



Original Article

Electrochemical Colour Removal of Azo Dyes Using Boron-Doped Diamond Electrodes and Silver Nanoparticles as Electrocatalyst

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Azo dyes are carcinogenic and if taken would lead to debilitating adverse health effects in animals, man and aquatic organisms. In this study, novel Boron Doped Diamond (BDD) electrodes coated with silver nanoparticles were applied. Iron (II) sulphate was used as a supporting electrolyte and silver nanoparticles as electrocatalyst to enhance the degradation efficiency. Degradation efficiency was monitored by UV-VIS spectrometry while some of the physico-chemical parameters were determined by standard methods for examination of water and wastewater as outlined in the APHA (2000). The absorption spectra for the four dyes were determined and their λ_{max} ranged between 470 to 590 nm in UV-VIS spectrum. Colour removal of 100% was achieved at the end of the electrochemical degradation. The colour levels of the treated textile wastewater were found to be BDL. The final treated wastewater was compared with National Environmental Management Authority (NEMA) and World Health Organization (WHO) effluent discharge standards for the possibility of re-use or direct discharge to a natural water course. From the study findings, it is evident that the concentration of the dyes considered efficient for colour removal was 10 ppm since there was less power consumption thus economical. An increased concentration from 0.1 to 0.5 g/l of FeSO₄ was added to act as a supporting electrolyte to enhance quick removal of the dye. As the concentration of silver nanoparticles increased from 0 to 8 ppm lowest power of 0.4536 watts within the group mean value of 0.03±0.0023 time (hours) and 0.63±0.0001 current (amperes) was recorded. Therefore, it was concluded that a greater concentration of AgNPs acted effectively as the electrocatalyst to eliminate the barrier during the dye removal process. In all four experiments using different kinds of textile dyes, it was worth noting that an increase in the inter-electrode distance from 2mm to 8 mm led to a decrease in the current production from 1.23±0.0140 A - 0.58±0.0048 A which resulted to a lot of time taken from 0.025±0.0012 hr - 0.723±0.0047 hr. The aspect of temperature was also considered under the above optimal conditions, and at 45°C the removal was faster as there was an increase in the chemical kinetics of the particles in the reaction system. As the pH increased from 4.0 to 7.0, current production increased from (0.21±0.0005-0.24±0.0014 A). From the group, analyzed pH range of 6.5±0.5 was noted to enhance better removal of the studied azo dye from the textile wastewater effluent. The textile azo dye colour was removed to below detectable levels (BDL) and thus could not be detected by human eye after treatment.

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INTRODUCTION

Dyes have got various usages in fields such as pharmaceuticals, food technology, textile industry products, beautification application, chromatography and printing industries (Osemba, 2019). (Zhang et al., 2021a) assert that more than 10,000 varieties of dyes and over 700,000 tons of the said dyes can be produced within a period of one year whereas (Selvaraj et al., 2021a) posit that more and beyond 668,000 tons are made of azo dyes. However, according to (Zafar et al., 2022), of all the azo dyes commonly utilized in the textile industries an amount of not less than 15% are lost and end up in various water bodies. The various categories of dyes are listed as; azo, anthraquinone and triarylmethane, acid dyes, disperse dyes, reactive dyes, mordant dyes (Pinheiro et al., 2022a). They have long life and contain carcinogen components (Ikram et al., 2022). Dyes possess chromophores which constitute delocalized electrons with conjugated double bonds (Kapoor et al., 2021a). They also contain auxochromes referring to substances which are either withdrawing electrons or take part in the donation of electrons changing electron

components and thereby increasing colour of the chromophores (Ngo & Tischler, 2022). Normally chromophores include the following; -C=O, -C=N-, -NO₂, -C=C, whereas the auxochromes include; -NH₃, -OH, -COOH, -SO₃H (Sharma et al., 2024). Textile effluents contain azo dyes which are easily noted by the human eye at a range of 0.1g/l and anything above this level is considered to be harmful to human health, animals and also aquatic organisms living in the water bodies where these azo dyes are discharged occasionally (Dihom et al., 2022). Azo dyes are considered to cause other health challenges like allergies and skin dermatoses (Zhang et al., 2021b). These textile waste waters if not treated have effects on human liver, the respiratory system, the circulation process, the immunity components and the reproduction process in human beings (Alzain et al., 2023). Azo dyes contain the nitro- and the amino-groups which are carcinogenic in nature and lead to the growth of tumors of the liver and other organ systems in living things (Selvaraj et al., 2021b). Thus, their removal is key. The components that constitute the effluents are many; for instance, xylene,

phenol, pH buffer, scouring and discoloration agents, salty water solutes, surfactants, biochemical enzymes, and pH changers (Pinheiro et al., 2022b). Several components explain the reason for the complicated nature of the effluent (Vishani & Shrivastav, 2022). The stability of the dyes results from the complexity of the molecules in the materials which are in the form of aromatic structure (Kapoor et al., 2021b). This calls into question of the effectiveness of physio-chemical decolouration of azo dyes using silver nanoparticles (AgNPs) with Iron (II) Sulphate (FeSO_4). Suvith and Philip (2014) state that, due to their strong and wide spectrum of antimicrobial activities, silver nanoparticles have gained major focus among all nanoparticles. (Shi et al., 2021) further noted that, when the reducing agent, FeSO_4 , is adsorbed on the nanoparticles, its reductive potential decreases. On the other hand, when dye molecules get adsorbed on nanoparticles (Jafari & Rahsepar, 2023), their reduction potential increase, as the molecules are electrophilic in nature (Kotwal et al., 2023) and hence, when both the species are adsorbed on nanoparticles, they become more negative for FeSO_4 molecules and more positive for dye molecule (El-Sayed et al., 2022).

Nanoparticles as Electrocatalyst in Dye Removal

Organic dye substances have harmful impacts on the water bodies when released without proper treatment (Osemba et al., 2024). There have been several attempts to treat these dyes using methods such as incineration, bioremediation and even ozonation (Jafari & Rahsepar, 2023). However, the outlined methods alone have proven to have several demerits like production of severe bad odour in the case of the bioremediation technique

and release of volatile and harmful substances in the case of incineration method (Malekabadi et al., 2022). Metal oxide as an electrocatalyst using zinc dioxide semiconductor has facilitated complete removal of the dyes in waste waters (Huang-Mu et al., 2023). The said nanoparticles help in the conversion of these dyes from their organic nature into water, carbon dioxide and less harmful compounds (Ma et al., 2022). Semiconductors like TiO_2 and ZnO are continuously applied to enhance the complete degrading process of the effluents as a result of their friendliness to the surroundings and the ease of their synthesis (Feng et al., 2024).

