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Chromatographic separation of eosin yellow dye from water using Ag Nanoparticle Impregnated activated carbon in packed mini columns with reusability assessment

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Abstract

A rapid and efficient chromatographic method was developed for the extraction and quantitative determination of Eosin Yellow (EY) dye from water using a mini packed column containing silver nanoparticle-impregnated activated carbon (AgNPs/AC). The composite adsorbent, prepared by depositing AgNPs onto activated carbon, provided enhanced surface activity and adsorption efficiency. Optimal conditions (pH 4-5, flow rate 5 mL min^{-1}, sorbent mass 0.04 g) ensured nearly complete retention and > 99% recovery of EY at its λ_max = 517 nm. Column performance, evaluated via breakthrough and chromatogram methods, confirmed high efficiency with favorable N, HETP, BC, and CC values. The proposed system was successfully applied to spiked tap, sea, and wastewater samples, achieving recoveries of 97-106%. The AgNPs/AC sorbent exhibited excellent reusability, maintaining over 95% performance after four cycles. This mini-column technique provides a simple, economical, and environmentally friendly approach for trace-level separation of EY and related pollutants from aquatic environments.

Keywords: Activated carbon, Chromatographic separation; Eosin Yellow, Packed Mini-column, Silver nanoparticles, Reusability

Introduction

Currently, the textile-dyeing industry is recognized as a leading source of wastewater generation and aquatic environmental pollution [1]. The effluents released from dyeing processes typically contain synthetic dyes, auxiliary chemicals, salts, and heavy metals that are persistent, toxic, and resistant to natural degradation (e.g., azo and cationic dyes with carcinogenic and mutagenic potential) [2]. Among the numerous dyes released from textile effluents, Eosin Yellow (Eosin Y) is of particular concern due to its widespread industrial and laboratory applications, as well as its persistence in aquatic environments. Eosin Yellow (also referred to as Eosin Y) is a synthetic, fluorescent, and acidic dye extensively used in both industrial and laboratory settings, and it is chemically identified as 2-(2, 4, 5, 6-tetrabromo-6-oxido-3-oxido-3H-xanthenes-9-yl)-15-benzoate disodium salt (Supplementary Information's, SI. 1) [3]. In histology, Eosin Yellow serves as a counterstain alongside hematoxylin, aiding in the detailed examination of tissue samples and providing contrast to help visualize cellular structures under the microscope [4]. Beyond its diagnostic uses, the dye is an essential reagent in various spectrophotometric methods for detecting trace organic pollutants, particularly in the context of environmental monitoring [5]. However, the growing use of Eosin Yellow, coupled with its environmental persistence, raises serious concerns regarding its toxicity and potential ecological impact. The toxicological profile of Eosin Yellow has become an important area of study, given its potential adverse effects on both aquatic life and human health. Research indicates that even at low concentrations, Eosin Yellow can be harmful to aquatic organisms and microorganisms, disrupting ecosystems [6]. Furthermore, the dye's persistence in the environment poses additional risks, as it resists conventional wastewater treatment techniques, contributing to the accumulation of toxic substances in aquatic ecosystems, which can endanger both wildlife and human populations [7]. These health risks are exacerbated in industrial environments where large amounts of the dye are used without sufficient safety precautions, highlighting the urgent need for stricter occupational safety regulations.

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Recent research has emphasized the importance of developing effective methods for detecting and removing Eosin Yellow from contaminated environments. For instance, demonstrated the use of carboxyl-functionalized multi-walled carbon nanotubes (COOH-fMWCNTs) attached to a glassy carbon electrode for the sensitive detection of Eosin Yellow at concentrations as low as 1.24 nM [8]. Additionally, photocatalytic degradation using green-synthesized cerium oxide nanoparticles (CeO_2 NPs) has proven effective in removing up to 99% of Eosin Yellow from wastewater under sunlight exposure [8]. Similarly, doping zinc oxide (ZnO) with gadolinium (Gd) and coupling it with graphitic carbon nitride ($g\text{-}C_3N_4$) has led to the development of a photocatalyst capable of degrading 96% of Eosin Yellow in synthetic wastewater [10-11]. These advancements highlight the ongoing need for innovative and sustainable methods to mitigate the environmental impact of Eosin Yellow.

Packed microcolumns are compact systems in which analytes adsorb onto a solid stationary phase, widely applied in chromatography, purification, and sample preparation [12-13]. Their small scale provides flexibility for diverse uses such as biomolecule separation, sample clean-up, and analysis of complex mixtures [14]. Compared with larger chromatography systems, mini-columns offer efficient and economical separations suitable for analytical chemistry and laboratory operations [15].

