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Original Research Article

Electrochemical Studies on Textile Dyes Ortho-Phenylenediamine with Reference to Color Removal by Activated Charcoal

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Abstract

In the present work, the electrochemical study has been carried out on the derivatives of azo and nitro dyes for Ortho-Phenylenediamine (OPD) predominantly used in colorants. The results of the electrochemical study are assessed in terms of decolorisation and reduction in toxicity. Kinetics of decolorisation was monitored and resulted after 15 minutes. This work also comparatively analyzes the decoloration of dyes at pH 10 and pH 6. The Spectrophotometry measures, energy of a substance absorbs at varying wavelengths of light. Transmittance at different wavelength shows the maximum absorbance at 290 nm and also the transparency of the material is maximum. The maximum absorbance is recorded at higher pH 10 for 10 ppm absorbance percentage is 0.329 for 30 minutes. For pH 6 at 290 nm for 10 ppm the percentage transmittance is 51.3 and absorbance percentage is 0.290. Activated Charcoal is best fit adsorbents used for removal of toxic dyes as well as for environmental pollution reduction.

Keywords: Ortho- Phenylenediamine Dye, Decolorisation, Transmittance, Absorbance, Colorants.

INTRODUCTION

Today color minded children of our ancestors make lavish use of color in human history. Not only cloth brilliant but dwellings are bright with color inside and out, magazine covers, wrapping paper. We use color so freely today because coloring materials are abundant and cheap (Borousan *et al.,* 2019). Different colorants in the form of nitro dyes have been identified in surface, rain, sea, drinking and ground water. Ortho-phenylene diamine dyes and its nitro derivatives are used to synthesize azo dyes, contributing brown and black colors in textiles, hair dyes acting as an oxidative precursor for vibrant, and other colour products (Kim *et al.,* 2023; Daneshvar *et al.,* 2005). Due to complex structure and Xenobiotic properties dyes are difficult to degrade. Ortho-Phenylene diamine dyes, precursors have been shown to be carcinogenic and mutagenic (Li *et al.,* 2012). Food products are consumed by human beings because they are nutritive and attractive color. In the world production of dyes in 2015 forecasted to be 2.2 metric tons. Water soluble dyes reduce its transparency (Slokar *et al.,* 1998; Rasheed *et al.,* 2026). Water purification from dyes is tremendous. Dyes pollution reckoned the chemists specially UK, USA, Germany, Japan, etc. for the treatment. Textile inndustry involves substantially high consumption of dyes and approx. 135-145 L of water is consumed for 01 kg textile products thereby produces huge volumes of colored water (Chauhdary *et al.,* 2022; Jeyalakshmi *et al.,* 2018; Robinson *et al.,* 2014). Wastewater originates from industries used for agriculture thereby results into deposits of dye in soils. Some studies reported the negative effect of dyes on soil. The pollutants include suspended solids, biochemical oxygen demand (BOD), COD, heat, color, acidity, basicity and other inorganic contaminants (Teli *et al.,* 2023; Anand 2026; Anand *et al.,* 2025). Colorwastes are hazardous to the environment, living species & human concern due to their high concentrations of pollutants that are extremely toxic.

Thus, appropriate and effective treatment of dye waste water to remove color and dye compounds is important. Several adsorbents used for the removal of organic dyes from aqueous media. Prominent among them are activated carbon, cellulose, and nano composites. Most of these techniques, having high operational costs (Anand *et al.,* 2025; Anand 2026). They produce chemical sludge due to the purifying process and require higher energy consumption. Activated Charcoal is commonly known as activated carbon. This carbon has small, low-volume pores that increase the surface area available for adsorption. It is composed of a microporous, homogenous structure with a high surface area and radiation stability. It has also robust chemical stability, low density, structural diversity, and suitability for field-scale applications. It is also utilized in a variety of applications, including medicine, metals recovery, the food and beverage industry, acute intoxication treatment, water purification, biogas purification, and air emission purification. In water treatment, activated charcoal as adsorbent, thought to be the simplicity, and reusability and efficient approach because of their unique characteristics generally originate from their internal pore morphology, surface characteristics, porosity, pore volume, chemical structure, and presence of functional groups from their source materia (Rahman *et al.,* 2024; Thuy *et al.,* 2025; Danu *et al.,* 2026; Ghosh *et al.,* 2021; Shekho *et al.,* 2025).