Silver Nanoparticles as Electrocatalyst in the Textile Dye Removal

This is an example of a nanoparticle used in the nanotechnologies with their sizes ranging from one nanometer to about a hundred nanometer (1-100 nm). Silver in its pure state occurs in four oxidation numbers, these include 0, +1, +2 and +3 with the greatest electrical and thermal conductivity compared to the rest of the metals. This metal also shows the least resistance. Silver in its metallic structure does not dissolve in water, however, the salts of the metal for instance silver nitrate dissolve in water (WHO, 2002). The concentration of the free silver ions in nature is way too low to cause health hazards according to the statistics provided by the World Health Organization (WHO, 2002). Silver nanostructures acted as electrocatalyst in the degradation of the azo dye in the textile wastewater effluent (El-Sayed et al., 2022) In Kenya, textile industries utilize substantial volumes of water and chemicals for the wet-processing of textiles. With the relaunching of the industry by the government, Waithaka (2017) posits that these chemicals,

ranging from inorganic compounds and elements to polymers and organic products are used for desizing, scouring, bleaching, dyeing, printing, and finishing. In the process, these textile firms release waste water into the water bodies making them unfit for human consumption. An assessment by (Bashir et al., 2023) revealed that the use of synthetic chemical dyes in various industrial processes, including paper and pulp manufacturing, plastics, dyeing of cloth, leather treatment and printing has increased considerably over the last few years, resulting in the release of dye-containing industrial effluents into the soil and aquatic ecosystems (Khan et al., 2023). This had harmful effects on the health and daily livelihood of residents around the industry (Sun et al., 2023). Despite these assertions, much is yet to be done to interrogate the effectiveness of silver nanoparticles on electrochemical colour removal in azo dyes using iron (II) sulphate, hence the study.

Experimental

A sample of 80 ml azo dye model was measured and placed into a 100 ml glass beaker. Boron doped diamond (BDD) electrodes were suspended into the solution and kept apart using an insulator. Electrodes were connected in series with an ammeter. The reaction was carried out to complete colour removal while recording the current and the time taken.

Electrochemical Measurements

There was simultaneous switching on of both timer and source of power as the electrochemical reaction started. The current generated was recorded and after degradation, the two were halted. Then the total time reading documentation

followed. The power consumed during the process was determined by;

$$\text{Power} = \text{Current (A)} \times \text{Potential Difference (V)} \times \text{Time (hours)} \dots \dots \dots \text{Eqn 1}$$

Effect of Voltage

Direct current was applied using an AC – DC converter and varied at two levels of 12 and 24 volts.

Effect of Dye Concentration

A stock solution of each dye was made of 100 ppm. The stock solution was diluted to give different concentrations from 10 ppm up to 50ppm using distilled deionized water. The current generated and time taken for complete removal of the dyes was recorded.

Effect of Silver Nanoparticles

Silver nanoparticles were applied to the dye samples at 0, 2, 4, 6 and 8 mg/L. A 5 ml of each concentration was added to the 80 ml of dye sample and reaction carried out at constant conditions. The time taken and current passed was recorded.

Effect of Current Density

The current density was adjusted in series of 10, 20, 30, 40 and 50 A/m². This was achieved using a stabilized variable rheostat connected in series and addition of SE.

Effect of Inter-Electrode Distance

The distance was varied at four levels; 2 mm, 4 mm, 6 mm and 8 mm. The reaction was then carried out at constant conditions.

Concentration of Iron (II) Sulphate

Iron (II) Sulphate was added in four different concentrations at 0.2, 0.4, 0.6, 0.8 and 1g/L to the sample at constant conditions. The reaction was carried out and time and current recorded.

Effect of Effluent pH

The adjustment of the effluent's pH was done from 4.0, 5.0, and 6.0 up to 7.0 using the pH meter current generated and time taken was recorded.

Degradation Efficiency

Degradation efficiency was monitored by taking a 2-ml treated sample and measuring its absorbance using UV-VIS spectrophotometer at a pre-

determined λ_{max} . The equation for calculating the quantity of dye removed or degraded;

$$R\% = ((A_0 - A_e) / A_0) \times 100$$

Where;

R% is the amount of dye removed,

A_0 is the initial dye absorbance,

A_e is the final dye absorbance.

Results and analysis**Effects of Silver Nanoparticles on Azo Dye Removal**

The study sought to analyze the effects of silver nanoparticles on removal of azo dyes using iron (II) sulphate. Results are shown in Table 1:

Table 1: Effects of AgNPs Concentration, Time, Current and Power Consumption on Azo Dye Degradation

Azo Dye Type	Conc. of AgNPs (mg/L)	Time (hours)	Current (Ampere)	Power Used (Watt-hour)	
				Minimum	Maximum
Reactive Red	0	0.16±0.0100	0.51±0.0107	1.9584	2.1216
	2	0.08±0.0050	0.57±0.0006	1.0944	1.1629
	4	0.07±0.0010	0.54±0.0093	0.9072	0.9360
	6	0.05±0.0076	0.60±0.0057	0.7200	0.9082
	8	0.031±0.005	0.64±0.0057	0.4761	0.4881
Reactive Deep	0	0.18±0.0100	0.48±0.0057	2.0736	2.2148
	2	0.11±0.0231	0.58±0.0081	1.5312	1.8786
	4	0.10±0.0100	0.57±0.0117	1.3680	1.5357
	6	0.10±0.0101	0.54±0.0022	1.2960	1.4327
	8	0.09±0.0113	0.42±0.0010	0.9072	1.1418
Disperse Black	0	0.21±0.0100	0.47±0.0007	2.3688	2.4853
	2	0.16±0.0057	0.49±0.0002	1.8816	1.9494
	4	0.09±0.0113	0.58±0.0018	1.2528	1.5778
	6	0.08±0.0121	0.57±0.0007	1.0944	1.2615
	8	0.03±0.0023	0.63±0.0001	0.4536	0.4885
Disperse Blue	0	0.22±0.0081	0.42±0.0105	2.2176	2.3567
	2	0.14±0.0104	0.49±0.0022	1.6464	1.7766
	4	0.09±0.0151	0.64±0.0028	1.3824	2.3295
	6	0.05±0.0094	0.65±0.0028	0.7800	0.8953
	8	0.04±0.0112	0.60±0.0007	0.5760	0.7459