In environmental applications, the adsorption of dyes is of particular importance since textile dyes exhibit high solubility, persistence, and stability in natural waters [14, 16]. Limited studies have addressed dye removal using packed-bed systems with modified supports [17, 18], though innovative strategies, such as those proposed by Vijayaraghavan *et al.* [19], demonstrate their potential. Overall, column-based adsorption remains advantageous due to its adaptability, reduced reagent demand, and cost-effectiveness [20, 21]

The chemical known as activated carbon (AC) has garnered significant scientific interest in the field of pollutant removal due to its porous structure, large surface area, non-toxic properties, and affordability [22]. A defining characteristic underlying these advantages is its high degree of microporosity, which enables efficient adsorption of diverse contaminants [23]. Furthermore, AC distinguishes itself from C atoms by the oxidation of elemental carbon on both of its surfaces, allowing it to well serve as an effective extractor in wastewater treatment [24]. Owing to its inert and porous nature, the AC has the ability to disperse various chemicals on its inner surface, therefore allowing these compounds to reach the reactants effectively [25]. Considerable effort has been dedicated to the development of various sources and extensive modification of activated carbon in order to enhance its physical and chemical properties against a range of organic contaminants, including textile dyes found in industrial wastewater [26]. Among the different approaches, the incorporation of nanomaterials has gained increasing attention, as their unique surface properties and high reactivity can significantly improve adsorption and remediation performance [27-28]. In particular, the distinctive chemical and physical properties of silver nanoparticles (AgNPs) make them indispensable in several sectors such as healthcare, medicine, consumer goods, food, and industry [29]. Therefore, this work presents the application of adsorption methods in the removal of eosin from the sample. Activated carbon silver nanoparticles (Ag NPs/AC) have been used as the adsorbent in column mode technology. The aim of this study is to use a column saturated with Ag NPs/AC in flow mode to conduct chromatographic separation and subsequent recovery of minute quantities of Eosin dye from a substantial volume of water. Furthermore, we are doing studies to evaluate the potential for reuse of the solid phase extractor that has been developed, which incorporates dispersed silver nanoparticles on activated carbon. The current study will make a substantial contribution to the advancement of strategies for the removal or reduction of textile dye residues from aquatic environments, including both industrial effluents and groundwater samples. It also provides a notable advantage by enabling the applicant to gain experiential knowledge with facilities that can readily adapt to crucial analytical methodologies.

2. Experimental

2.1 Reagent, chemicals and materials

In this work, analytical grade eosin dye, an anionic dye with a hue of red and a fractional weight of 691.86, was used. BDH chemicals including activated carbon, silver nitrate, and sodium borohydride ($NaHB_4$) were sourced from Poole, UK. A standard stock solution of Eosin Y dye was made by dissolving the given weight of Eosin Y dye in deionized water (1000 mL) at a concentration of 1000 µg mL-1. Diluted solutions of Eosin Y dye ranging from 0.001 to 40 µg mL-1 were generated by diluting the stock solution of the dye in deionized water to the appropriate concentration. Equimolar quantities of acetic acid, phosphoric acid, and boric acid (0.4 mol L-1) were combined to produce Britton-Robinson (B-R) buffer solutions with pH values ranging from 2 to 11. The pH of the solution was then adjusted to the desired value using NaOH (0.2 mol L-1) [30]. The min-column flow employed a mixture of NaOH and/or acetone as the eluting agents.

2.2 Instrumentation

Absorbance and UV-visible spectra were measured using a Thermo Scientific™ GENESYS 10 UV-Vis spectrophotometer fitted with 10 mm matched quartz cells. The pH of the produced buffer solution was measured using a JENWAY pH-meter, manufactured in the United Kingdom, equipped with a glass-calomel electrode. A Solid Phase Extraction Manifold (Agilent Technologies, 1200 USA) was used to perform chromatographic extraction SI 2 The measurement of the water contact angle (CA) was obtained using a contact angle goniometer-FTA200 First Ten Angstroms.

A set of digital micropipettes (Volac) (Model 3505, UK) with volumes ranging from 100 to 1000 µL, 20 to 200 µL, and 0.5 to 10 µL were used to prepare increasingly diluted solutions of Eosin Y dye solvent. The ultra-pure water was supplied using a Milli-Q Plus system manufacturing by Millipore in Bedford, MA, USA.

2.3. Recommended procedures

2.3.1 Preparation of silver nanoparticles (Ag NPs)

In this investigation silver nano particles (Ag NPs) were prepared using sodium borohydriate ($NaBH_4$) as reducing agent for silver nitrate ($AgNO_3$) solution as follows [31]. Ag nano particle prepare by facile preparation of Ag NPs was realized by the addition of 100 mL of $AgNO_3$ 0.001 M dropwise into 300 mL $NaBH_4$ (0.002 M) into) inside ice bath until yellow color is appear. **SI 3** The particles produced as a result of the reduction of $AgNO_3$ are called as Ag NPs.

2.3.2 Preparation of Ag NPs impregnated activated charcoal

Activated carbon (AC) was initially washed 2-3 times with deionized water, followed by drying in an oven at 450 °C. In the absence of light, a precisely weighed amount of activated carbon (5.0 ± 0.001 g) was added to the prepared silver nanoparticle solution (150 mL, silver sol) under constant stirring for 24 h. The mixture was then filtered, and the resulting AgNPs-modified AC was washed 3-4 times with deionized water and dried at 120 °C for 2 h. The obtained AgNPs/AC composite was subsequently employed as a solid-phase microextraction (SPME) sorbent.

