPs) is powerful method to transform dye pollutants into harmless substance. In direct anodic oxidation process surface of anode gives platform for adsorption of pollutants and then their degradation occurs by direct anodic electron transfer mechanism[3]. In an indirect oxidation process, electrochemical generation of strong oxidising agents like ozone, chlorine, hydrogen peroxide takes place which acts as active agents to degrade pollutants.

In this research work, electrodes made up of thin films of boron doped with diamond are used for electrooxidation of dye effluents[4]. These electrodes show low absorption and provide inert surface. They are resistant against corrosion and have high O_2 evolution over voltage. Further green technology of phytoremediation using plant systems is employed for remediation and restoration of sites contaminated by textile effluents[5]. Plant systems can completely remove pollutants using adsorption, accumulation and enzyme-mediated degradation. Thus plants have capacity of assimilation of toxic substances using complex metabolic activity. Many plant species like *Eichhornia crassipes, Cystoseira indica* and *Gracilaria pérsica, Glandularia pulchella, Musa sapientum, Prosopis cineraria Tagetes patula,* *Petunia grandiflora, Salix viminalis* and *Gaillardia grandiflor*a have been found useful in treatment of waste generated from textile industries[6,7].

In this context, species of fast growing small trees found in extremely arid condition of South Asia is *Prosopis cineraria* (Khejri) is suitable for this purpose. It belongs to flowering tree in pea family, Fabaceae. It is a very useful specie as it gives fodder, fuel and shade. It is used in dry lands for sand dune stabilization and soil improvement. It is an ideal plant for phytoremediation purpose as it has high metal accumulation capacity and deep root system[8,9]. Also its ease of propagation and cultivation in hot and dry conditions further makes it most suitable for this purpose. Many methods are used till date for removal of textile effluents from waste water by electrochemical methods using biological procedures till date but use of *Prosopis cineraria* in coupled electrochemical oxidation- phytoremediation of textile effluents is not yet carried out in wide sense[10]. Thus the objective of this research work is to implement a coupled system electrooxidation with *Prosopis cineraria* for treatment of textile effluents and its comparision with electrochemical oxidation process[2].

Experimental Section

Collection of Samples

For analysis of textile effluents waste water samples were collected from textile industries involved mainly in dying and washing from Sanganer, Jaipur. Here this water is not treated by any method and discharged as such in Sewage system. So test samples were collected from this place and then sent to laboratory for refrigeration. These samples were then characterized for physiological analysis.

Electrooxidation treatment

Electrochemical Reactor

In this process an electrochemical reactor consisting of five parallel electrodes made up of Boron-doped diamond in a 1 L cylindrical reactor were used. Among them three electrodes are anode while two are cathode[11,12]. The whole experimental set up is shown in Fig.1.

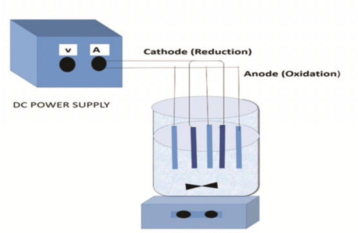

Fig. 1 — Schematic diagram of Electrochemical reactor

Operating conditions

Experiments were performed at varied *p*H (5.45, 7.2 and 11) by applying three different current densities of 4.0 mA·cm^{-2}, 7.0 mA·cm^{-2}, and 10.0 mA·cm^{-2} and reaction time was taken as 400 min.

Procedure

The process of electrooxidation was carried out in batches on the basis of two important factors *p*H and current density. The experimental design is shown in Table 1. After completion of each step, electrode surface is cleaned by dipping in solution of Na_2SO_4 for 1 hr and rinsed with distilled water[3].