The test was carried out at 95% level of significance on the hypothesis of whether there is any effect of concentration of the AgNPs on power used, $H_0: CE=0$ Vs. $H_1: CE \neq 0$. The results

from the ANOVA table for the same indicated that the value ($p=0.002349$) is less than ($p= 0.05$) hence we reject the null hypothesis and conclude that subjecting the sample to different concentrations resulted to difference in power used. Therefore, AgNPs had great impact on the azo dye degradation. The greater concentration of 8 ppm of the nanoparticles consumed the least power of 0.4536 watts within the mean values of 0.03 ± 0.0023 hours and 0.63 ± 0.0001 current (amperes) in the case of disperse black. The largest amount of power was consumed in all the four cases of the model azo dyes where the application of the said nanoparticles was not done for instance in the case of the same disperse black with power consumption of 2.3688 watts within the means and standard deviation values of 0.21 ± 0.0100 time (hours) and 0.47 ± 0.0007 current (amperes). Silver nanoparticle has the ability to act as an electro-catalyst due its nano size nature which enhances a large surface area to volume ratio. The explanation is in line with findings of the catalytic properties of silver nanostructures supported on the silica spheres (Sebastian, Andrew, Connr, Aidan & Lior, 2019). In all the four cases where zero (0 mg/L) of the AgNPs was applied low current range of (0.42 ± 0.0105 - 0.51 ± 0.0107 amps) was generated leading to high power consumption hence not economical. Addition of the AgNPs led to an increase in the current generation thus lowering the power consumption in watt-hour given that the reaction would take the shortest time to degrade the chromophore in the azoic textile dyes. Table 1 further illustrated the impact of increasing the concentration of the silver nanoparticles on the reaction rate of each of the azoic dye used in this research.

Effect of Time on Degradation of Dyes

The effect of time was studied by carrying out electrochemical treatments at different time intervals while recording the current in the circuit. Absorbance values were obtained from the UV-VIS spectrophotometer. The determination of the time taken to remove the chromophores of the said dye solutions was done using UV-VIS Spectroscopic analysis at the determined λ max value of the dye. As the removal of dye proceeded, the result was the breaking of bonds holding the chromophores involved, thus the removal of the coloured substances which absorbs UV-VIS radiation at the determined wavelengths, similar observations were made by Guthrie (2003). In all the four azo dye types, it was clear that absorbance decreased with an increase in electrochemical degradation time that resulted in the decrease of the concentration of the dye molecules in the sample solution. This is in line with Beer (1976), who stated that absorbance is directly proportional to the concentration whenever path length and the extinction coefficient are held constant. The figures 1 (a), (b), (c) and (d) below illustrate a trend in which there was decrease in absorbance as the electrochemical time was varied between zero and 50 minutes. This indicated that time was a major factor in the reduction of coloured chromophores of the azo dye. As the dyes mineralization proceeded for a longer time, colour chromophores were reduced and the dye absorbance decreased. Therefore, a time of 50 minutes was considered reliable and economically viable because the absorption spectra for the four dyes had been reduced to value $>97.8\pm 0.34\%$ as the group mean for the four commonly used textile dyes. The WHO (2002) recommends that treatment of textile waste water should be done to

ensure that organic-coloured materials are before discharging to the water course. The results lowered to the levels that human eye cannot detect are shown in the figures 1 (a), (b), (c) and (d).

Figure 1 (a): A plot showing the effect of time on the electrochemical degradation of disperses black dye scanned between 520 nm and 670nm.

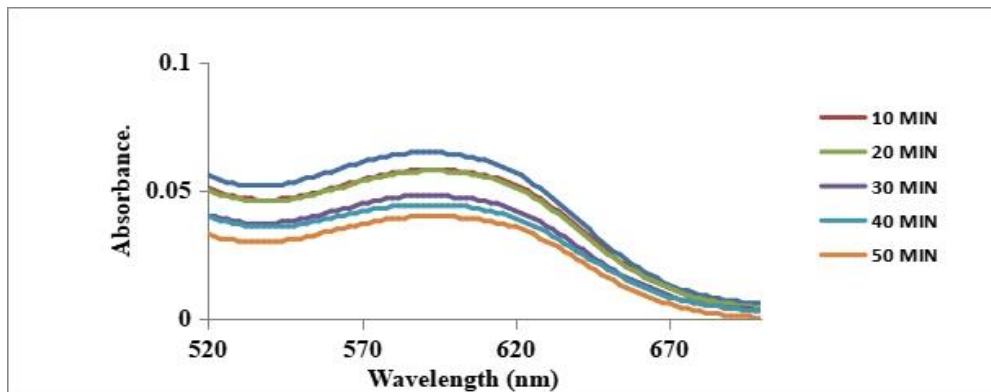


Figure 1 (b): A plot showing the effect of time on the electrochemical degradation of disperses blue scanned between 470 nm and 620nm.