2.4. Recommended mini column (Flow) experiments

- A column with an internal diameter of 0.9 cm and a height of 6.2 cm was employed to effectively pack the suggested AC modified NPs (0.04±0.001 g) for complete enrichment and recovery of known concentrations (0.005-40 µg/mL) at different flow rates.
- Deionized water was loaded with dye at known doses ranging from 0.005 to 40.0 µg mL-1. The test solutions were sequentially passed through the packed column at a flow rate ranging from 5.0 to 10 mL/min. The extraction percentage (E,%) of the dye under investigation was calculated by measuring the absorbance before and after percolation through the sorbent packed column, compared to a blank reagent.
- At a flow rate of 1-2.0 mL/min, the retained species of the tested dye were effectively recovered using acetone (5 mL) and/or sodium hydroxide NaOH (1.0 M) as selective eluating agents.
- The recovery percentage for each concentration was calculated by measuring the absorbance of the tested dye as it passed through the micro sorbent packed column before and after desorption with acetone (5.0 mL) or sodium hydroxide. This was done using the optimized parameters of pH, wavelength, preconcentration factor, and dilution.

2.5. Analytical performance

2.5.1 Chromatogram (Gluenkauf) method

Under vacuum, a series of mini-columns with an internal diameter of 0.9 cm and a height of 6.3 cm were filled with activated carbon modified nanoparticles weighing 0.04±0.001 g. The recorded values of Eosin Y were 1, 5, 10, and 20 mg L−1. Each dye solution (100.0 mL) was percolated separately through the columns at flow rates of 2, 5, 10, 15, and 20 mL/min. The retained species were retrieved from the aluminium nanoparticles treated activated carbon packed column using acetone (10 mL) and/or NaOH (1.0 M) as the appropriate eluent at a flow rate of 1-2 mL/min. The absorbance measurement at 517 nm of the effluent solution confirmed the complete retention of EY onto AgNPs/AC. The absorbances of the retrieved solutions were subsequently evaluated in comparison to the reagent blank. Dye recovery (%) was calculated by comparing analyte concentrations measured prior to and following adsorption. The numerical value (N) and the vertical dimension (H) of the theoretical plates were ultimately calculated using the Gluenkauf equation, as previously documented [33].

2.5.2 Breakthrough (S-shaped) capacity curve method

This experiment involved passing different fractions (200 mL) of the test feed aqueous solution (2 L) containing 10 µg mL-1) of Eosin Y under optimal conditions through an AC packed min-column treated with Ag NPs (0.04g ± 0.002) at flow rates of 5 and 10 mL min-1 until the concentration of the tested Eosin Y in the effluent equaled that of the feed. The concentration of the Eosin Y under investigation was established by measuring the absorbance of the effluent at Hmax compared to a reagent blank for each tested Eosin Y. The breakthrough capacity, critical capacity, plate number (N), and height equivalent to a theoretical plate (H) were evaluated following established procedures [33]. The critical capacity refers to the amount of compound that can be retained on the mini-column when it is allowed to transition through the packed column until the tested Eosin Y is first detected in the effluent.

2.5.3. Extraction and recovery of Eosin Y from the test aqueous solution

Different doses of eluating agents, such as NaOH, acetone, and NaOH-acetone, were separately evaluated to determine their effectiveness in fully recovering the Ag NPs from the Ag NPs treated AC packed column at a flow rate of 1.0-2 mL/min. We percolated separate aqueous solutions (100 mL) containing Eosin Y at different concentrations (0.001 - 1µg mL-1) at pH < 4.7 via mini-columns packed with activated carbon immobilized nanoparticles (0.04 ±0.002g) at a flow rate of 5-10 mL min-1. Additionally, a blank experiment was conducted without the presence of Eosin Y dye. The effluent exhibited full retention of Eosin Y, as evidenced by the absorbance at αmax of Eosin Y compared to the reagent blank. A selection of several eluting agents, including acetone -NaOH (1.0 M) in a 1:1 and 1:2 ratio, was evaluated to achieve full recovery. Distinct proportions (5ml) of the eluating agent were filtered through the AC packed treated with Ag NPs. The absorbances of the eluate fractions were measured, relative to a reagent blank, at the maximum absorbance (max). Successful retrieval of Eosin Y from nanoparticles treated activated carbon sorbent packed mini-column was accomplished by percolating a precise volume (5 mL) of 1.0 M NaOH at a flow rate of 0.5 mL min-1.

2.6 Validation and analytical applications of the established methodology

2.6.1 Flow (mini-column) mode of separation: Extraction and recovery of Eosin Y from environmental water

- The activated carbon treated nanoparticles were effectively colloidal packed in a column to achieve 100% enrichment and recovery of Eosin Y added into samples from tap water, seawater, and wastewater.
- In this experiment, 400 mL of tap-, sea-, and waste water samples were treated with Eosin Y dye at concentrations ranging from 0.05 to 5 mg mL-1 at a pH level below 4.7. The samples were then filtered using a 0.45 µm filter membrane and kept in low density polyethylene (LDPE) bottles.
- In this experiment, a 100 mL test water sample was passed through packed columns containing activated carbon treated nanoparticles (0.04 + 0.002 g) at a flow rate of 5 mL min-1. In the absence of the tested chemicals, a blank experiment was conducted at the same flow rate. Percentage of extraction (% E) was calculated by measuring the absorbance before and after percolation through the sorbent packed column.
- Retained Eosin Y species were retrieved using NaOH (1 M) and acetone (10 mL) at a flow rate of 1-2.0 mL/min at a flow rate of 0.5 mL min-1. After adjusting the solution to a pH of 4.7 or lower using NaOH, the absorbance of the whole effluent was measured at µmax compared to a reagent blank. The recovery% values were calculated by measuring the absorbance of Eosin dye before percolation through the sorbent packed column and after desorption with acetone (10.0 mL) at specified pH and µmax values, compared to a reagent blank.