Biological treatmemt

Coupled System phytoremediation with Prosopis cineraria

For biological treatment, green coloured wide spread, straight and long branches of *Prosopis cineraria* tree were collected. After that branches were cut with an equal size of 25 cm (approx.) and dipped in 300 mL distilled water in containers of volume 1 L. These containers were first placed in sunlight 12 h and then in dark again for 12 h, and room temperature is kept nearly 20-25°C After that 8-10 branches from above containers were kept in 1 L jars containing 500 mL of oxidised water obtained after electrooxidation treatment, thus making a hydroponic system. These jars were kept as such for 30-40 days. Now at fixed time intervals of 10 days and water fractions were taken from base for carrying out experiments for analysis of parameters. Also, the growth of plants was carefully examined during whole period.

Analysis of parameters

Physicochemical Determination

Physiochemical parameters like *p*H, color, turbidity, conductivity, BOD and COD were determined for textile waste water samples before

Table 1 — Experimental set up of electrooxidation process

Experiment No.	*p*H	Current density mA·cm^{-2}
1	5.45	4.0
2	5.45	7.0
3	5.45	10.0
4	7.2	4.0
5	7.2	7.0
6	7.2	10.0
7	11.0	4.0
8	11.0	7.0
9	11.0	10.0

treatment and after both electrooxidation treatment and coupled system phytoremediation treatment.

Results and Discussion

Physiochemical parameters of textile effluent

At first all the collected samples were analyzed for determination of physiochemical parameters and mean values of each was calculated. Then results obtained were compared with the standard values of parameters given for wastes discharged from textile industries by Central Pollution Control Board (CPCB). The *p*H of tested samples was found to be 8.95 which is much higher. Likewise BOD is found to be 550 mg/L and COD was 1785 mg/L which are also more than limits prescribed by WHO. These values of BOD and COD clearly indicate that oxygen level in water is very low and water is highly polluted. The ratio BOD/COD was found to be 0.3 and it emphasizes to the fact that effluents are not biodegradable.The turbidity was 1212 mg/L, and the color was 1150 Pt-Co U and thus highly coloured liquid effluents were observed.

Electrooxidation treatment

After carrying out electrooxidation treatment at two levels at different *p*H and current densities small fractions of oxidised water were analysed and physiochemical parameters like *p*H, BOD, COD, color, turbidity are determined and their removal efficiencies are calculated. Results of effect of *p*H and effect of current density on removal efficiencies can be seen in Table 2.

Effect of current density

Electrooxidation process mainly depends on current density. It is considered as important parameter for this process. Rate of electro-chemical reactions and performance of electrodes are controlled by it. To study the effect of current density process of electrooxidation was carried out at constant *p*H of 7.2 by applying three varying current densities i.e. 4.0, 7.0 and 10.0 $mA \cdot cm^{-2}$. From the graphs shown in Fig. 2 (a) direct relation between current densities and removal efficiency can be observed[13]. This can be understood by the fact that oxidants like hydroxyl radicals, chlorine etc are generated at higher current densities and hence clear decrease in values of various parameters can be observed[12].

Table 2 — Removal efficiencies of parameters after electrooxidation treatment

Experiment	*p*H	Current density ($mA \cdot cm^{-2}$)	BOD (%)	Colour (%)	Turbidity (%)	COD (%)
1	5.45	4	67.9	60.83	65.6	70.5
2	5.45	7	78.4	75.5	84.6	85.5
3	5.45	10	84	88.9	90.5	90.4
4	7.2	4	80.6	85.5	85.65	80.5
5	7.2	7	87.5	92	85.7	89.4
6	7.2	10	90.0	98.7	99.9	99.5
7	11	4	58.56	65.5	90.6	82.1
8	11	7	94.73	78.5	94.7	92.5
9	11	10	94.38	85.5	98.5	96.3

At current density of 10 $mA \cdot cm^{-2}$, highest removal efficiency can be noted. BOD is reduces from 550 mg/L to 55 mg/L, thus gives 90% removal efficiency, COD is reduced from 1785 mg/L to 85 mg/L and 95% of removal efficiency can be seen. Colour is reduced from 1150 Pt-Co U to 15 Pt-Co U, 98.7% removal efficiency is found. Turbidity is reduced from 950 NTU to 5 NTU, thus 99.5% of removal efficiency was observed.