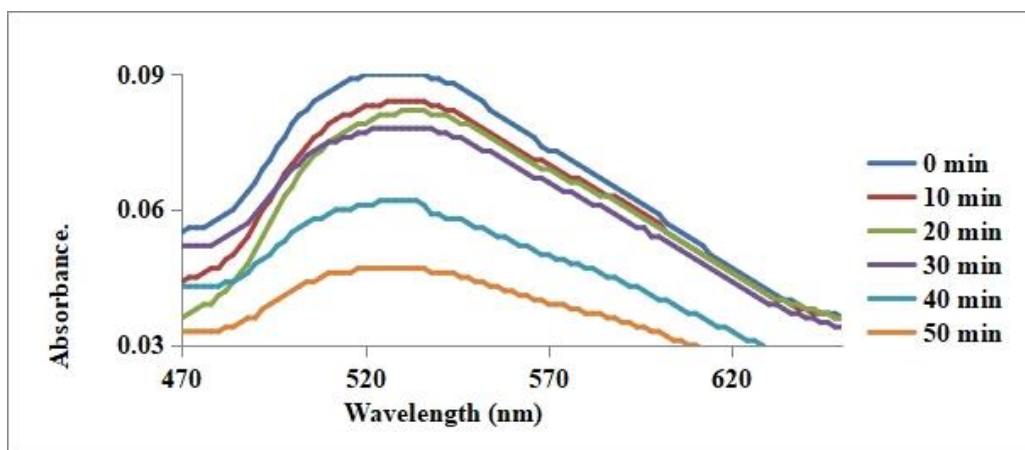


Figure 1 (c): A plot showing the effect of time on the electrochemical degradation of reactive red scanned between 470 nm and 620nm

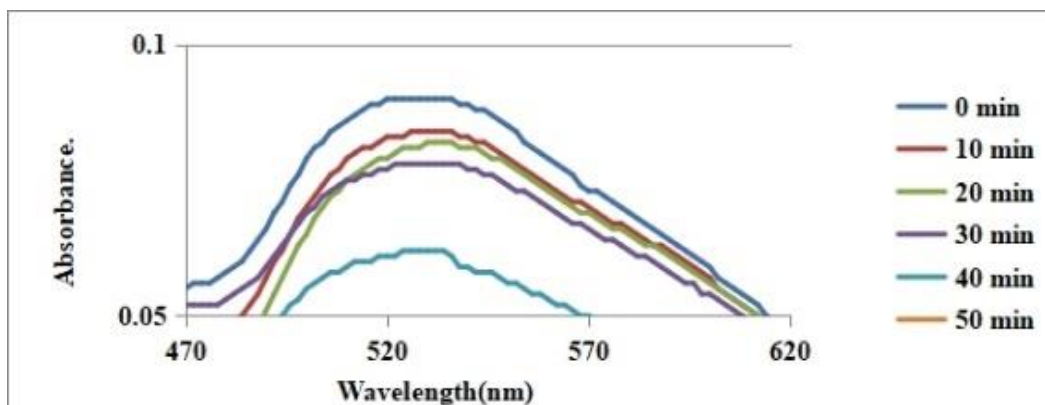
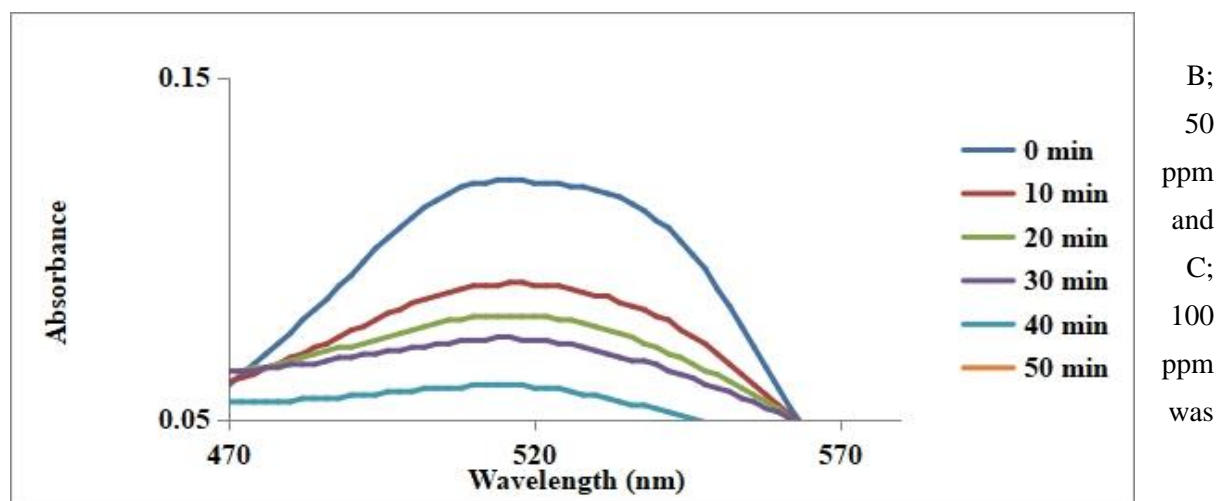


Figure 1 (d): A plot showing the effect of time on the electrochemical degradation of reactive red scanned 470nm and 570nm.



Effect of the Concentration on Dyes Degradation

To observe the effect of initial dye concentration on the dye removal efficiency by electrochemical degradation, experiments were carried out for three different dye concentrations at constant time of 50 minutes. The dye removal efficiency decreased with an increase in the dye concentration. At 50 minutes of operation, the dye removal decreased from 99.87% in 10 ppm to 37.21% in 100 ppm. Hence 100% dye removal was obtained in quick time compared to higher concentration. Hence, it is quite clear that under the present operating conditions, the lower is the dye concentration the better would be the removal efficiency. Zhang et al., 2021b., reported similar results for the removal of reactive dye solutions by EC process. Concentration of the four dyes affected the rate at which the degradation took place with the removal efficiency being best at 10ppm of the dye concentration. The impact of using very high concentrations proved to be otherwise uneconomical due to the high energy consumption. Spectroscopic analysis using different concentrations for instance. A; 10 ppm,

done using the UV-VIS spectroscopy. The dye degradation rate resulted from direct proportionality between the electrochemical reaction time and the concentration of the different dye solutions. The concentration of the dye had consistent effect on degradation trend for the four dyes. The figures 2 (a), (b), (c) and (d) below illustrate the effect of different dye concentrations and their removal using an electrochemical process.

Figure 2 (a): A plot showing effect of concentration on electrochemical degradation of reactive red dye scanned between 420nm and 520nm.