3.4 Ag NPs/AC packed mini column:

3.4.1 Chromatographic separation of Eosin Y onto Ag NPs treated AC packed mini-column

The initial tests utilizing the established sorbent packed column were carried out in the following manner: A range of known concentrations (5.0-40µg mL-1) of Eosin Y dye in deionized water (100 mL) with a pH below 4.7 were separately filtered through a mini-column packed with Ag NPs laden AC absorbent (0.04 ±0.002g) at a flow rate of 10±2 mL min.-1. Furthermore, a blank experiment was conducted at a same flow rate. An analysis of the dye in the effluent was conducted using spectrophotometry. The findings are given in

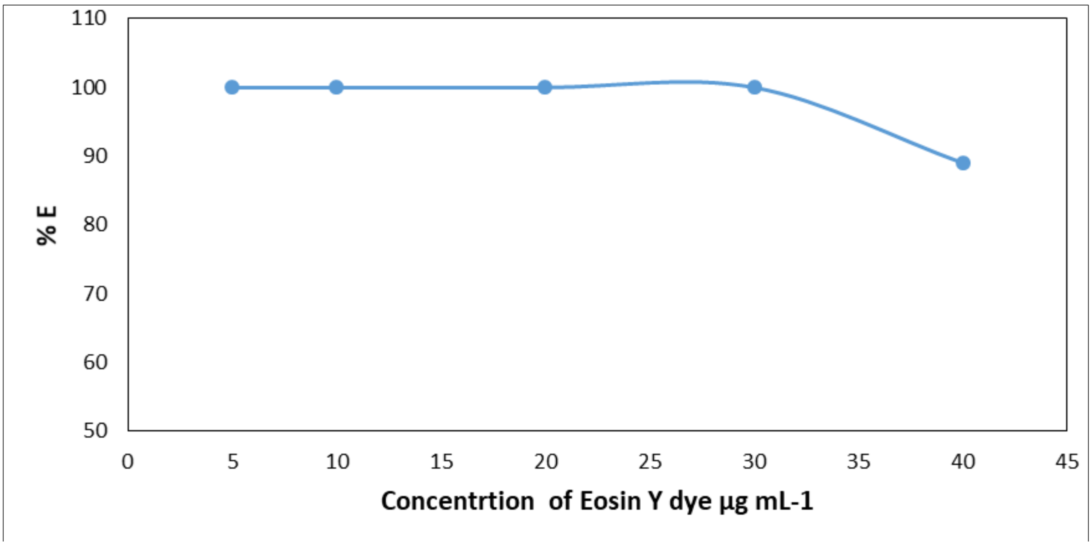

Fig 2: The experimental results indicated that the extractor utilized completely retained the dye.

An important factor in chromatographic separation by column is the flow rate of the sample solution percolating through the sorbent packed column. This rate determines the time required for full extraction of the analyte from the extraction medium. A critical study was conducted to examine the effects of different flow rates (2.0-20 mL/min) while maintaining a constant concentration of the dye (10µg/mL).

The findings are illustrated in Fig 3, where absolute retention (90.0-100%) of the dye was attained at a flow rate below 10.0 mL/min and declined at higher flow rates. The high percentage of dye removal was attained at low flow rates due to the necessity of increased surface contact time between the sorbent and the dye, which leads to enhanced mass transfer to the solid phase and therefore a higher removal ratio [34].

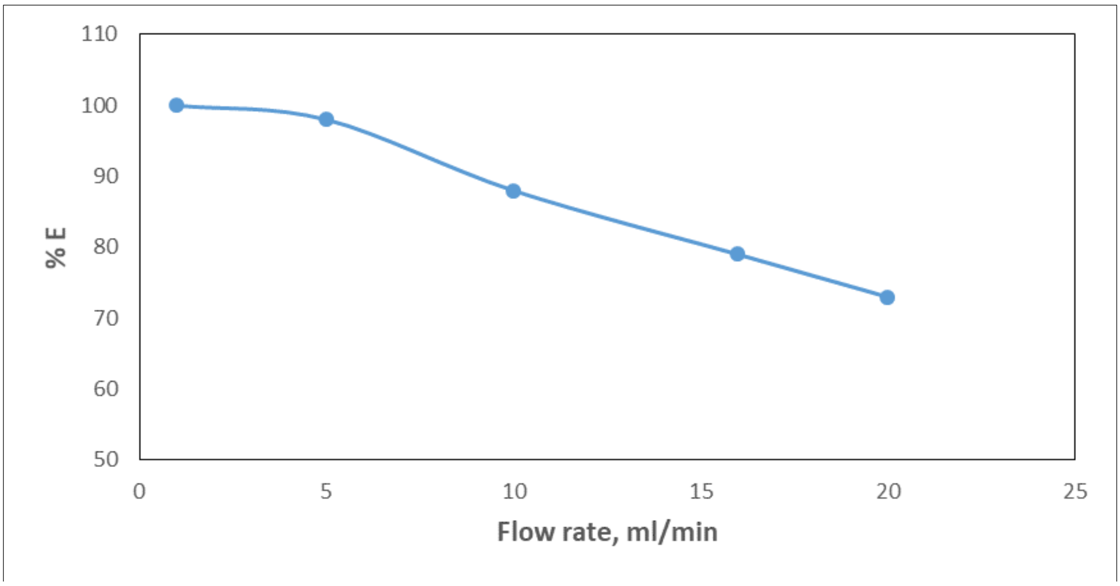

Fig 3: Impact of flow rate on Eosin Y dye (10 µg mL^{-1}) retention onto Ag NPs/AC packed mini- column at various flow rates