Effect of *p*H

To study the effect of *p*H on the process of electrooxidation, the experiments were performed at constant current density of 3.5 $mA \cdot cm^{-2}$ at three different *p*H (5.45, 7.2, 11) and the results obtained can be seen by observing graphs shown in Fig 3. From careful study of graphs, it is clear that in alkaline medium at *p*H 11, highest removal efficiencies were found. Removal efficiency of BOD was 90%, COD 96.4%, colour 97.8%, and turbidity 99%.

Effect of conductivity

Conductivity of solution initially does not changes much but near the end it increases as number of ions increases during degradation and mineralization in electrooxidation treatment process. Effect can be seen clearly in Fig.4.

Coupled system phytoremediation with Prosopis cineraria

Treatment of oxidised water further with *Prosopis cineraria* for by phytoremediation is found to be very effective in reducing almost all the physiochemical parameters the textile waste water[14]. A complete study of parameters during the whole period of treatment indicates that initially in early days of treatment 8-10 days a slow decrease was observed. But after 20 days of contact time, a noticeable reduction in values of all parameters can be seen from graphs shown in Fig. 5. The reduction of BOD by 36%, COD by 55%, colour by 90.8%, and turbidity by 75% and thus 92% of overall removal efficiency clearly indicates that the coupled system of electrooxidation treatment using phytoremediation with Prosopis cineraria is found to

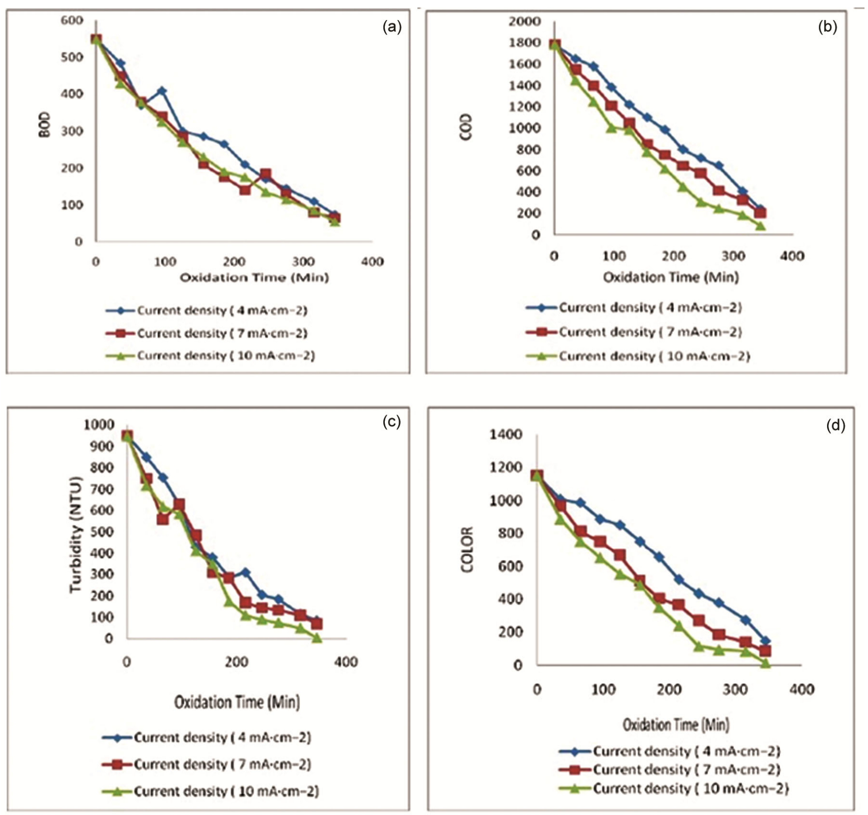

Fig. 2 — Plot of (i) BOD (mg/L) versus Oxidation time; (b) COD (mg/L) versus Oxidation time,m; (c) turbidity (NTU) versus Oxidation time and (d) Colour (pt-Co U) versus Oxidation time *p*H 7.2 at three different current densities of 4 mA cm^{-2}, 7 mA cm^{-2} & 10 mA cm^{-2}