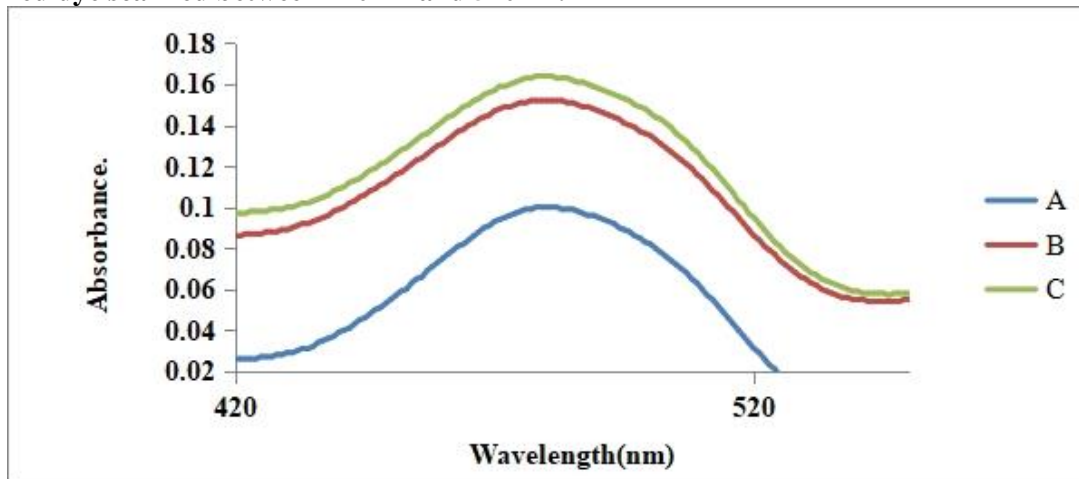


Figure 2 (b): A plot showing effect of concentration on electrochemical degradation of disperse black dye scanned between 420nm and 520nm.

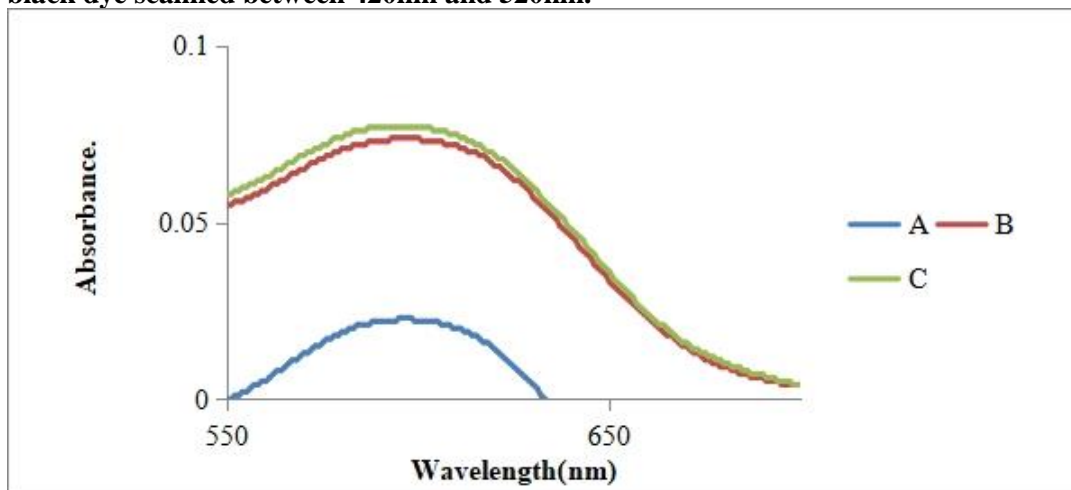


Figure 2 (c): A plot showing the effect of concentration on electrochemical degradation of reactive deep dye scanned between 400nm and 600nm.

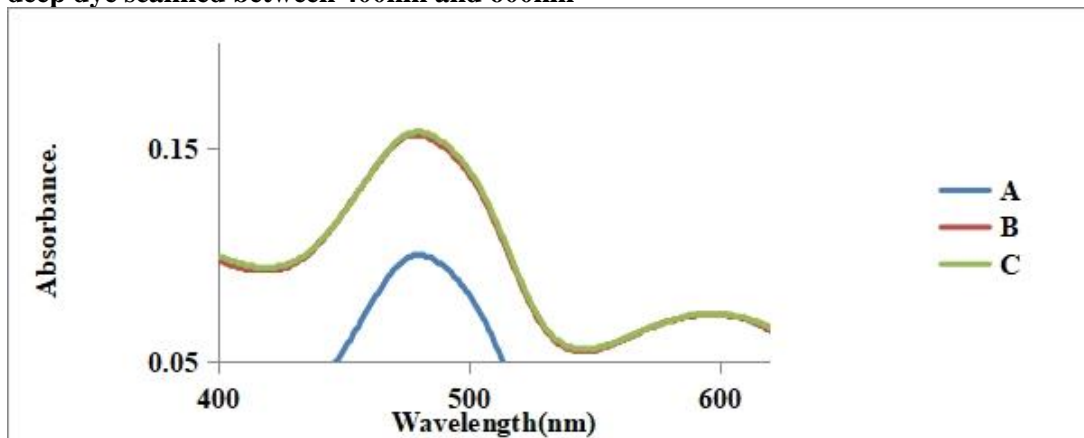
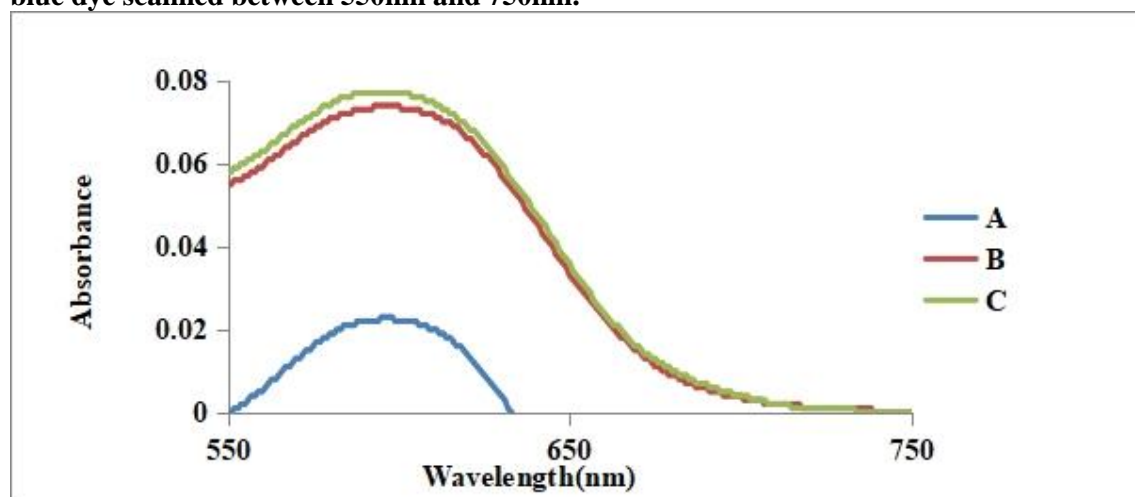


Figure 2 (d): A plot showing effect of concentration on electrochemical degradation of disperse blue dye scanned between 550nm and 750nm.



