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Research Article

An Ultraviolet-visible Spectrophotometric Approach to Establish a Method for Determining the Presence of Fluorescein Sodium Dye

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Abstract

This research look over the application of adsorbent as bentonite. Bentonite, aluminum phyllosilicate clay made up of montmorillonite. Montmorillonite known for enormous water absorption and high surface area. Dyeing industries are crucial ecological hazards donating upto twenty percent of industrial water pollution. These industries discharge toxic sewer water containing heavy metals, mutagenic substances, carcinogenic amines, and non-biodegradable chemicals, affects human health and aquatic ecosystems. The contamination of water with toxic dyes poses serious threats to surrounding. Therefore it is mandatory to overcome the environmental challenges with reliable and ability of component and environmental impact. Bentonite having capability to detoxified the harmful substances. It has the dormant for sorption the pesticide endrin possibly due to a combination of hydrophobic and charge-dipole. This study examined the potential of bentonite as adsorbent techniques for treating fluorescein sodium dyes from aqueous solutions. Experiment is done on the particular concentration of 200 ppm and at fixed pH of 2, 4 6, 8 and 10. Results recorded by the systronics spectrophotometer for absorbance Vs wavelength at pH 2 and 10 for fixed interval of time, Absorbance Vs Time, and decolorisation of dye. The performance of bentonite regarding color removal was optimum when the initial pH was 10 for 15 minutes and under ideal circumstances, decolorisation was shown to be 99.97% at alkaline pH. At pH 2 and 4 constant absorbance is achieved by 99.99% for a time intervals of 15 minutes. At an acidic pH the absorbance gradually decreased with respect to time. The spectrophotometric data at a wavelength of 490 nm is 2.683 at pH 10, shows the absorbance of toxic substances. As the wavelength is gradually increased the absorbance is also increased. The response of adsorbent as bentonite for the removal of fluorescein dyes from aqueous solution as well as for healthy environment is excellent and verified.

Keywords

Fluorescein Sodium, Bentonite, Adsorbent, Decolorisation, Absorbance, Dye

1. Introduction

Without a doubt, the treatment of water, which is one of our most essential necessities, is critical [1]. The chemicals found in effluent from industrial activity have a harmful impact on living organisms. Untreated textile effluents are discharged in the drain which deteriorate the water bodies [2-5]. Dyes such as MB, RhB, CR, OPD, PPD, Fluorescein Sodium, Disperse

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Violet 26, MR, and CV are the important sources of industrial pollutants originates from various industries such as the textile, cosmetic, leather, food, pharmaceutical, paint and varnish, and pulp and paper industries and used as colorants [6-9]. The textile industry, as a traditional manufacturing sector, is one of the industries with high labor intensity, large water consumption, and serious pollution. China is the largest exporter of textiles of all kinds, followed by the India, European Union and the USA. World's largest exporter of textiles, China's annual water consumption and wastewater discharge are staggered [10-13]. The American Dye Manufactures Institute stated that dye concentrations in coloured effluents ranges from 1000-1500 ADMI units. Composition of wastewater is extremely complicated, usually containing acids, bases, dyes, hydrogen peroxide, starch, surfactants, dispersants, and other chemical substances, and generally has a strong color and high concentration of organic compounds [14, 15]. Because of poor wastewater management policies of developing countries, 20% to 40% waterborne diseases are caused by industrial wastewater. At present one lakh chemical compounds are produced all over the world, with a total mass of approximately 70 thousand tonnes of dyestuff is manufactured yearly, and the majority of these dyes are organic as well as water soluble. Which results the bad biodegradability [16, 17]. The existence of dyes in the environment has mild to severe toxic effects on human health, including carcinogenic, mutagenic, allergic, and dermatitis effects, kidney disease and toxicity, causing serious harm not only to aquatic life but also no humans. As a result, an efficient dye removal method is imperative to minimize these issues [18].

Accordingly, countless studies have focused on effectively removing organic dyes from wastewater. The techniques utilized for the remediation of dye from wastewater using coagulation / flocculation, electrocoagulation, filtration, adsorption, ion-exchange, advanced oxidation processes (AOPs), activated sludge processes (ASP), sequencing batch reactors (SBR), membrane bioreactors (MBR), moving bed biofilm reactors (MBBR), Chemical Oxidation, Reverse Osmosis (RO), photo- Fenton, Biological Treatment and constructed wetlands (CW). Although these methods can be effective, they often involve high operating costs, the need to use chemical compounds that may be toxic, and in addition to, they can generate secondary pollution.

