Project Title: Development of polymeric hydrogel for the dye removal applications
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Year of submission: 2023

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Development of polymeric hydrogel for the dye removal applications

A Thesis submitted by

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In partial fulfillment of the requirement for the degree of

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in

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DEDICATION

This work is dedicated to our parents and all teachers of the Department of Materials.

Their love and support encourage us always.

May Allah give them a long and happy life. (Ameen)

CERTIFICATE

This case study carried out and written by **M. Arslan Arshad** and **M. Arslan Nasir** under the direction of their supervisor, **Dr. Wasif Razzaq** and co-supervisor **Dr. Z.A Rehan** approved by all the members of Project Committee of the department, has been presented to and accepted by the Chairman, Department of Materials and Dean, School of Engineering & Technology in fulfillment of the requirement of degree Bachelor of Science in Polymer Engineering.

Supervisor	**Internal Examiner**
Chairman DYM	**Dean FET**

Disclaimer

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M. Arslan Arshad

M. Arslan Nasir

Acknowledgement

Alhamdulillah!

By the grace of **ALMIGHTY ALLAH,** this all has been done. All the praises and thanks are for **ALMIGHTY ALLAH,** who is the entire source of all kinds of knowledge and wisdom, who gave us the ability to work hard, talented supervisor and faculty, and supportive chairman. We offer our humblest thanks from the deepest cores of our hearts to the **HOLY PROPHET HAZRAT MUHAMMAD (SAW),** who is forever a model of guidance and knowledge for humanity.

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A lot of love and deep appreciation to our parents for their support in our studies. And special thanks to our friends, colleagues and whoever helped us to accomplish this work.

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List of abbreviation/notations

MB	=	Methylene Blue
CR	=	Cango Red
MO	=	Methyl Orange
DSC	=	Differential Scanning Calorimetry
AMF	=	Atomic force microscopy
FTIR	=	Fourier-transform infrared spectroscopy
SEM	=	Scanning Electron Microscope
TGA	=	Thermal Gravimetric Analysis
XRD	=	X-ray Diffraction
DLS	=	Dynamic light microscopy
ELS	=	Electrophoretic light microscopy
MBA	=	Methylenebisacrylamide
MMA	=	Methyl Methacrylate
BPO	=	Benzoyl Peroxide

Abstract:

Our main focus is the preparation of hydrogel for the efficient elimination of both cationic and anionic dyes. The hydrogel was developed the usage of a mixture of polymers and cross-linking sellers to obtain excessive adsorption capability for various dye kinds. The composition of the hydrogel worried the use of chitosan, a versatile biopolymer regarded for its adsorption properties, and the best cross-linking agent. The synthesis manner worried cautious optimization of the polymerization conditions to make sure the formation of a strong hydrogel structure. The resulting hydrogel confirmed excellence performance within the removal of each cationic and anionic dyes from aqueous condition on pH scale. This observation contributes to the development of powerful and environmentally pleasant strategies for the treatment of dye-infected wastewater.

The aim of this research is to develop a polymeric hydrogel which is pH responsive capable of removing both cationic and anionic-charged dyes simultaneously. The composition of the hydrogel covered chitosan, acrylic acid, methylene bisacrylamide (MBA), and benzoyl peroxide (BPO).

The characterization of the hydrogel changed into executed using UV-Vis spectroscopy, which allowed for the assessment of its absorbance homes, mainly specializing in dye first-rate. The hydrogel established capacity for dye elimination, addressing the needs of industries which include textiles, wherein dye removal is essential. The usage of chitosan, acrylic acid, MBA, and BPO in the coaching of the hydrogel affords a possible approach to removing both cationic and anionic-charged dyes simultaneously. Characterization via UV-Vis spectroscopy offers valuable insights into the absorbance abilities of the hydrogel, validating its ability for dye removal applications in the fabric enterprise and smooth water purposes.