3.5. Column performance

3.5.1. Breakthrough (S-Shaped curve) capacity curve method

The effectiveness of ACNPs treated AC packed mini-column in retaining Eosin Y was assessed by determining the nanoparticle number (N) and the height equivalent to a theoretical plate (HETP), along with the critical capacity (CC) and breakthrough capacity (BC). Therefore, in a second column experiment, a 2L aqueous solution containing Eosin Y at a concentration of 10 g mL-1 was passed through a mini-column packed with AC treated NPs (0.04 ± 0.001g) at different flow rates (5 and 10 mL min-1) under ideal experimental conditions. The findings are displayed in Figure 3.5. The values for N and HETP were determined using the equation in reference [35]:

$$N = \frac{V_{50}\grave{V}}{(V_{50}\grave{V})^2} = \frac{L}{HETP} \quad (1)$$

In this context, V50 represents the volume of the feed solution at the center (50% extraction) of the S-shaped curve. V^ denotes the volume at which the feed solution has a value of 0.1578 of the initail concentration, thus at a non-extraction of the tested chemical at 15.78%. The findings are illustrated in Fig 3.5. The calculated values of mL min-1and 10 mL min-1for N were determined to be 101.5 and 37.8 respectively. The corresponding calculated values for HETP were 0.02 and 0.05 at flow rates of 5 and 10 mL min-1, respectively. Consequently, the HETP values, which indicate the column efficiency, rise when the flow rate is increased from 5 to 10 mL min-1. The column performance was determined by calculating the breakthrough capacity (BC) using equations provided in references [35-36].

$$\mathrm{BC} = \frac{V_{50} \times C_0}{W} \qquad (2)$$

The values of C_0 and W represent the starting concentration of the feed solution (analyte) and sorbent dosage (g), respectively. BC values were determined at different flow rates (5 and 10mL min-1) with sorbent concentrations of 225 and 150 mg g-1 correspondingly. The critical capacity (CC) was determined by calculating the quantity of analyte maintained on the column before an initial detection in the effluent per gram of solid sorbent, as shown in Fig 4. The respective values of CC for Eosin Y were determined to be 203.8 and 127.5 mg g-1 sorbent. These results demonstrate the effective performance of ACNPs packed mini-columns in both preconcentration and recovery of the tested Eosin Y.

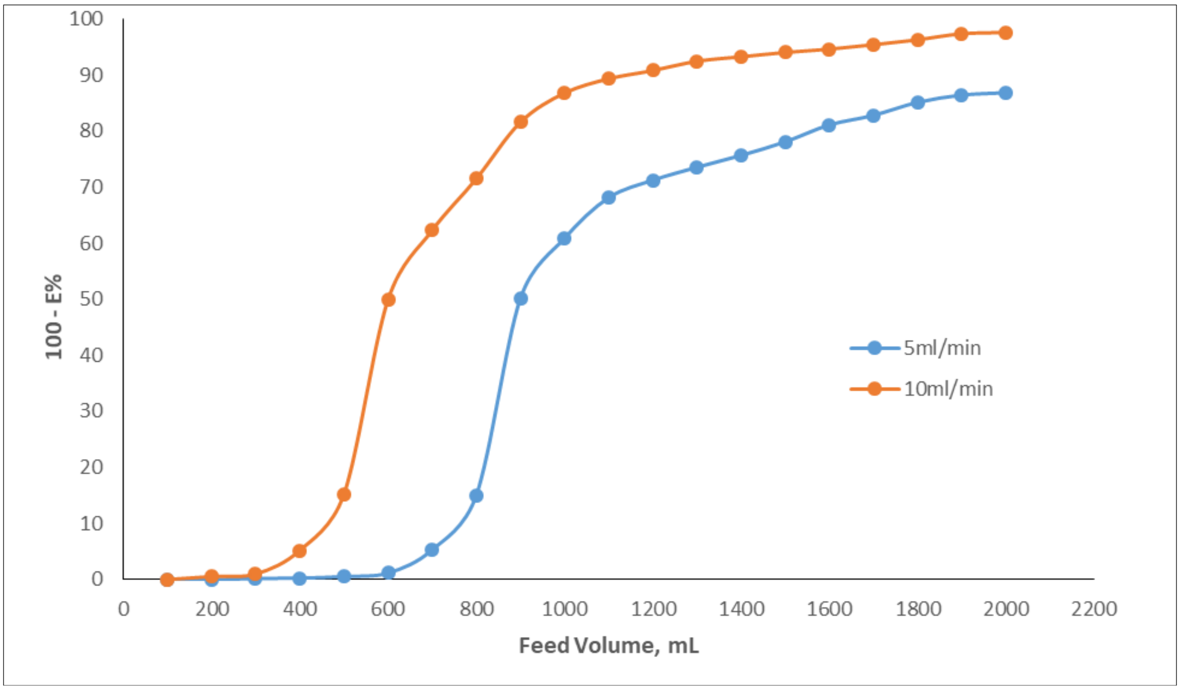

Fig 4: Breakthrough capacity curve for Eosin Y retention onto the Ag NPs/AC packed mini-column at various flow rates.