Throughout the adsorption method is efficient due to its low cost, ease of handling, and energy-saving features. Adsorption methods involve the movement of solids from the bulk liquid to the surface of the adsorbent. The adsorption of dyes is facilitated by hydrogen bonding and electrostatic interactions [19, 20]. The effectiveness of adsorption is determined both by the properties of the adsorbate (dye) and by the properties of the adsorbent—its specific surface area, volume and pore distribution, surface charge, functional groups, easy fabrication, high effective surface area, multi-functionalities, high surface volume ratio, high reactivity, large number of active sites, reusability, low cost, and high efficiency. Among the countless materials tested as adsorbents of dyes from aqueous solutions are: activated carbons, zeolites, metal oxides, natural sorbents such as powdered walnut shells, and, more recently, biochars and bentonite.

Recent studies have been focused on the excellent adsorption capability of bentonite and have extensively utilized it as an adsorbent to remove organic dyes from wastewater. Bentonite has been used in its original form and it is sieved.

2. Materials and Methods

2.1. Materials

The chemicals utilized in this study, including fluorescein sodium dye (C. I. NO. 45350), M. W- 376.28, sodium hydroxide (98%), and hydrochloric acid (37%), were bought from Merck. UV–Visible Spectrophotometer 2703, equipped with a 1 cm (0.5 mL) quartz cell was utilized for recording the absorption spectrum and absorption measurements at a wavelength of 490 nm was employed. pH measurements were conducted using a Systronic digital pH meter with an integrated glass pH electrode. Micropipettes and volumetric flasks of appropriate sizes were employed to quantify the reagents and solution volumes. All measurements were carried out at the University department of Chemistry, India.

2.2. Methods

A fluorescein sodium dye stock solution was prepared by diluting the fluorescein powder with deionized water. Fluorescein sodium dye weighing was performed using a digital balance (SR NO. E-17496, Roy Electronics, Varanasi, India). A 0.2g dye was weighed and dissolved in 10 mL of deionized water in a 1000 mL volumetric flask. The volume was then made up to 1000 mL with deionized water to prepare a 200 ppm stock solution of 1000 mg/L fluorescein sodium dye. Take 100 ml of dye solution and measure the pH, weighed 1 g of bentonite and put in a 250 ml conical flask. Put this flask on the stirrer for proper mixing upto 15 minutes. Then filter the solution by whatman, 125 mm ø filter papers. Similarly, experiment was done for fixed time intervals of 15 minutes and at pH of 2, 4, 6, 8 and 10. Filtrate were analysed by spectrophotometer AU 2703. Each dye was scanned in the wavelength ranging from 190 nm to 600 nm. The absorbance of the degraded sample was noted at λmax = 490 nm.

3. Results

The fluorescein sodium dye absorbed on the surface of adsorbent i.e bentonite. The effect of pH on the adsorption of dye on adsorbent surface, was performed by varying the pH from 2 to 10 of dye solutions by using NaOH and HCl. The absorbance graph (Figure 1) at pH 2 shows that at a wavelength of 200 nm the maximum absorbance is 2.5 for 45 minutes. With the increament of wavelength the absorbance is decreased. From, Figure 2 it reveals that at higher pH 10 and concentration, the absorbance is maximum above 400 wavelength for 60 minutes. Figure 3 depicts that with increase in time upto 60 minutes, at high concentration and basic medium, the absorbance capability of bentonite is maximum. Figure 4 disclose the decolorisation percentage of dye by adsorbent at different time intervals.