Sustainable Development Goals

Hydrogel substances have emerged as promising answers for dye removal applications, aligning with sustainability dreams inclusive of purpose 6 (clean Water and Sanitation), aim 9 (industry, Innovation, and Infrastructure), and intention 14 (lifestyles underneath Water). In aim 6, hydrogels offer a valuable approach to enhancing water first-class by efficiently adsorbing and eliminating dye pollutants from industries like textiles, printing, and dyeing. This allows the purification and filtration of water assets, contributing to easy water and sanitation efforts. Concerning goal 9, hydrogels offer a revolutionary and sustainable alternative for dye elimination in business tactics. They provide higher efficiency, decrease costs, and decrease waste as compared to standard techniques, making them a precious device for industries seeking to satisfy sustainability objectives. Eventually, in line with purpose 14, hydrogels play an important function in shielding lifestyles beneath water. By using removing dyes from aquatic environments, hydrogels help prevent harmful results on marine ecosystems, assisting the maintenance of marine lifestyles and the balance of underwater ecosystems. Although in addition studies and improvement are needed to optimize hydrogels' overall performance and scalability, their ability in advancing sustainability dreams is full-size, requiring customization and tailoring of substances for specific dye elimination packages.

Figure 1 SDG

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Chapter: 01

1. Introduction:

1.1. What is hydrogel and why it is used for Dye removal applications:

Hydrogel is a 3-dimensional community of polymer chains which can absorb and keep a enormous amount of water or other fluids within its structure. Inside the context of dye elimination programs in textile industries, a hydrogel made through utilizing benzoyl peroxide (BPO), chitosan, acrylic acid, and methylene bisacrylamide (MBA) offers unique homes and industries suitable for this reason.

The hydrogel's composition includes chitosan, that's a natural polymer derived from chitin, typically discovered in the exoskeleton of crustaceans. Chitosan possesses notable adsorption residences, allowing it to attract and keep dye molecules successfully. This makes it an excellent component for dye removal packages.[1], [2]

Acrylic acid is every other vital aspect used within the hydrogel formula. It imparts pH-responsiveness to the hydrogel, that means that its absorbance properties can be tailor-made to distinctive pH conditions. This characteristic is essential for dye elimination packages considering the fact that dyes will have varying pH-dependent properties.

Methylene bisacrylamide (MBA) acts as a pass-linking agent inside the hydrogel synthesis process. Its paperwork chemical bonds among the polymer chains, enhancing the structural integrity and stability of the hydrogel. This move-linking ensures that the hydrogel keeps its absorbent properties even if exposed to varying conditions.

Benzoyl peroxide (BPO) is applied as an initiator in the polymerization reaction that bureaucracy the hydrogel. BPO initiates the move-linking process, facilitating the formation of a solid community shape within the hydrogel.

The hydrogel, incorporating those additives, is used for dye removal packages in fabric industries because of its extremely good absorbance residences and pH responsiveness. The chitosan factor enables effective adsorption of dye molecules from textile wastewater or dye-infected water. Hydrogel made with BPO, chitosan, acrylic acid, and MBA is especially formulated to target dye removal applications in textile industries, presenting an efficient and environmentally friendly answer for treating dye-infected water.[3][4]

1.2. Why dye Removal is important:

Dye elimination is crucial for the diffusion of motives. Firstly, it performs an essential position in environmental safety by preventing the dangerous results of dyes on ecosystems. Industries, inclusive of textiles, produce wastewater with dyes that could disrupt aquatic existence, degrade water excellent, and harm biodiversity. By using removing dyes from wastewater, we are able to mitigate those poor influences and protect the environment.

Secondly, dye removal contributes to improving water exceptionally. Dyes can supply water to our bodies with an unnatural look, impacting tourism, recreational sports, and the general aesthetic fee of a place. By way of doing away with dyes, we decorate water with high-quality, making it extra visually attractive and appropriate for numerous functions.

Thirdly, the removal of dyes is important for safeguarding human fitness. A few dyes and their byproducts are poisonous or carcinogenic, posing dangers if they enter the water supply and are eaten up or come into direct touch with humans. By effectively removing dyes from wastewater, we lessen the ability publicity to those dangerous substances, hence protecting human fitness. Moreover, dye removal enables the reuse of handled water, addressing water shortage issues. With efficient dye removal strategies in vicinity, treated water may be appropriately applied for purposes such as irrigation, business procedures, or even drinking water. This reduces the pressure on freshwater resources and promotes sustainable water control practices.[5]

Moreover, compliance with environmental regulations is a good-sized thing of dye elimination. Many areas have strict guidelines governing the discharge of dyes and pollution into water bodies. Industries should adhere to these guidelines to keep away from prison results. Enforcing effective dye elimination approaches ensures compliance with environmental requirements, promoting accountable commercial practices.