Effects of addition of Iron (II) Sulphate on Degradation of the Dyes

Iron (II) sulphate acts as support electrolyte. The salt increases the conductivity of the waste water to be treated by electrochemical method. Increase in the salt concentration also increases the ion concentration in the solution and hence reduces the resistance between the electrodes. This was done by taking into account the beginning time

and comparing them to the amount of ion concentration as the electron exchange in this chemical reaction proceeded. There is inverse proportionality between the absorbance of the four dyes and the concentration of the iron (II) salt in g/L. Increase in the salt concentration decreases the cell voltage at constant current density and reduces the power consumption in electrolytic cell (Hameed, Ahmad & Aziz, 2007). This is clearly illustrated by the figures 3 a, b, c, d below.

Figure 3 (a): A plot showing effect of iron (II) Sulphate concentration on disperse blue dye degradation scanned between 450nm and 600nm in the UV spectrum

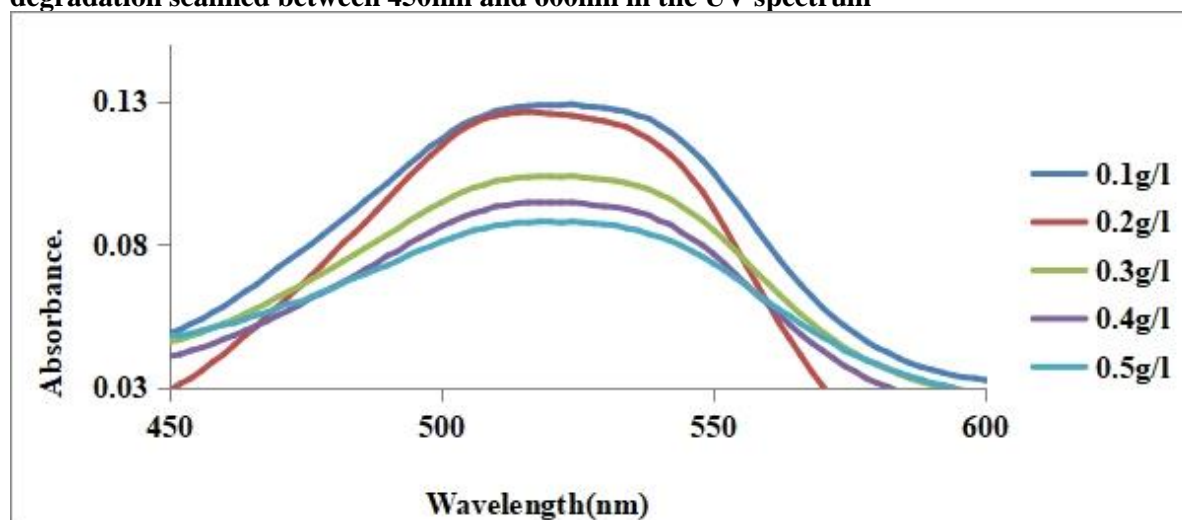


Figure 3 (b): A plot showing effect of iron (II) sulphate concentration on reactive deep dye degradation scanned between 470nm and 620nm

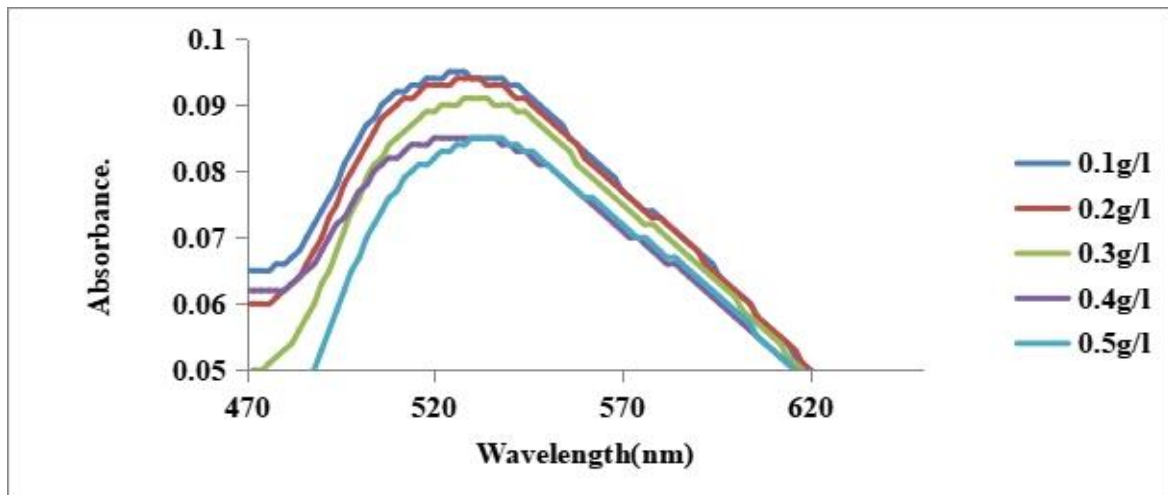


Figure 3 (c): A plot showing effect of iron (II) sulphate concentration on reactive red dye degradation scanned between 420nm and 620nm in UV spectrum.