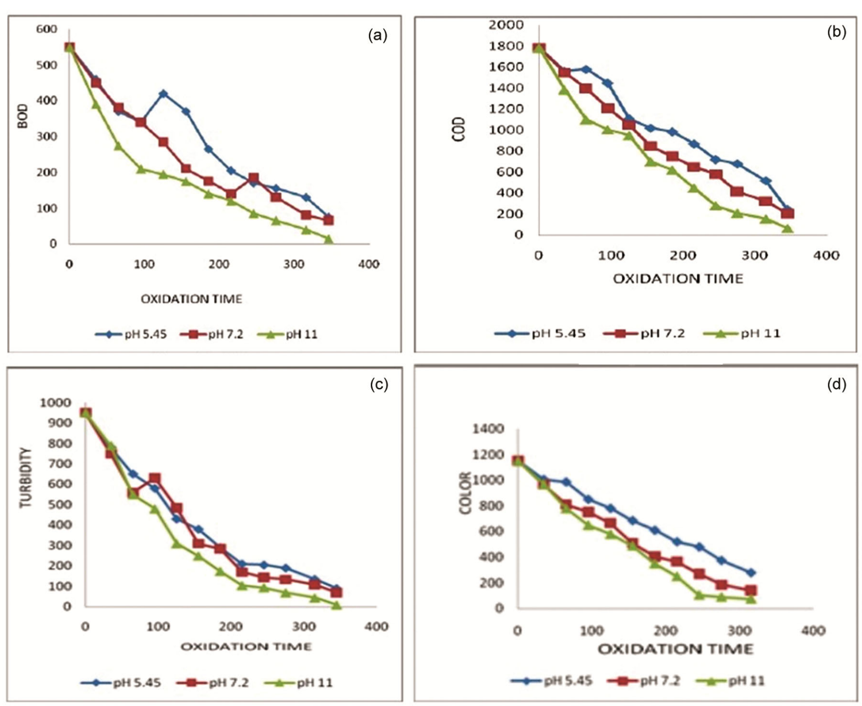

Fig. 3 — Plots of (v) BOD)(mg/L) versus oxidation time, (vi) COD(mg/L) versus oxidation time, (vii) turbidity(NTU) versus oxidation time, and (viii) Colour (Pt-Co U) versus oxidation time at current density of 3.5 mA cm^{-2} at three different *p*H of 5.45, 7.2 and 11.0

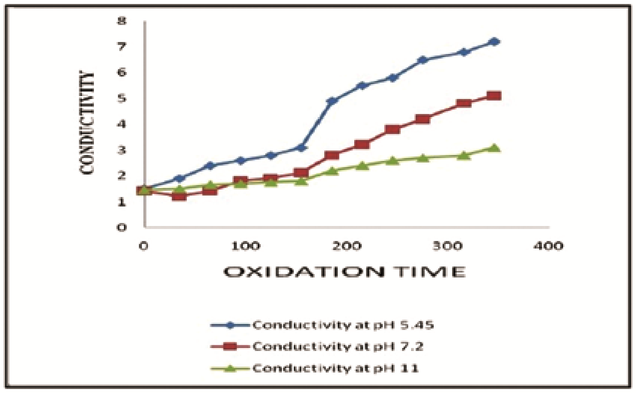

Fig. 4 — Plots of conductivity versus oxidation time at three different *p*H values