Moreover, the purpose of the work was to evaluate the removal efficiency of activated charcoal and color in dye wastewater, as well as to evaluate the maximum absorbance percentage at pH 6 and 10. We investigated the use of adsorbents like activated charcoal in aqueous medium at different pH to determine the absorption capacity and to minimize the toxicity of dyes. Adsorption is another simple facile process extensively used in the treatment of industrial dye effluents. This process involves the movement of dye molecules present in the liquid phase to a solid surface of various adsorbents (Wu *et al.,* 2020; Sarkar *et al.,* 2024; Moosavi *et al.,* 2020).

2. EXPERIMENTAL

2.1 Materials and Methods

The stock solution of 100 ppm ortho-phenylene-diamine (OPD) is prepared by dissolving OPD in deionised water and 10 ppm and 200 ppm solution is prepared by dilution method $V_1N_1 = V_2 N_2$ at pH 6. The pH is reduced from 10 to 6 and by addition of N/2 HCL. 100 ml of 100 ppm and 200 ppm OPD solution is simultaneously treated with 1g activated charcoal at a regular interval of 15 minutes, 30 minutes, 45 minutes and 60 minutes. The residual concentrations are analysed by UV double beam Spectrophotometer Systronics AU 2703. The magnetic stirrer was used for stirring at an rpm of 220.The absorbance of the degraded sample was noted at λmax = 290 nm. Absorbance can be calculated from percent transmittance (%T) using the formula

Absorbance = 2 – log (%T)

Where,

Transmittance (T) is the fraction of incident light which is transmitted.

3. RESULTS AND DISCUSSION

3.1. Results

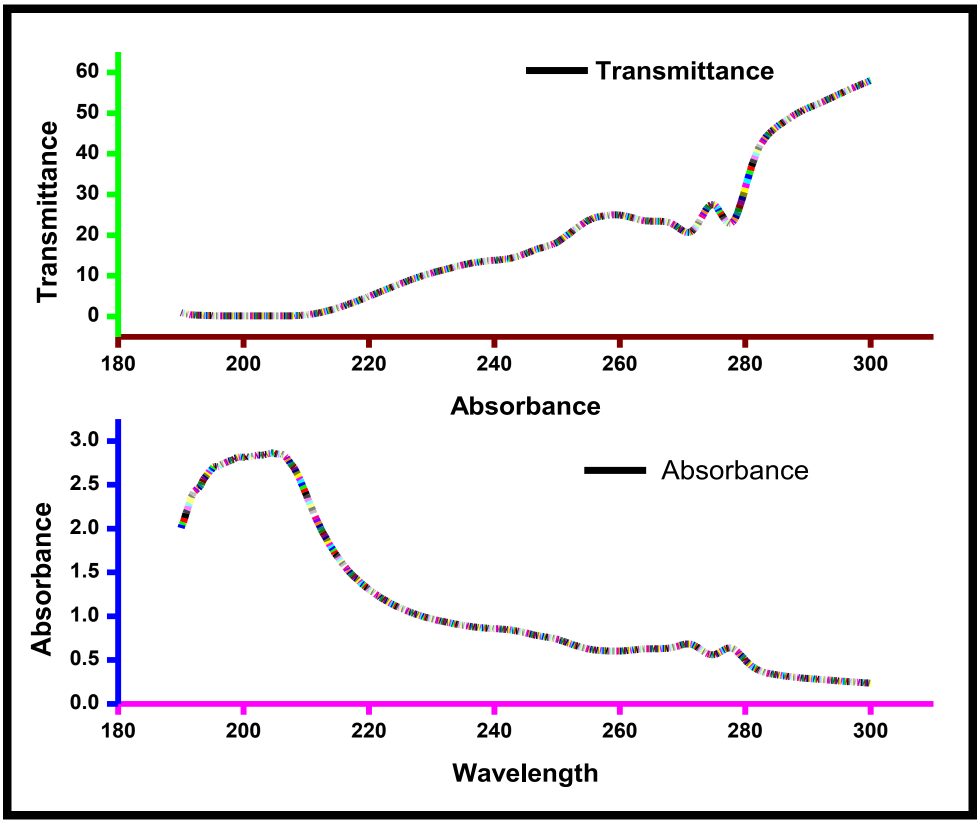

Figure 1(A): Plot of Transmittance Vs Absorbance at initial concentration of 200 ppm at pH 6. Figure(B): Plot of Absorbance Vs Wavelength(nm) at initial concentration of 200 ppm at pH 6