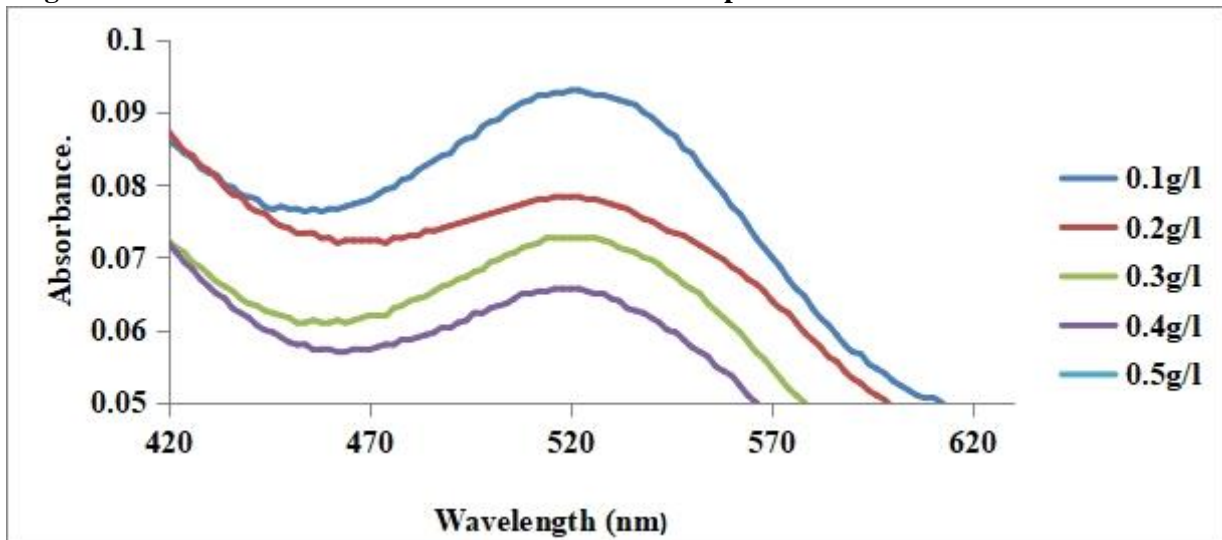
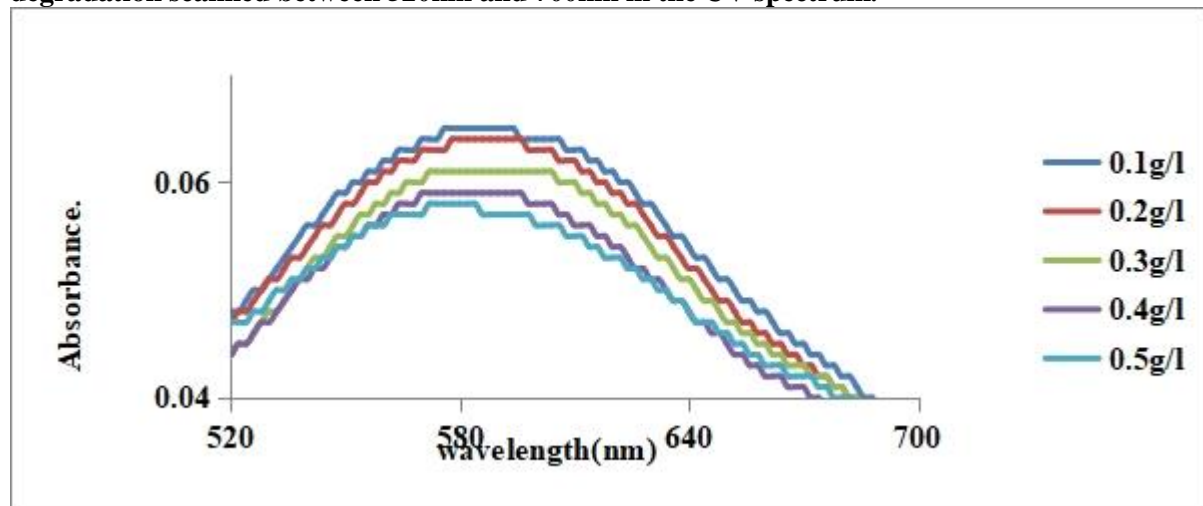


Figure 3 (d): Plot showing effects of iron (II) sulphate concentration on disperse black dye degradation scanned between 520nm and 700nm in the UV spectrum.



Effects of Variation of Potential Difference on Azo Dyes Degradation

Variation of the potential difference of the direct current on the DMM at 12 and 24 volts was necessary. The variation allowed for proper determination of required voltage to ensure effectiveness and efficiency of the azo dye removal. Therefore, the total time and the quantity

of current that the process of colour removal required was taken into consideration in order to determine the optimal conditions for the whole process. The results of the Potential difference applied; time taken, current and power consumption at 12 and 24 V are as shown in the Table 2. Each of the dye gave different values on power consumption at different potential difference.

Table 2: Effects of Variation of Potential Difference, Current and Power Consumption on Azo Dyes Degradation

S/N	Dye	Time (hours)	Pd (V)	Current (Amps)	Power (watt-hour)	
					Minimum	Maximum
1 (a)	R. red	0.83±0.0018	12	0.30 ±0.0021	2.999	3.0154
1(b)	R. red	0.12 ±0.0026	24	0.52±0.0003	1.498	1.5309
2(a)	R. deep	1.17±0.0081	12	0.30±0.0014	4.200	4.2609
2(b)	R. deep	0.14±0.0019	24	0.52±0.0033	1.747	1.8972
3(a)	D. blue	0.78±0.0110	12	0.30±0.0009	2.808	2.8562
3(b)	D. blue	0.10±0.0075	24	0.52±0.0017	1.248	1.3459
4(a)	D. black	0.73±0.0027	12	0.30±0.0037	1.0601	2.672
4(b)	D. black	0.16±0.0010	24	0.52±0.0031	1.997	2.0213