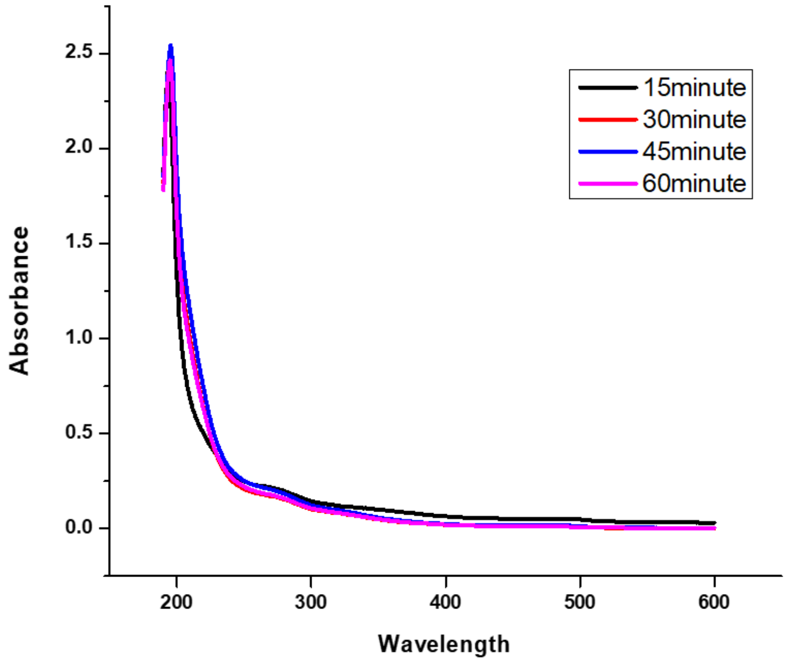

Figure 1*. Absorbance at different wavelength at pH 2.*

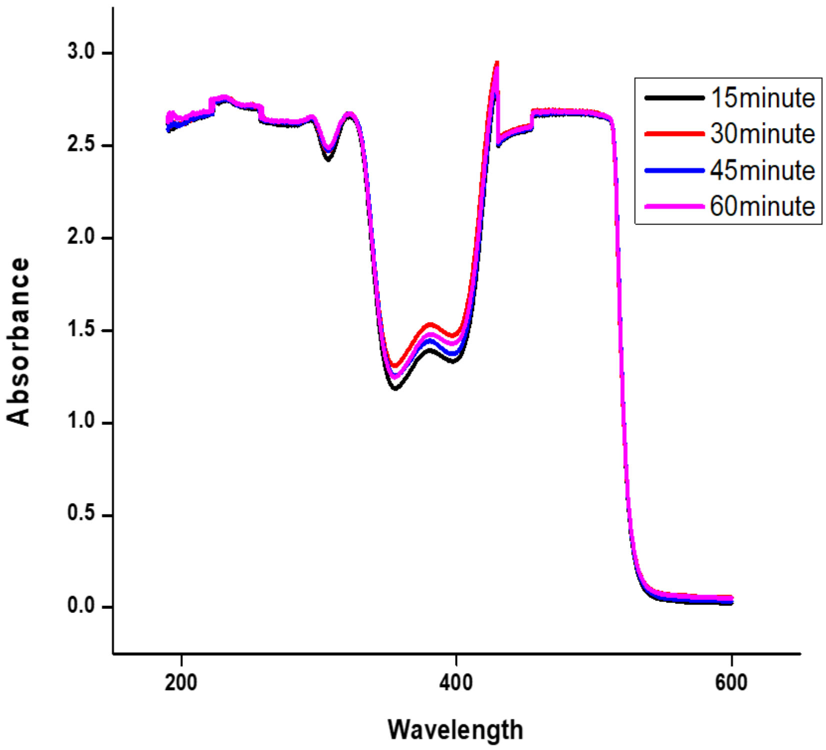

Figure 2*. Absorbance at different wavelength at pH 10.*

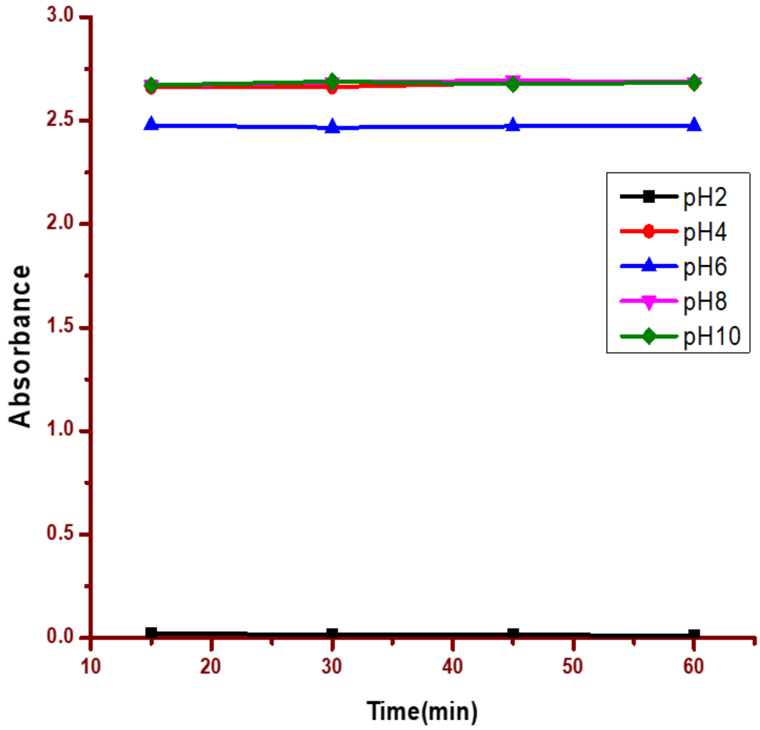

Figure 3. Absorbance at different time intervals and pH.

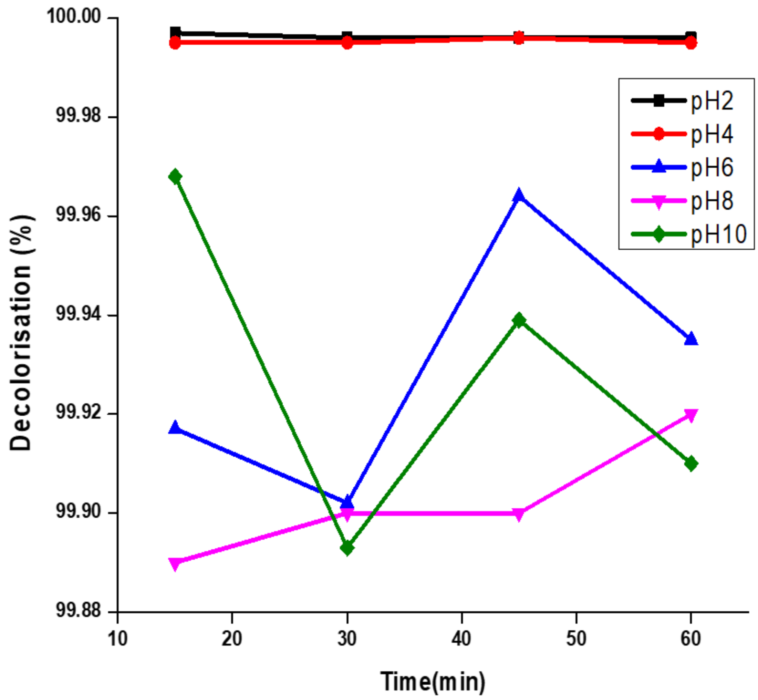

Figure 4. Decolorisation at different time intervals and pH.

The degradation rate was calculated from formula

$$\% \text{ decolorisation} = \frac{C_i - C_t}{C_i} \times 100$$

where, C_i stands for initial concentration and C_t stands for concentration at time t.

Table 1, Reveals the absorbance of fluorescein sodium dye at wavelength range from 400 nm to 500 nm, which is recorded by spectrophotometer. Fluorescein dye has a maximum absorbance wavelength of approximately 490 nm in aqueous solutions, producing a yellowish-green fluorescence. At this wavelength the absorbance 2.683 was recorded. The absorbance is same upto 490.4 nm after 490.6 nm the absorbance is increased for a while and then gradually increase in wavelength results decrease in absorbance value upto 2.675.