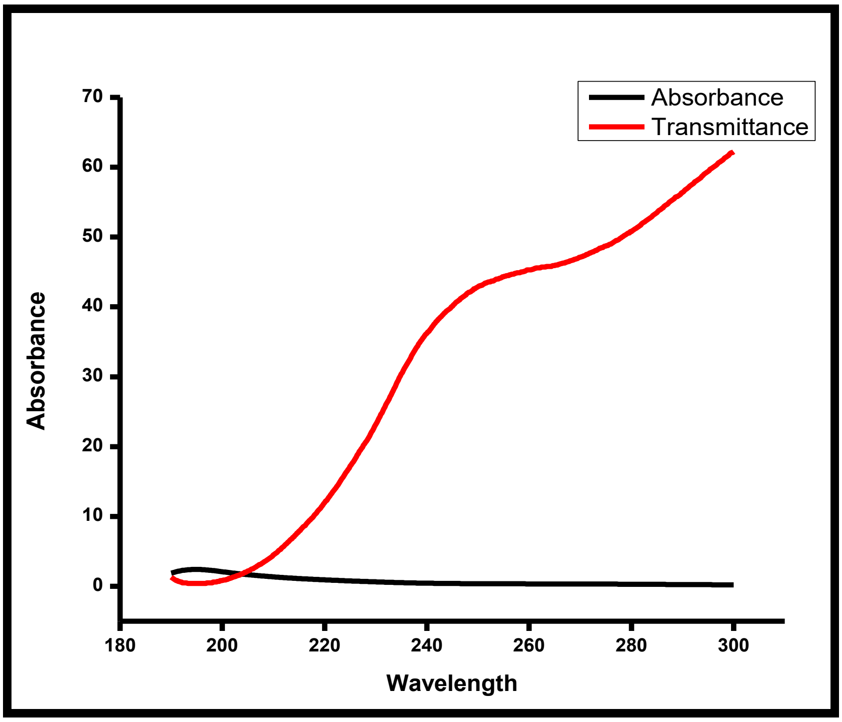

Figure 2: Plot of Absorbance Vs Wavelength at an initial concentration of 10 ppm at 15 minutes at pH 6

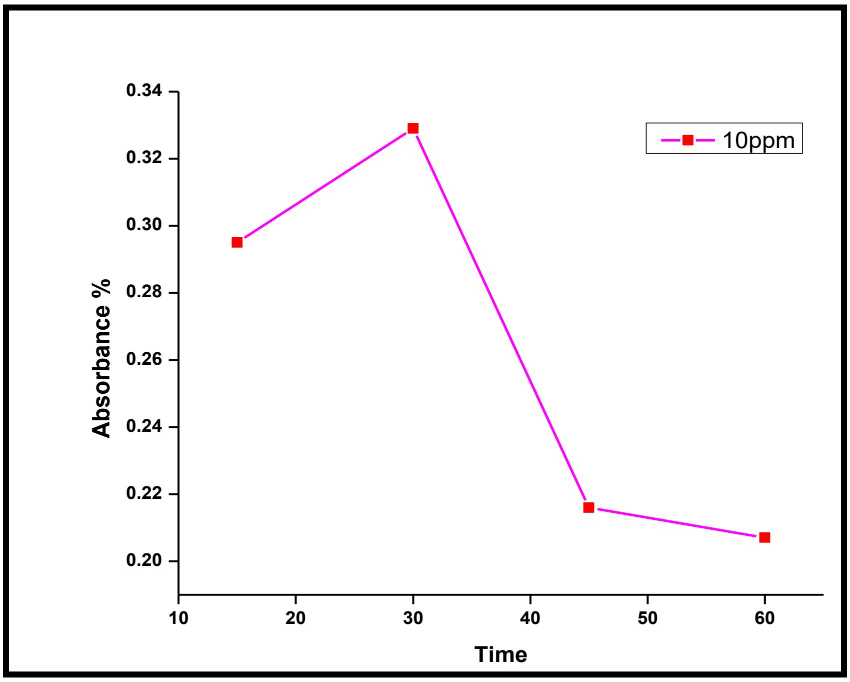

Figure 3: Plot of Absorbance Vs Time at an initial concentration of 10 ppm at pH 10

Table 1: Experimental Data of OPD at 10 ppm for pH 10

Wavelength(nm)	Abs	Trans(%T)	Energy	Energy(100%T)
300.0	0.275	53.1	12658	23839
299.8	0.275	53.0	12648	23878
299.6	0.276	52.9	12645	23911
299.4	0.277	52.8	12640	23939
299.2	0.278	52.7	12625	23970
299.0	0.279	52.6	12615	23998
298.8	0.280	52.5	12598	24029
298.6	0.281	52.4	12591	24053