In all the electrochemical processes, applied voltage is the most important parameter for controlling the rate of reaction within the electrochemical system (Cocker et al., 2001). The potential difference as a variable determines the production rate of coagulant, adjusts the polarization issues and affects the of formed flocs (Bazrafshan, 2013). The test was carried out at 95% level of significance on the hypothesis whether there is any effect of variation of potential difference on power used, $H_0: CE = 0$ Vs. $H_1: CE \neq 0$. One-way ANOVA analysis also showed that there is significant difference between the different concentrations of the silver nanoparticles applied to each of the dye and the power consumed in each case for instance ($P=0.016676$) for the reactive red, ($P=0.01147$) for the reactive deep, ($P=0.01750$) for the disperse blue and ($P=0.01261$) for the disperse black. Similar observations were made by Maghanga (2009) who stated that subjecting the sample to the Pd of 12V or 24V had significant difference in power used and that more current was produced where greater voltage was applied that acted as a powerful driving force during the removal of textile dye through the electrochemical process. In Table 2, a greater potential difference of 24V generated the most current of $0.52 \pm 0.0003A$ in the

case of the reactive red dye, $0.52 \pm 0.0033A$ for the reactive deep, $0.52 \pm 0.0017A$ for the disperse blue and $0.52 \pm 0.0031A$ in the case of the disperse black dye compared to that of 12 volts where the current produced by the said azo dyes were as follow; $0.30 \pm 0.0021A$ reactive red, $0.30 \pm 0.0014A$ reactive deep, $0.30 \pm 0.0009A$ disperse blue and $0.30 \pm 0.0037A$ for the disperse black dye. The greater voltage normally increases the current intensity which is necessary parameter in electrolysis which increases the degradation rate linearly (Tabarra *et al.*, 2014). Greater potential difference of 24 volts ensured that time taken to remove the textile waste water dyes was smaller for instance, $0.12 \pm 0.0026hr$ for the reactive red as compared to $0.83 \pm 0.0018 hr$ at a potential difference of 12 volts. The similar trend is observed in the other dyes: $0.14 \pm 0.0019 hr$ at pd of 24 volts and $1.17 \pm 0.008 hr$ at pd of 12 volts in the case of the reactive deep, $0.10 \pm 0.0075 hr$ at pd 24V and $0.78 \pm 0.0110 hr$ at pd of 12V for disperse blue and finally $0.16 \pm 0.0010 hr$ at pd 24V and $0.73 \pm 0.0027 hr$ at pd of 12V for the disperse black dye. These findings affirm the findings of Murphy et al (2006) where the applied voltage was considered to be the thermodynamic driving force for any particular chemical reaction whereby the removal of contaminants rate increased with

increasing voltage used (Murphy et al. 2006) considering chemical reaction kinetics as the limiting rate path.

anode were used at different spacing of 2 mm, 4 mm, 6 mm and 8 mm. Electrolysis condition entailed a potential difference of 24 volts.

Effect of Inter-Electrode Distance, Current and Power Consumption on Dye Removal

The stainless-steel electrodes as cathode and boron-doped diamond (BDD) electrode as the

Table 3: Effect of Inter-Electrode Spacing, Current and Power Consumption on the Degradation of the various Azo Dyes

Dye	Inter-Electrode (mm)	Time (hours)	Current (Amps)	Power (watt)	
				Minimum	Maximum
R. red	2	0.025±0.0012	1.23±0.0140	0.738	0.7822
	4	0.063±0.0134	0.92±0.0051	1.391	1.4285
	6	0.546±0.0065	0.65±0.0034	8.518	8.6641
	8	0.723±0.0047	0.58±0.0048	10.064	10.2134
R. deep	2	0.030±0.0087	1.31±0.1204	0.943	1.3286
	4	0.0792±0.0011	0.87±0.0094	1.654	1.6948
	6	0.651±0.0099	0.67±0.021	10.467	10.9604
	8	1.876±0.0047	0.49±0.0039	22.061	22.9231
D. black	2	0.043±0.0036	0.87±0.021	0.897	0.9965
	4	0.076±0.0082	0.99±0.0118	1.806	2.0224
	6	0.611±0.0032	0.63±0.0243	9.238	9.6449
	8	1.043±0.0033	0.49±0.0245	12.265	12.9197
D. blue	2	0.039±0.0051	1.18±0.0234	1.104	1.2738
	4	0.064±0.0075	0.88±0.062	1.351	1.6165
	6	0.451±0.0014	0.45±0.0057	4.871	4.9478
	8	1.045±0.0033	0.23±0.0019	5.768	5.8344

Table 3 shows that the electrode spacing affects the rate of azo dye degradation. In all four experiments using different kind of dyes, it was clear that an increase in the inter-electrode distance from 2mm to 8 mm led to a decrease in the current production from 1.23±0.0140A - 0.58±0.0048A which resulted into a lot of time taken from 0.025±0.0012 hr - 0.723±0.0047 hr. Therefore, to degrade the reactive red azo dye a lot of power ranging from 0.738-10.2134 watts was utilized in the process. From the ANOVA (P=0.00231) revealed that there were statistically significant differences in the mean inter- electrode distance and power consumption in the reactive red dye. The same trend in the power consumption by the other azo dye types was noted as follows: Reactive deep the current produced decreased from 1.31±0.1204A - 0.49±0.0039A since time taken to remove the said textile dyes increased from 0.030±0.0087hr - 1.876±0.0047hr. The

disperse blue dye had its current generated decrease from 1.18±0.0234 - 0.23±0.0019A as the spacing of the electrodes increased, for the disperse black the decrease in current production was from 0.87±0.021 - 0.49±0.0245A. These trends were similar to the findings of Crespilho (2004). He stated that the distance between electrodes is an important variable to optimize operating cost. The greater the distance between the electrodes, the greater is the difference in the applied potential because the solution presents higher resistivity to the electrical current. The best distance for efficient degradation in all the four cases was at 2 mm inter-electrode distance. The power consumption at this spacing in all the cases was significantly lower compared to the rest. These results on the interelectrode spacing agrees with the findings of Mallah (2014) which indicated that a smaller interelectrode distance as a parameter increases the rate of the said textile

waste water with a reliable factor. According to Daneshvar, Khatae, Amani and Rasoulifard (2007), increasing the electrode spacing reduces the treatment efficiency which can be attributed to the fact that at constant voltage, electrical resistance

Conclusion

The absorption spectra of the four dyes were determined and ranged between the wavelengths of 470 up to 590 nm in UV-Vis spectrum. The disperse black and blue had their highest absorbance at 586 nm and 532 nm wavelengths respectively. The reactive red and deep had their maximum absorption at the wavelengths of 512nm and 476nm respectively. Increasing time from 0 to 50 minutes showed consistency in the reduction of the peaks in terms of their respective absorbance within the same wavelengths. The concentration of the dyes considered efficient for colour removal was 10 ppm since there was less power consumption thus economical. Increased concentration from 0.1 to 0.5 g/l of FeSO₄ was added to act as support electrolyte to enhance quick removal of the dye

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