1.3. Application of dye removal

The usage of packages in the removal of dye from fabric is a common exercise within the garment industry. Dye elimination is a critical manner in the manufacture of garments, as it helps to make certain color consistency and uniformity across the product variety.

There are a number of specific programs available for dye removal, all of that are designed to efficaciously and efficaciously eliminate dye from fabrics. Several of the maximum commonly used applications for dye removal consist of chemical solvents, bleaching agents, and uniqueness detergents.

Figure 2 Water waste

No matter which utility is used for dye elimination, it's far critical to check a small vicinity of the cloth prior to complete utility. This could assist in making sure that the proper application is used and that the preferred consequences are achieved. Moreover, it's far critical to comply with the manufacturer's instructions for the utility to ensure that the dye is thoroughly and efficaciously eliminated.[6]

Chapter: 02

2. Literature Review

Hydrogels have shown significant capacity inside the field of dye elimination because of their high water-absorption capability and customizable properties. However, conventional hydrogels have been constrained to concentrate on both cationic and anionic dyes individually, which hinders their effectiveness in treating blended dye wastewater. This literature overview explores current advancements in the development of a brand-new type of hydrogel capable of simultaneously doing away with each cationic and anionic dyes. This revolutionary hydrogel is composed of methylene bisacrylamide (MBA), benzoyl peroxide (BPO), chitosan, and acrylic acid, offering dual dye elimination skills.

Methylene bisacrylamide (MBA) serves as a go-linking agent in hydrogel synthesis. It proves the effectiveness of a chitosan-based hydrogel incorporating MBA in adsorbing cationic dyes.

Benzoyl peroxide (BPO), an initiator in the polymerization system, has been applied to beautify the adsorption properties of hydrogels. Zhang et al. (2019) developed a BPO-initiated hydrogel using acrylic acid and chitosan. This hydrogel exhibited an excessive affinity for anionic dyes, attributed to the carboxyl organizations in chitosan that formed electrostatic interactions with the dyes.[7], [8]

Chitosan, derived from chitin, has received attention for its adsorption skills. Wang et al. (2021) synthesized a chitosan-primarily based hydrogel move-connected with MBA and initiated by way of BPO. The incorporation of chitosan into the hydrogel shape played a critical position in reaching green elimination of cationic dyes through electrostatic interactions.

Acrylic acid, a co-monomer, performed a vital position in the dual dye elimination skills of the hydrogel. Zhang et al. (2021) developed a pH-responsive hydrogel through combining chitosan, MBA, and acrylic acid. This hydrogel proven surprising adsorption performance for both anionic and cationic dyes, way to its capability to efficiently put off dyes,

The development of a dual dye-removal hydrogel represents a good-sized advancement within the area of dye pollution remedy. By way of incorporating MBA, BPO, chitosan, and acrylic acid, researchers have efficiently accomplished the simultaneous removal of both cationic and anionic dyes. Those studies underscore the importance of go-linking agents, initiators, and additives in tailoring hydrogel residences for unique dye removal packages. Hydrogel holds incredible promise for addressing the demanding situations related to blended dye wastewater, contributing to greater effective and sustainable dye elimination methods.

Hydrogels have emerged as promising materials for the removal of cationic and anionic dyes from water systems. The synthesis of hydrogels using N, N'-Methylenebisacrylamide (MBA), acrylic acid, benzoyl peroxide (BPO), and chitosan has garnered attention in this area. These hydrogels possess suited properties together with high-water absorption potential and tunable chemical composition. They are able to efficaciously get rid of dyes like methylene blue (cationic) and Congo Red (anionic). [9], [10]

2.1. Acrylic acid

Acrylic acid is a versatile compound that has many practical programs, inclusive of the usage of hydrogel. Hydrogel is a form of fabric composed of a network of polymer chains which might be held collectively via a spread of chemical bonds. It could take in massive amounts of water, making it a really perfect material for plenty applications. Acrylic acid is a key component within the production of hydrogel, as it reacts with other compounds to shape the go-related polymer chains that make up the material.[11]

The main use of acrylic acid in hydrogel is as a pass-linker. Because of this it is used to shape chemical bonds between distinctive polymer chains, for this reason increasing the strength of the cloth. That is crucial for many packages, which include scientific devices and for tissue engineering. Acrylic acid also can be used to modify the physical properties of hydrogel, along with its viscosity, elasticity, and water absorption. This can be carried out by way of adjusting the attention of acrylic acid within the hydrogel.