3.5.2. Chromatogram (Gluenkauf method)

The analytical performance of the AC packed column treated with Ag NPs was determined using the chromatogram (Gluenkauf technique) as presented below: Under the optimal settings of dye retention, an aqueous solution (100 mL) loaded with Eosin Y (5.0 µg mL-1) was percolated through Ag NPs immobilized AC packed columns at a flow rate of 5 mL min-1. The absence of Eosin dye in the effluent confirmed its complete retention on the sorbent. Experiments were conducted to retrieve the dye from the packed material using several eluating agents such as NaOH (1.0 mol L-1) and acetone, for both 1:1 and 1:2 ratio (v/v) each respectively, at a flow rate of 0.25 mL/min. Five hundred microliters of the eluating agent were percolated down the sorbent packed column at a flow rate of 0.25 milliliters per minute. At the optimal wavelength, the absorbance of the eluated fractions (eluate) was measured compared to a reagent blank. The achieved findings are illustrated in Fig 5. Numerical values for N and HETP were determined using the equation [35] from Fig 5.

$$\mathrm{N} = \frac{8V_{\max}^2}{W^2} = \frac{L}{\mathrm{HETP}} \qquad (3)$$

Where $V_{\max}$ represents the volume of the eluate at its highest point, W represents the breadth of the peak at 1/e times the maximum solute concentration, and L is the length of the bed in millimeters.

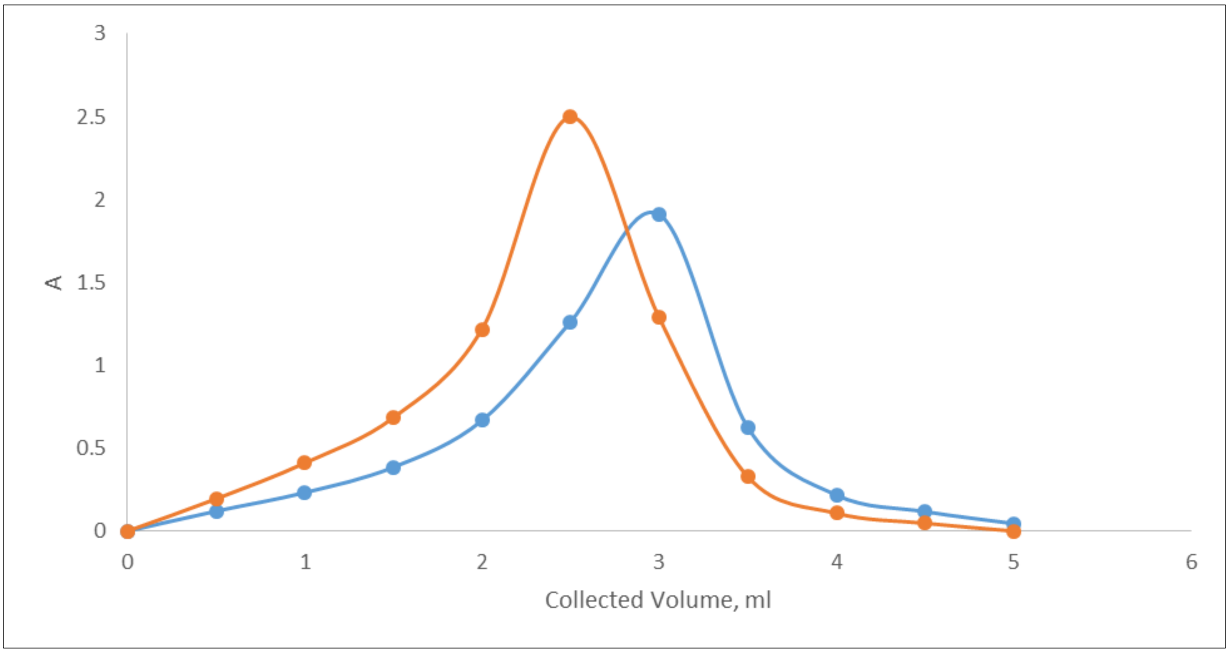

Fig 5: Recovery of the dye Eosin Yellow from Ag NPs/AC column

An analytical usefulness of an Ag NPs/AC sorbent packed mini-column was successfully evaluated for complete collection, recovery, and measurement of Eosin Y dye at trace and ultra-trace concentration range (0.001-1.0 µg mL^{-1}), as determined from the parameters N, HETP, BC, and CC. In this experiment, aqueous solutions (100 mL) containing different defined concentrations of Eosin Y were separately percolated through mini-columns packed with Ag NPs/AC at a flow rate of 7 mL min-1, compared to a blank solution. The absorbance of the effluent following percolation through the sorbent packed column revealed that complete extraction of Eosin Y from the test solutions was accomplished. The data corresponding to a flow rate of 0.25 mL/min are depicted in SI 6. Recovery of the dye species retained in the sorbent packed column was achieved by employing 5 mL of a 1M NaOH solution and acetone. Achieved was full recovery (99.0 ± 2.1-101 ± 0.1) of the Eosin Y in the sample. The recovery percentages of the dye at different known concentrations in the presence of NaOH and acetone as an appropriate eluating agent are presented in Table 1. The results confirm the analytical effectiveness of the proven sorbent formulation for the full removal and measurement of the dye from ambient water samples.