Table 1. *Absorbance data for pH 10.*

Wavelength (nm)	Absorbance
500.0	2.675
499.8	2.675
499.6	2.677
499.4	2.676
499.2	2.678
499.0	2.678
498.8	2.679
498.6	2.679
498.4	2.679
498.2	2.680
498.0	2.680
497.8	2.681
497.6	2.681
497.4	2.682
497.2	2.681
497.0	2.681
496.8	2.681
496.6	2.682
496.4	2.684
496.2	2.685
496.0	2.685
495.8	2.684
495.6	2.683
495.4	2.681
495.2	2.681
495.0	2.681
494.8	2.682
494.6	2.683
494.4	2.684
494.2	2.683
494.0	2.681
493.8	2.679
493.6	2.678
493.4	2.679
493.2	2.682
493.0	2.683
492.8	2.683
492.6	2.683
492.4	2.683
492.2	2.684
492.0	2.682
491.8	2.681
491.6	2.681
491.4	2.684
491.2	2.685
491.0	2.685
490.8	2.684
490.6	2.684
490.4	2.683
490.2	2.683
490.0	2.683
489.8	2.684
489.6	2.685
489.4	2.686
489.2	2.684
489.0	2.684
488.8	2.683
488.6	2.684
488.4	2.684
488.2	2.685
488.0	2.684
487.8	2.683
487.6	2.683
487.4	2.683
487.2	2.684
487.0	2.686
486.8	2.687
486.6	2.688
486.4	2.687
486.2	2.687
486.0	2.686
485.8	2.686

Wavelength (nm)	Absorbance
485.6	2.685
485.4	2.684
485.2	2.684
485.0	2.683
484.8	2.684
484.6	2.684
484.4	2.685
484.2	2.684
484.0	2.683
483.8	2.683
483.6	2.682
483.4	2.683
483.2	2.684
483.0	2.685
482.8	2.686
482.6	2.686
482.4	2.686
482.2	2.687
482.0	2.686
481.8	2.685
481.6	2.685
481.4	2.684
481.2	2.684
481.0	2.686
480.8	2.687
480.6	2.687
480.4	2.687
480.2	2.686
480.0	2.686
479.8	2.685
479.6	2.684
479.4	2.685
479.2	2.686
479.0	2.688
478.8	2.689
478.6	2.690
478.4	2.689
478.2	2.688
478.0	2.687

Wavelength (nm)	Absorbance
477.8	2.687
477.6	2.686
477.4	2.686
477.2	2.685
477.0	2.684
476.8	2.685
476.6	2.685
476.4	2.686
476.2	2.683
476.0	2.683
475.8	2.682
475.6	2.684
475.4	2.684
475.2	2.686
475.0	2.686
474.8	2.686
474.6	2.685
474.4	2.684
474.2	2.684
474.0	2.683
473.8	2.684
473.6	2.685
473.4	2.687
473.2	2.688
473.0	2.689
472.8	2.688
472.6	2.687
472.4	2.687
472.2	2.686
472.0	2.686
471.8	2.686
471.6	2.687
471.4	2.685
471.2	2.685
471.0	2.685
470.8	2.687
470.6	2.688
470.4	2.688
470.2	2.688

Wavelength (nm)	Absorbance
470.0	2.687
469.8	2.686
469.6	2.686
469.4	2.687
469.2	2.690
469.0	2.691
468.8	2.691
468.6	2.690
468.4	2.690
468.2	2.689
468.0	2.688
467.8	2.687
467.6	2.687
467.4	2.686
467.2	2.685
467.0	2.685
466.8	2.684
466.6	2.683
466.4	2.682
466.2	2.683
466.0	2.682
465.8	2.684
465.6	2.683
465.4	2.685
465.2	2.686
465.0	2.687
464.8	2.688
464.6	2.686
464.4	2.687
464.2	2.687
464.0	2.686
463.8	2.684
463.6	2.683
463.4	2.685
463.2	2.685
463.0	2.685
462.8	2.685
462.6	2.686
462.4	2.689

Wavelength (nm)	Absorbance
462.2	2.688
462.0	2.688
461.8	2.684
461.6	2.683
461.4	2.680
461.2	2.681
461.0	2.682
460.8	2.683
460.6	2.683
460.4	2.682
460.2	2.681
460.0	2.681
459.8	2.681
459.6	2.684
459.4	2.685
459.2	2.685
459.0	2.684
458.8	2.684
458.6	2.685
458.4	2.687
458.2	2.687
458.0	2.686
457.8	2.683
457.6	2.683
457.4	2.683
457.2	2.683
457.0	2.682
456.8	2.682
456.6	2.683
456.4	2.684
456.2	2.684
456.0	2.681
455.8	2.681
455.6	2.678
455.4	2.680
455.2	2.669
455.0	2.655
454.8	2.626
454.6	2.612