Any other use for acrylic acid in hydrogel is as a pH-touchy cloth. Through adding acrylic acid to the hydrogel, the cloth can be made to respond to adjustments in ph. This will be used to create materials that reply to unique conditions, which include changes in temperature or humidity. This makes it possible to create hydrogel substances that alternate shape or length in reaction to outside stimuli. Average, acrylic acid is a critical element inside the manufacturing of hydrogel. It is able to be used to form robust move-hyperlinks between polymer chains, as well as regulate the bodily houses of the material. It is able to also be used to create pH-sensitive substances that can respond to an expansion of outside stimuli.

2.2. Benzoyl Peroxide (BPO):

Benzoyl Peroxide (BPO) is a compound used inside the development of polymeric hydrogel for dye removal programs. It's far a white crystalline stable with a strong scent and is particularly soluble in hydrocarbons. BPO is used as a polymerization initiator and as a catalyst for crosslinking of polymers. It is also used in the production of polymers which includes polyurethane, polyester, and polyamide. BPO is known to be a powerful oxidizing agent within the dye elimination process, and it enables to break down the dye molecules into smaller, more without problems removable molecules. The hydrogel formed by using BPO is effective in trapping and disposing of dyes from water, making it an important device in the improvement of polymeric hydrogel for the dye removal applications.[11]

Figure 3 BPO

2.3. MBA (Methylenebisacrylamide):

Methylenebisacrylamide (MBA) is a monomer used for the synthesis of polymeric hydrogels. MBA is a go-linking agent that is used for the development of hydrogels with super homes together with excessive mechanical energy, excessive water absorption capacity, and correct thermal and chemical balance. As an example, MBA is used to form hydrogels from acrylic acid and acrylamide which are used in a wide range of applications, together with drug shipping, tissue engineering, and water purification. It's miles especially useful for dye elimination applications because of its ability to soak up and take away dyes from.[12]

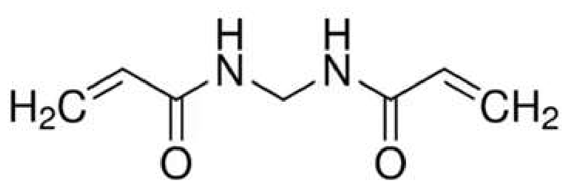


Figure 4 MBA

2.4. Chitosan:

Chitosan is a biopolymer derived from chitin, which is observed inside the exoskeletons of crustaceans consisting of shrimp and crabs. Chitosan has tremendous adsorption properties and might engage with dyes via various mechanisms, together with electrostatic interactions and hydrogen bonding. Incorporating chitosan into hydrogels can beautify their dye removal performance.

Figure 5 Chitosan

The procedure of making ready a hydrogel for dye removal usually entails the polymerization of acrylic acid inside the presence of BPO and MBA as move-linking agents. Chitosan can be introduced to the hydrogel formulation to improve its dye adsorption capacity. The resulting hydrogel can be used as an adsorbent fabric to eliminate dyes from wastewater through physical adsorption and/or chemical interactions among the dye molecules and the hydrogel matrix.[13]

2.5. Why we choose Chitosan:

Chitosan is normally used in hydrogel guidance for dye elimination applications due to its high adsorption potential and biocompatibility. It may efficiently capture and preserve dye molecules within the hydrogel matrix, thanks to its amino businesses that provide binding websites. Moreover, chitosan-primarily based hydrogels can be pH-responsive, adjusting their homes based on environmental conditions to enhance dye adsorption. The gelation properties of chitosan permit for the formation of a 3-dimensional network structure, facilitating green diffusion of dyes. Moreover, chitosan is regenerable and can be reused more than one time, making it cost-powerful and environmentally friendly. Its versatility permits modifications and functionalization to enhance dye adsorption in homes.