Wavelength(nm)	Abs	Trans(%T)	Energy	Energy(100%T)
298.4	0.282	52.3	12576	24071
298.2	0.283	52.2	12559	24095
298.0	0.284	52.0	12551	24134
297.8	0.285	51.9	12540	24164
297.6	0.286	51.8	12518	24182
297.4	0.287	51.7	12508	24219
297.2	0.288	51.5	12491	24231
297.0	0.289	51.4	12472	24275
296.8	0.290	51.3	12448	24286
296.6	0.291	51.2	12439	24302
296.4	0.292	51.1	12421	24338
296.2	0.293	51.0	12405	24350
296.0	0.294	50.9	12393	24377
295.8	0.295	50.7	12374	24412
295.6	0.296	50.6	12353	24435
295.4	0.297	50.5	12335	24469
295.2	0.298	50.3	12320	24500
295.0	0.299	50.2	12305	24521
294.8	0.301	50.0	12280	24555
294.6	0.302	49.9	12261	24569
294.4	0.303	49.8	12243	24598
294.2	0.304	49.7	12222	24623
294.0	0.305	49.5	12200	24652
293.8	0.306	49.4	12176	24667
293.6	0.307	49.3	12166	24685
293.4	0.308	49.2	12145	24717
293.2	0.310	49.0	12127	24751
293.0	0.311	48.9	12099	24764
292.8	0.312	48.7	12074	24800
292.6	0.314	48.6	12054	24808
292.4	0.315	48.4	12028	24833
292.2	0.316	48.3	12010	24859
292.0	0.317	48.2	11985	24859
291.8	0.318	48.1	11974	24882
291.6	0.319	48.0	11946	24897
291.4	0.320	47.9	11915	24919
291.2	0.321	47.7	11890	24934
291.0	0.323	47.6	11863	24969
290.8	0.324	47.4	11840	24977
290.6	0.325	47.3	11821	24998
290.4	0.326	47.2	11794	25019
290.2	0.328	47.0	11765	25032
290.0	0.329	46.9	11745	25031
289.8	0.330	46.7	11711	25063
289.6	0.332	46.6	11682	25072
289.4	0.333	46.5	11660	25087
289.2	0.334	46.4	11634	25095
289.0	0.335	46.2	11615	25117
288.8	0.336	46.1	11593	25119
288.6	0.337	46.0	11565	25132
288.4	0.338	45.9	11536	25156
288.2	0.339	45.8	11508	25145
288.0	0.341	45.6	11485	25172
287.8	0.342	45.5	11457	25187
287.6	0.343	45.3	11434	25195
287.4	0.345	45.2	11393	25208

Wavelength(nm)	Abs	Trans(%T)	Energy	Energy(100%T)
287.2	0.346	45.1	11365	25217
287.0	0.347	45.0	11338	25235
286.8	0.348	44.8	11311	25224
286.6	0.350	44.7	11285	25233
286.4	0.351	44.6	11255	25255
286.2	0.352	44.4	11226	25265
286.0	0.354	44.3	11198	25278
285.8	0.355	44.2	11174	25288
285.6	0.356	44.0	11143	25304
285.4	0.358	43.9	11120	25328
285.2	0.359	43.7	11094	25347
285.0	0.360	43.6	11068	25365
284.8	0.362	43.5	11044	25390
284.6	0.363	43.4	11025	25409
284.4	0.364	43.3	11003	25426
284.2	0.365	43.1	10979	25452
284.0	0.366	43.0	10959	25465
283.8	0.368	42.9	10942	25493
283.6	0.369	42.8	10910	25522
283.4	0.370	42.6	10892	25549
283.2	0.371	42.5	10870	25574
283.0	0.373	42.4	10847	25594
282.8	0.374	42.3	10828	25614
282.6	0.375	42.2	10812	25646
282.4	0.377	42.0	10789	25668
282.2	0.378	41.9	10770	25709
282.0	0.379	41.7	10751	25748
281.8	0.381	41.6	10727	25780
281.6	0.382	41.5	10712	25814
281.4	0.383	41.4	10693	25833
281.2	0.384	41.3	10669	25877
281.0	0.386	41.1	10648	25899
280.8	0.387	41.0	10626	25908
280.6	0.388	40.9	10608	25933
280.4	0.390	40.8	10593	25980
280.2	0.391	40.7	10575	25999
280.0	0.392	40.6	10556	26029