Wavelength (nm)	Absorbance
454.4	2.604
454.2	2.603
454.0	2.603
453.8	2.601
453.6	2.600
453.4	2.600
453.2	2.601
453.0	2.602
452.8	2.602
452.6	2.601
452.4	2.601
452.2	2.600
452.0	2.600
451.8	2.599
451.6	2.599
451.4	2.598
451.2	2.598
451.0	2.597
450.8	2.598
450.6	2.598
450.4	2.598
450.2	2.597
450.0	2.598
449.8	2.598
449.6	2.597
449.4	2.597
449.2	2.596
449.0	2.596
448.8	2.595
448.6	2.594
448.4	2.594
448.2	2.594
448.0	2.594
447.8	2.594
447.6	2.594
447.4	2.593
447.2	2.592
447.0	2.591
446.8	2.591

Wavelength (nm)	Absorbance
446.6	2.591
446.4	2.591
446.2	2.590
446.0	2.589
445.8	2.588
445.6	2.589
445.4	2.589
445.2	2.589
445.0	2.589
444.8	2.588
444.6	2.588
444.4	2.587
444.2	2.586
444.0	2.587
443.8	2.586
443.6	2.585
443.4	2.584
443.2	2.583
443.0	2.583
442.8	2.583
442.6	2.582
442.4	2.581
442.2	2.581
442.0	2.581
441.8	2.580
441.6	2.579
441.4	2.579
441.2	2.579
441.0	2.578
440.8	2.577
440.6	2.576
440.4	2.577
440.2	2.575
440.0	2.575
439.8	2.574
439.6	2.574
439.4	2.572
439.2	2.571
439.0	2.570

Wavelength (nm)	Absorbance
438.8	2.569
438.6	2.568
438.4	2.568
438.2	2.569
438.0	2.569
437.8	2.568
437.6	2.567
437.4	2.566
437.2	2.565
437.0	2.564
436.8	2.563
436.6	2.562
436.4	2.561
436.2	2.560
436.0	2.560
435.8	2.560
435.6	2.558
435.4	2.558
435.2	2.558
435.0	2.557
434.8	2.555
434.6	2.553
434.4	2.552
434.2	2.552
434.0	2.551
433.8	2.551
433.6	2.550
433.4	2.550
433.2	2.549
433.0	2.546
432.8	2.545
432.6	2.542
432.4	2.542
432.2	2.541
432.0	2.540
431.8	2.539
431.6	2.537
431.4	2.534
431.2	2.531

Wavelength (nm)	Absorbance
431.0	2.529
430.8	2.526
430.6	2.524
430.4	2.521
430.2	2.554
430.0	2.611
429.8	2.753
429.6	2.848
429.4	2.920
429.2	2.918
429.0	2.911
428.8	2.903
428.6	2.893
428.4	2.886
428.2	2.877
428.0	2.870
427.8	2.859
427.6	2.850
427.4	2.839
427.2	2.833
427.0	2.825
426.8	2.819
426.6	2.809
426.4	2.798
426.2	2.787
426.0	2.775
425.8	2.764
425.6	2.755
425.4	2.745
425.2	2.737
425.0	2.724
424.8	2.712
424.6	2.696
424.4	2.684
424.2	2.669
424.0	2.657
423.8	2.644
423.6	2.632
423.4	2.620

Wavelength (nm)	Absorbance
423.2	2.608
423.0	2.594
422.8	2.580
422.6	2.564
422.4	2.548
422.2	2.533
422.0	2.518
421.8	2.502
421.6	2.487
421.4	2.471
421.2	2.456
421.0	2.440
420.8	2.425
420.6	2.409
420.4	2.393
420.2	2.377
420.0	2.361
419.8	2.345
419.6	2.328
419.4	2.312
419.2	2.295
419.0	2.280
418.8	2.264
418.6	2.247
418.4	2.231
418.2	2.214
418.0	2.198
417.8	2.182
417.6	2.166
417.4	2.149
417.2	2.133
417.0	2.117
416.8	2.101
416.6	2.085
416.4	2.067
416.2	2.051
416.0	2.034
415.8	2.019
415.6	2.003