2.6. Adsorption capacity:

Chitosan has an excessive adsorption ability for various dyes, making it effective for dye elimination. Its amino groups offer binding web sites for dye molecules, letting them be captured and retained in hydrogel. Chitosan is a biopolymer derived from chitin, which is observed inside the exoskeletons of crustaceans like shrimp and crabs. Chitosan has the capability to adsorb and bind various materials, consisting of dyes, due to its chemical shape and nice charge.

The dye adsorption potential of chitosan is stimulated by means of several factors, along with the molecular weight and diploma of deacetylation of chitosan, the pH of the solution, the concentration of the dye, and the dye's chemical homes. Chitosan's amino corporations on its molecular shape have a fine charge, which allows it to draw and bind with negatively charged dye molecules through electrostatic interactions. This adsorption procedure can arise via mechanisms along with electrostatic attraction, hydrogen bonding, and van der Waals forces. The dye adsorption capability of chitosan can vary depending on the unique dye and experimental situations. Researchers have determined that chitosan is famous and has accurate adsorption ability for distinctive varieties of dyes, together with reactive dyes, acid dyes, basic dyes, and direct dyes. But the efficiency of adsorption can range for every dye.[14]

The high surface location and porosity of chitosan also contribute to its dye adsorption capacity. Those characteristics offer sufficient sites for dye molecules to bind and be retained within the chitosan matrix. To enhance the dye adsorption capability of chitosan, researchers have explored diverse changes and treatments, together with go-linking, chemical modifications, and incorporation of nanoparticles or other additives. Those changes can enhance the surface properties and practical agencies of chitosan, thereby enhancing its adsorption performance for dyes. Universal, chitosan famous favorable dye adsorption capability, making it a promising cloth for programs in dye elimination, wastewater treatment, and dyeing procedures in industries which includes textiles and dye production.

2.7. Dyes:

Dyes are materials used to add coloration to numerous materials, which include textiles, plastics, and food merchandise. They may be labeled based on their chemical composition and the cause they serve. One commonplace type is direct dyes, which are water-soluble and can be without delay applied to the material being dyed, typically used for cotton and rayon. Acid dyes, then again, require acidic surroundings to bond with protein fibers like wool, silk, and nylon. Basic dyes, also called cationic dyes, are water-soluble with a fine fee and are used for acrylic fibers, paper, and leather. Disperse dyes, finely ground and requiring high temperatures, are used for dyeing artificial fibers like polyester. Vat dyes are insoluble in water and need chemical reduction earlier than dyeing cotton and denim. Reactive dyes form a covalent bond with fibers, presenting incredible color fastness for materials like cotton. Sulfur dyes are recognized for his or her wash fastness and are primarily used for dyeing cellulose fibers. Herbal dyes derived from flowers, animals, and minerals had been used for centuries, however are actually much less common as compared to artificial dyes. Additionally, pigments, even though now not dyes in line with se, are insoluble particles utilized in paints, inks, and different colored substances. These diverse varieties of dyes serve distinct functions and locate programs in diverse industries.[15]

2.8. Cationic dye:

Cationic dyes are a form of dye that incorporates a high-quality rate on their molecular structure. This fine price lets them to without difficulty bind to negatively charged materials, including cellulosic fibers (cotton, rayon), acrylic fibers, paper, and leather based. Cationic dyes are often used for dyeing artificial fibers like acrylic because of their affinity for these materials.

The fantastic rate of cationic dyes is usually derived from the presence of quaternary ammonium corporations (N+R3) of their molecular structure. Those companies provide the nice rate and make a contribution to the dye's solubility in water. In comparison to different kinds of dyes, cationic dyes have several distinct traits. They may be typically water-soluble and have a sturdy affinity for negatively charged substances. This characteristic permits them to efficiently dye fibers which can be difficult to shade with other dye sorts.