Table 2: Experimental Data of OPD at 10 ppm at pH 6

Wavelength	Absorbance	Transmittance (%T)
300.0	0.206	62.2
299.8	0.207	62.1
299.6	0.207	62.1
299.4	0.208	62.0
299.2	0.209	61.9
299.0	0.210	61.7
298.8	0.210	61.6
298.6	0.211	61.5
298.4	0.212	61.4
298.2	0.213	61.3
298.0	0.214	61.1
297.8	0.214	61.0
297.6	0.215	60.9
297.4	0.216	60.8
297.2	0.217	60.7
297.0	0.218	60.6

Wavelength	Absorbance	Transmittance (%T)
296.8	0.219	60.4
296.6	0.220	60.3
296.4	0.220	60.2
296.2	0.221	60.1
296.0	0.222	60.0
295.8	0.222	59.9
295.6	0.223	59.8
295.4	0.224	59.7
295.2	0.225	59.5
295.0	0.226	59.4
294.8	0.227	59.3
294.6	0.228	59.2
294.4	0.229	59.1
294.2	0.229	59.0
294.0	0.231	58.8
293.8	0.231	58.7
293.6	0.233	58.5
293.4	0.233	58.4
293.2	0.234	58.3
293.0	0.235	58.2
292.8	0.236	58.1
292.6	0.237	58.0
292.4	0.238	57.9
292.2	0.238	57.7
292.0	0.239	57.6
291.8	0.240	57.5
291.6	0.241	57.4
291.4	0.242	57.3
291.2	0.243	57.1
291.0	0.244	57.0
290.8	0.245	56.9
290.6	0.246	56.8
290.4	0.247	56.7
290.2	0.248	56.5
290.0	0.249	56.4
289.8	0.250	56.3
289.6	0.251	56.1
289.4	0.252	56.0
289.2	0.252	55.9
289.0	0.253	55.8
288.8	0.254	55.8
288.6	0.255	55.7
288.4	0.255	55.5
288.2	0.256	55.4
288.0	0.257	55.3
287.8	0.258	55.2
287.6	0.259	55.1
287.4	0.260	55.0
287.2	0.261	54.8
287.0	0.262	54.7
286.8	0.263	54.6
286.6	0.264	54.5
286.4	0.265	54.4
286.2	0.266	54.2
286.0	0.267	54.1
285.8	0.268	54.0

Wavelength	Absorbance	Transmittance (%T)
285.6	0.269	53.9
285.4	0.270	53.8
285.2	0.270	53.7
285.0	0.271	53.5
284.8	0.273	53.4
284.6	0.273	53.3
284.4	0.274	53.2
284.2	0.275	53.1
284.0	0.276	52.9
283.8	0.277	52.8
283.6	0.278	52.7
283.4	0.279	52.6
283.2	0.280	52.5
283.0	0.281	52.4
282.8	0.282	52.3
282.6	0.283	52.2
282.4	0.283	52.1
282.2	0.284	52.0
282.0	0.285	51.9
281.8	0.286	51.7
281.6	0.287	51.6
281.4	0.288	51.5
281.2	0.289	51.4
281.0	0.290	51.3
280.8	0.290	51.2
280.6	0.291	51.1
280.4	0.292	51.0
280.2	0.293	50.9
280.0	0.294	50.8

3.2. DISCUSSION

Figure 1 (A and B) shows that at an higher initial concentration of 200 ppm solution and at a fixed wavelength of 290 nm, the percentage transmittance is 51.3 and absorbance is 0. 290.The graph gradually increases and then decreases and again linearly increases. Activated Charcoal which is used as an adsorbent for removal of dye at an higher concentration achieved maximum absorbance at a fixed wavelength.

Figure 2 clearly shows that at an initial concentration of 10 ppm solution, the used adsorbent achieved maximum absorbance 0.249 at a percentage transmittance of 56.4 and at 290 nm. Thus we conclude that at an higher concentration and low transmittance the absortion of the material is maximum.

Figure 3 depicts that the absorbance gradually increases and then decreased and again decrease at an time interval of 15 minutes. From Table 1 & 2, the maximum absorbance at 30 minute is 0.329 and transmittance percentage is 46.9 recorded by spectrophotometer and then linearly decreases upto 60 mintues and the absorbance percentage 0.207 is recorded.

4. CONCLUSION

The chemical oxygen demand concentration of coloured dye solution gradually decreased indicating considerable decrease in toxicity. At an higher concentration and low transmittance percentage, the absortion of the material is maximum. At high pH, activated charcoal reflects the maximum absorbance percentage for 30 minutes. Higher the concentration results maximum absorbance percentage.

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