Wavelength (nm)	Absorbance
415.4	1.988
415.2	1.973
415.0	1.958
414.8	1.943
414.6	1.929
414.4	1.915
414.2	1.901
414.0	1.887
413.8	1.874
413.6	1.861
413.4	1.849
413.2	1.836
413.0	1.824
412.8	1.812
412.6	1.800
412.4	1.788
412.2	1.776
412.0	1.764
411.8	1.753
411.6	1.742
411.4	1.732
411.2	1.721
411.0	1.711
410.8	1.701
410.6	1.691
410.4	1.681
410.2	1.672
410.0	1.663
409.8	1.654
409.6	1.645
409.4	1.636
409.2	1.628
409.0	1.620
408.8	1.611
408.6	1.604
408.4	1.596
408.2	1.589
408.0	1.583
407.8	1.576

Wavelength (nm)	Absorbance
407.6	1.570
407.4	1.563
407.2	1.557
407.0	1.551
406.8	1.545
406.6	1.540
406.4	1.534
406.2	1.529
406.0	1.524
405.8	1.519
405.6	1.515
405.4	1.510
405.2	1.505
405.0	1.499
404.8	1.493
404.6	1.489
404.4	1.484
404.2	1.481
404.0	1.477
403.8	1.474
403.6	1.471
403.4	1.468
403.2	1.465
403.0	1.462
402.8	1.460
402.6	1.457
402.4	1.455
402.2	1.453
402.0	1.451
401.8	1.449
401.6	1.447
401.4	1.446
401.2	1.444
401.0	1.442
400.8	1.441
400.6	1.440
400.4	1.439
400.2	1.437
400.0	1.437

4. Discussion

Figure 1. Depicts that the acidic behaviour of fluorescein dye at pH 2. The maximum absorbance is 0.021 at 15 minutes for 200 ppm at a wavelength of 490 nm. As the wavelength linearly increased, the absorbance continuously decreased upto 0.004 at 600 nm. Whereas at alkaline pH 10, the absorbance is 2.671 for 15 minutes, 2.688 for 30 minutes, 2.676 for 45 minutes and the maximum absorbance is 2.683 achieved at a time interval of 60 minutes at 490 nm as shown in Figure 2.

Figure 3 exhibit that at an acidic pH 2 the absorbance is poor but at an alkaline pH 10 and time interval of 60 minutes the absorbance is maximum for 200 ppm.

Figure 4. Clearly shows that at acidic pH 2 and 4 and higher concentration the approximately the constant decolorisation percentage is achieved by 99.99% for a time interval of 15 minutes. At neutral pH 8, the maximum decolorisation percentage, 99.96% is achieved with linearly increase in time.

At pH 10, initially the decolorisation is increased and decolorisation percentage 99.97 is recorded, after 15 minutes it decreased and then again increased for a while. At pH 6, the decolorisation percentage is continuously increased upto 45 minutes and then decreased.

5. Conclusions

This study demonstrates the bentonite performance, easy availability, cost effectiveness, high porosity, recycling ability, and abundant active sites on its surface, as bentonite was used for the removal of fluorescein sodium dye. At acidic pH the constant decolorisation percentage is achieved by 99.99% for a time interval of 15 minutes. At pH 10 the initial decolorisation percentage is 99.98 but after a time interval of 15 inutes it decreased.

Abbreviations

MB	Methylene Blue
RhB	Rhodamine B
CR	Congo Red
OPD	Orthophenylenediamine
PPD	Paraphenylenediamine
DV	Disperse Violet
MR	Methyl Red
CV	Crystal Violet

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Author Contributions

Amit Anand: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft

Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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Biography

Amit Anand, Research Scholar Tilka Manjhi Bhagalpur University, Bhagalpur, India. My research work is based on dyes and water pollution. My Five research articles are published in different peer reviewed and scopus journals. I am honoured with various prestigious awards such as best paper presentation (2026) by Ixora Research Association, Jharkhand, India; Best Young Researcher Award-2023 by Global Leader Foundation, Delhi, India and Indian Icon Awards (2024) by Kiteskraft Productions LPP, Punjab, India. I believes that "learning is not about remembering facts, it's about thinking and investigating how things work."