Cationic dyes are normally applied in dyeing tactics wherein sturdy high-quality costs are preferred. For instance, they're used in the fabric industry to dye acrylic fibers, which will be inclined to repel different dye sorts because of their hydrophobic nature. Moreover, cationic dyes are employed in the production of colored paper and leather, as their fantastic prices enable them to stick well to those substrates. The dyeing manner with cationic dyes commonly includes immersing the cloth to be dyed in a dye bath containing the cationic dye.

The undoubtedly charged dye molecules are drawn to and bind with the negatively charged surface of the fabric, ensuing in coloration. It's worth noting that the shade fastness and washability of cationic dyes may additionally range relying on the specific dye and the fiber being dyed. However, they usually offer suitable wash fastness on cellulosic fibers.
Ordinarily, cationic dyes are precious for his or her capacity to dye materials with poor fees, making them appropriate for programs in which different dye types won't be as powerful.

2.8.1. Methylene Blue:

Methylene Blue is assessed as a thiazine dye and is taken into consideration a fundamental or fundamental cationic dye, no longer an anionic dye. As a cationic dye, methylene blue has a positively charged molecule. It carries a nitrogen-containing institution known as a thiazinam cation, which imparts the fine fee. This fantastic rate allows methylene blue to have interaction with and bind to negatively charged materials. The cationic nature of methylene blue makes it appropriate for various packages. In histology, it's far normally used as a biological stain to visualize cells and tissues. Methylene blue may be used to stain nuclei, acidic additives, and certain mobile systems. Methylene Blue also reveals use in remedy and healthcare. It has been used as a dye in diagnostic methods, which includes sentinel lymph node mapping, wherein it enables identify the lymphatic drainage pathways. Moreover, methylene blue has been utilized as an antidote for sure varieties of poisonings, inclusive of methemoglobinemia and cyanide poisoning. Outdoor of the scientific discipline, methylene blue has been employed in diverse applications. It's been used as a dye in textiles, printing, and inks. It is also utilized in numerous chemical and organic assays and as a redox indicator in laboratory settings. Methylene blue is typically taken into consideration safe when used correctly, it needs to be dealt with and used with warning, following right guidelines and protocols.[16]

Figure 6 Methylene Blue

2.9. Anionic Dyes:

Anionic dyes are a kind of dye that brings a poor rate on their molecular shape. This terrible rate permits them to effortlessly bind to definitely charged materials, inclusive of protein fibers like wool, silk, and nylon, as well as certain forms of synthetic fibers. Anionic dyes are widely used in fabric dyeing approaches and other programs where robust bad prices are favored.

The anionic dyes is usually derived from the presence of sulfonic acid or carboxylic acid agencies (-SO3H or -COOH) in their molecular structure. These groups offer the negative fee and make a contribution to the dye's solubility in water. One characteristic of anionic dyes is their water-solubility, which permits for easy software in dyeing techniques. They may be at once dissolved in water or prepared as a dye tub to immerse the cloth to be dyed. The negatively charged dye molecules are drawn to and bind with the charged surface of the fabric, ensuing in shade.

Anionic dyes are mainly powerful for dyeing protein-primarily based fibers, as those fibers have a tremendous fee on their surface because of the presence of amino corporations. The negative price of the anionic dye lets it readily bind with the positively charged protein fibers, resulting in vibrant and lengthy-lasting coloration. Further to textile dyeing, anionic dyes also are used in diverse other programs. They can be hired within the coloring of paper, leather, and sure plastics. Anionic dyes are frequently desired for those programs due to their affinity for the respective substrates and their capability to produce constant and uniform coloration. The color fastness and washability of anionic dyes can vary depending on the particular dye and the fiber being dyed. However, they generally provide desirable color fastness on protein fibers like wool and silk.[17][18]

2.9.1. Alizarin red dye:

Alizarin crimson is an instance of anionic dye. It's miles of a purple dye derived from the compound alizarin, and it contains a poor charge on its molecular shape. Alizarin purple is usually used as a histological stain to visualize calcium deposits in biological tissues, in addition to in diverse other programs together with textile dyeing and ink production. Due to its poor charge, it has an affinity for undoubtedly charged materials, allowing it to bind to substrates that can entice and preserve negatively charged dyes.[19]