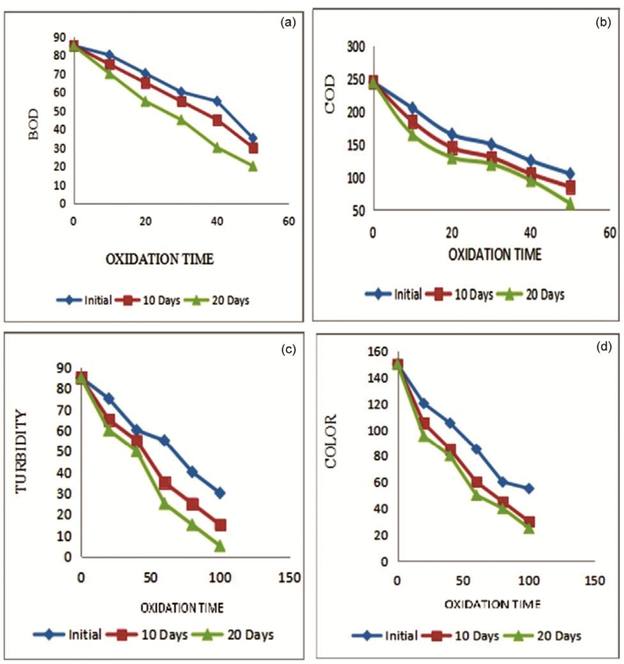

Fig. 5 — Plots of (x) BOD (9mg/L) versus oxidation time, (xi) COD(mg/L) versus oxidation time, (xii) turbidity(NTU) versus oxidation time, and (xiii) Colour (pt-Co U) versus oxidation time coupled system treatment with *Prosopis cineraria* at initial time, 10 days, and 20 days

be very effective method for removal of harmful textile effluents from waste water[15]. Developments of plants were also observed in good numbers.

Conclusion

Water is a valuable natural resource and quality of life we need for our present and future truly depends on our ability to manage the quality of water resources. Effluent discharge from textile contributes a lot in polluting water of these resources.So to maintain water quality parameters it is necessary to degrade pollutants and then discharged in water resources. Though many conventional methods were employed for treatment of waste but electrooxidation and phytoremediation using plant species is one of the economical and environmental friendly methods of removal of textile wastes as shown in present research work.

References

1 Brillas E & Martínez-Huitle C A, *Appl Catal B Environ*, 166 (2015) 603.
2 Ambrogi E K, Asenath-Smith E, Ballard W A, Moores L C & Brame JA, *Cross-Comparison of Advanced Oxidation Processes for Remediation of Organic Pollutants in Water Treatment Systems*, Technical Report, ERDC TR-19-3, January 2019, U.S. Army Engineer Research and Development Center Environmental Laboratory.
3 Eslami A, Moradi M, Ghanbari F & Vatanpour V, *Environ Eng Manag J*, 15 (2016) 2319.
4 Kapałka A, Fóti G & Comninellis C, *Electrochim Acta*, 53 (2007) 1954.
5 Khandare R V & Govindwar S P, *Biotechnol Adv*, 33 (2015) 1697.
6 Cosio C, Vollenweider P & Keller C, *Environ Exp Bot*, 58 (2006) 64.
7 Corseuil H X & Moreno F N, *Water Res*, 35 (2001) 3013.
8 Magdziak Z, Gąsecka M, Goliński P & Mleczek M, *Phytoremediation*, Springer International Publishing (2015) 45.
9 Natarajan R & Manivasagan R, *Environ Eng Res*, 25 (2019) 788.
10 Díaz C B, Morales G R & Chávez A A, *Phytoremediation*, Springer International Publishing, (2015) 335.
11 Fernandes A, Pacheco M J, Ciríaco L & Lopes A, *J Hazard Mater*, 199 (2012) 82.
12 Nava J L, Recéndiz A, Acosta J C & González I, *Water Sci Technol*, 58 (2008) 2413.
13 Simon N, Girard H, Manesse M, Ballutaud D & Etcheberry A, *Diam Relat Mater*, 17 (2008) 1371.
14 Yıldırım K & Kasım G Ç, *Chemosphere*, 194 (2018) 722.
15 Val J, Monge E, Heras L & Abadia J, *J Plant Nutr*, 10 (1987) 995.