Table 1: Analytical results for the extraction and recovery of Eosin Y from deionized water by Ag NPs/AC packed column at flow rate of 5 mL min^{-1}

Eosin Y added, µg/mL	Eosin Y, found, µg/mL	Recovery,%
1	1.1±0.1	101±0.1
0.5	0.5±0.2	100±0.4
0.1	0.12±0.2	102±4
0.05	0.049±0.02	99±2
0.01	0.01	100±4
0.005	detected	nd.
0.001	n.d.	nd.

*nd.= not detected.

3.6. Retention and recovery of Eosin Y dye by flow (mini-column) mode

Using N and HETP values of the silver nanoparticle (Ag NP) treated activated carbon packed mini-column, we conducted a thorough investigation on the extraction and recovery of the Eosin Y dye from samples of ambient water (tap, sea, and waste water). In this experiment, different environmental water samples (1000 mL) were individually contaminated with known concentrations (0.05-5 µg/mL) and passed through the AC packed mini column treated with Ag NPs at a flow rate of 5 mL/min. The dye retention parameters were optimized as described over. The absorbance of the effluent solution at 517 nm revealed that complete retention of Eosin Y was attained. The dye species that were retained were retrieved from the sorbent packed column by applying NaOH (5 mL, 1M) at a flow rate of 1 ml/min. The recovery was then monitored using spectrophotometry at a wavelength of 517 nm. The statistical findings are succinctly presented in Table 3.2. Confirming the suitability of the established Ag NPs treated AC packed column for full extraction, recovery, and detection of trace and ultra trace levels of Eosin dye in natural water samples, a satisfactory recovery percentage in the range of 97.04±4.0-106.02 was recorded.

Table. 2: Results of the extraction and recovery of Eosin Y spiked environmental (tap, sea and waste) water samples by the proposed Ag NPs/AC packed mini-column

Sample	Eosin Y dye added, µg/mL	Eosin Y dye found, µg/mL	Recovery,%
Tap water	0.05	0.05 ± 0.01	100 ± 0.01
	0.1	0.1 ± 0.01	100 ± 0.1
	0.5	0.499 ± 0.01	99.8 ± 0.1
	5	5.1±0.1	102.1±0.1
Sea water	0.05	0.05 ± 0.01	100 ± 0.01
	0.1	0.1 ± 0.01	100 ± 0.1
	0.5	0.498 ± 0.01	99.6 ± 0.1
	5	4.96±0.021	106.02±1.02
Wastewater	0.05	0.05 ± 0.01	100 ± 0.01
	0.1	0.1 ± 0.01	100 ± 0.01
	0.5	0.498± 0.01	99.6 ± 0.1
	5	4.86 ± 0.01	97.04 ±0.26

3.7. Reusability of the established solid platform

The reusability of the constructed solid phase platform was evaluated under optimised analytical conditions for eosin dye sorption and recovery. Following each column experiment, the solid-phase mico extraction (SPME) was collected, washed several times with deionized water and acetone, followed by drying at room temperature between sheets of filter paper, and then reintegrated into the column for the extraction procedure. Analyte absorption and stripping by the established SPME were not significantly reduced (±4%) after 4 repetitions, resulting in a sorption and recovery of Eosin Y over 95±-4.5%.

4. Conclusion

Chemically treated silver nanoparticles applied to activated carbon (AC) offered an inexpensive method for completely separating Eosin yellow from water. In order to achieve complete removal and measurement of trace and ultra-trace levels of specified textile colors, a low-cost and efficient dispersive solid phase micro extractor packed flow column was developed using silver nanoparticles treated activated carbon.

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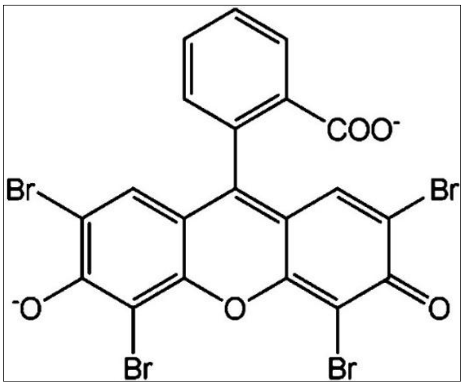
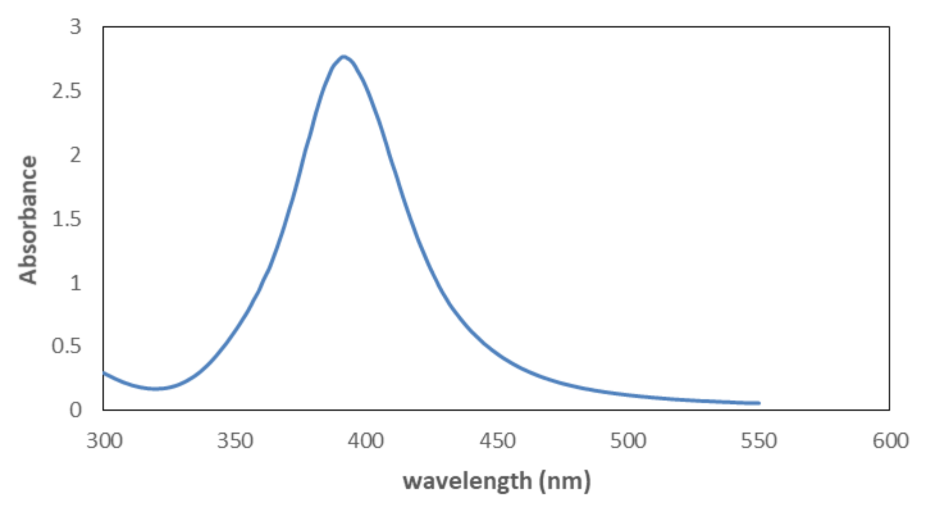
Supplementary Information