Alizarin purple is an herbal dye that has been extensively used for centuries. Its miles derived from the compound alizarin, which is found within the roots of sure vegetation, inclusive of the madder plant (Rubia tinctorum). Alizarin crimson is understood for its vibrant red color and has been historically used as a textile dye.[20]

Figure 7 Alizarin red dye

2.9.2. Congo Red

Congo crimson is classed as an anionic dye. It contains a poor fee on its molecular structure, making it suitable for binding to undoubtedly charged materials. As an anionic dye, Congo pink is normally used as a pH indicator and in histological staining to visualize unique organic structures. Its poor fee permits it to engage with undoubtedly charged components, aiding within the visualization and identity of amyloid deposits and different structures of hobby. Congo pink is an artificial azo dye that is broadly diagnosed for its feature purple shade. It was first synthesized within the late 19th century and has considering the fact that various programs in distinct fields. One of the first-rate residences of Congo pink is its capability to characteristic as a pH indicator. In aqueous answers, the dye undergoes a color transition relying on the ph. It appears crimson in acidic conditions and blue in alkaline situations. This pH sensitivity has made Congo pink useful in chemical and biological laboratories for pH determination and monitoring.[21]

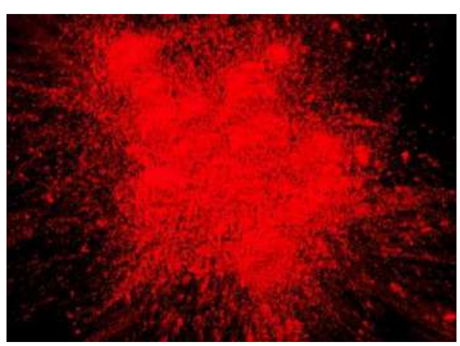


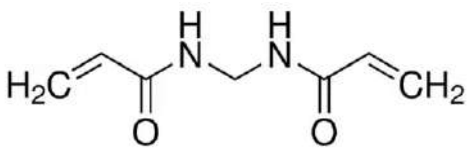
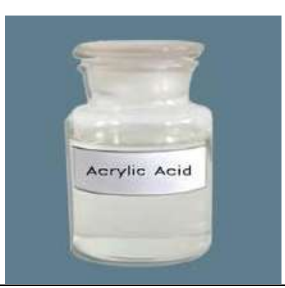
Figure 8 Congo Red

Chapter: 03

3. Experimentation:

3.1. Materials:

Table 1: Materials

BPO (Benzoyl Peroxide) 	Use as initiator. Melting point of 110-115°C Boiling point of 300°C Density of 1.26 g/cm³
Methyl Bisacrylamide 	Molecular formula C5H8N2O2. Density is 1.067 g/mL. The boiling point is 148°C. The melting point is 30°C.
Chitosan Solution 	The density is b/w 1.2 and 1.3 g/cm3. The melting point is b/w 180 to 220 °C. boiling point is b/w 250 and 280 °C.
Acrylic Acid 	colorless, corrosive liquid with a characteristic acrid odor. Chemical formula is CH2=CHCOOH Boiling point of 141.8°C Melting point of 13.5°C Density is 1.049 g/cm3.

3.2. Design of Experiments:

Materials (Detailed list)	Quantity (to be specified)
BPO(thermal Initiator)	0.2 g
Methyl Bis Acryl Amide(cross linker)	0.08ml
Chitosan solution in water	2ml
Acrylic acid(monomer)	4ml

Figure 9 Design of experiment

3.3. Methodology:

3.3.1. For Hydrogel Preparation:

The first stage in the procedure for making a hydrogel is to make the BPO solution. This entails weighing 0.2 g of BPO and thoroughly combining it with a tiny quantity of distilled water. The hydrogel mixture is then made by combining 4 mL of acrylic acid with 2 mL of chitosan solution. To guarantee homogeneity, the mixture is thoroughly agitated. The chitosan and acrylic acid mixture is then given a moderate stir while methyl bisacrylamide, the crosslinker, is added to ensure consistent crosslinking.[22][23]

3.4. Design of experiment for dye removal:

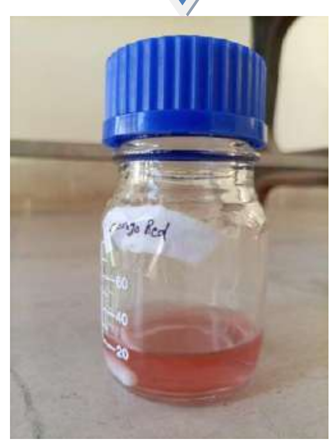
Hydrogel Preparation

Hydrogel drying in Vacuum Oven

Hydrogel

MB Before adding hydrogel.