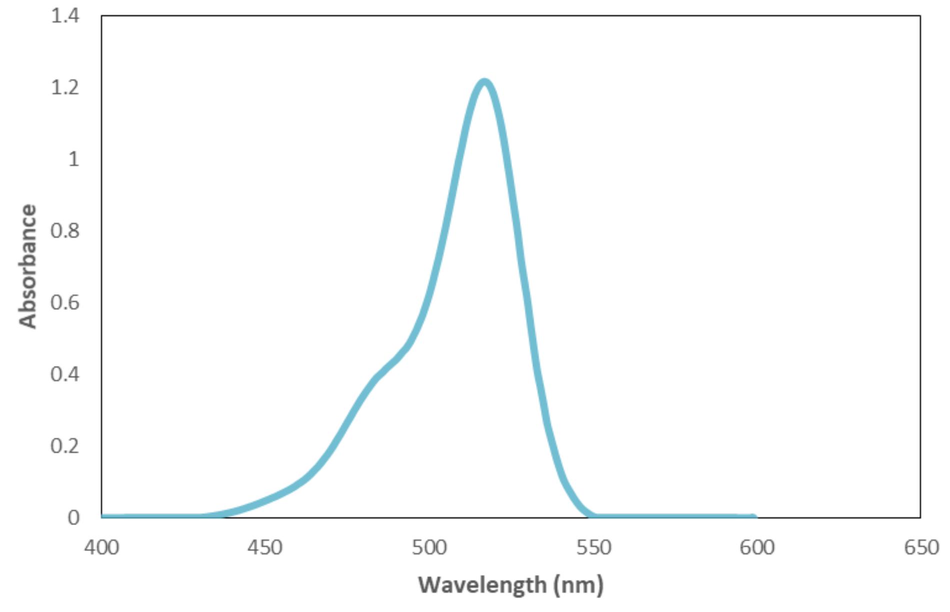


SI 1: Chemical structures of Eosin Yellow.

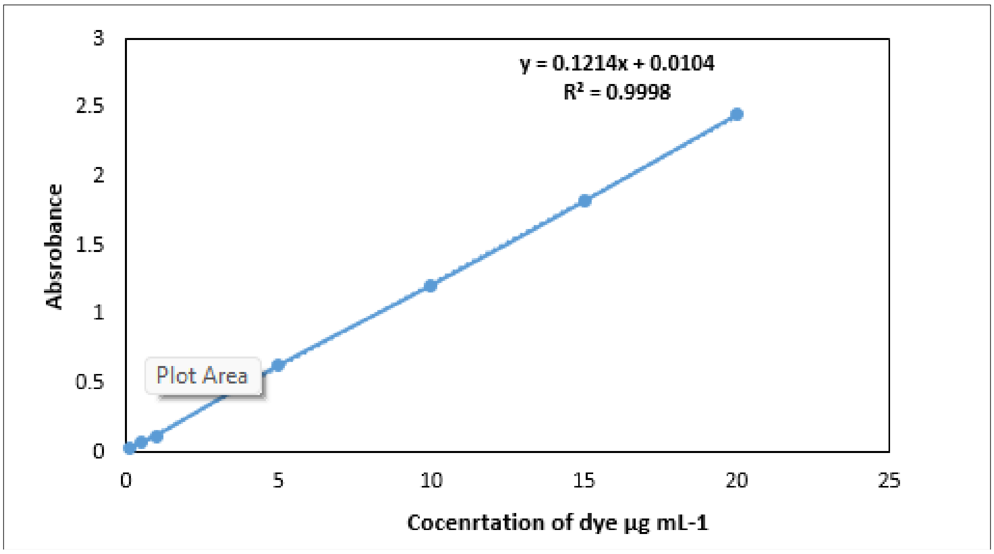
SI 2: Solid phase extraction manifold (Agilent Technologies).



SI 3: Electronic UV-Visible absorption spectrum of silver nanoparticles



SI 4: Electronic spectrum of Eosin Y (10µg/mL) in solution of pH ≤ 4.7.



SI 5: Absorbance values measured at 517 nm for Eosin Y dye solutions (0.1–20 µg mL^{-1}, pH ≤ 4.7) produced a linear calibration plot relative to a water blank.

SI 6: Separation of Eosin Y dye (0.001-1g mL^{-1}) on a solid-phase extraction manifold (Agilent Technologies).