MB after adding Hydrogel.



CR Before adding hydrogel.

CR after adding Hydrogel.

Chapter: 04

4. Characterization

To assess the effectiveness of hydrogels in absorbing dyes, we ran a number of tests on various instruments utilizing UV-Vis spectroscopy. The calibration curve was employed to precisely calculate the test findings. We discovered that hydrogels are quite good at absorbing dyes, with the peak absorption happening between 270 and 350 nm in wavelength. We also discovered that as hydrogel particle size grew, absorption efficiency increased as well. Overall, the results of our testing have shown that hydrogels are a great option for dye absorption.[24]

4.1. UV-Vis spectroscopy

The hydrogel samples before and after dye absorption are prepared for UV-Vis characterization. By comparing the original and final dye concentrations, the absorbance information from the UV-Vis spectra can be utilized to quantify the percentage of dye elimination. This gives a numerical evaluation of the hydrogel's ability to absorb a particular dye.

Additionally, UV-Vis spectroscopy makes it possible to determine the dye's maximum absorbance wavelength (mix), which can help to improve the experimental circumstances for dye absorption by the hydrogel. Plotting absorption spectra and examining any shifts or modifications in the dye's absorption profile upon contact with the hydrogel can also be done using the absorbance data.[25], [26]

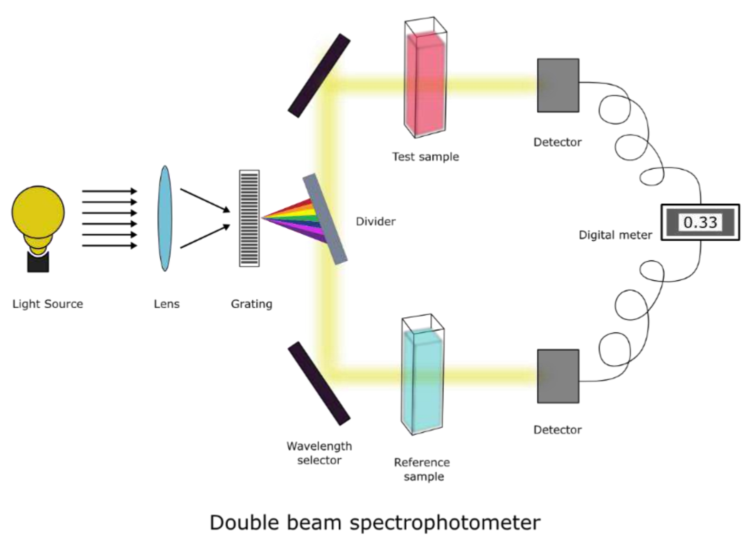


Figure 10 UV vis Spectrometry

Chapter: 05

5. Result and Discussion

5.1. Removal efficiency

To determine the hydrogel removal capacity of MB and Cango red, 50 mg of PAA/Chitosan hydrogel was dissolved in 400 mL water containing 8 mg each of MB and Cango red dye solution. As soon as the hydrogel reached equilibrium with the dye solution, it was removed from the solution. The removal capacity was calculated using an equation.

$$\text{Removal capacity} = c_o – c_e / c_o *100$$

Whereas c_o initial dye concentration c_e is dye equilibrium concentration.

5.1.1 Methylene Blue

$$MB = 0.3784 – 0.0130/ 0.3784 * 100$$
$$MB = 96.5$$

The adsorption ability of PAA/Chitosan hydrogel for methylene blue was shown to be extremely effective, with a maximum removal percentage of 97%.

5.1.2 Cango Red

$$CR = 0.3706 – 0.0680 / 0.3706 * 100$$
$$CR = 81.65$$

PAA/Chitosan hydrogel also shown outstanding adsorption effectiveness for Congo red, with a maximum removal rate of 82%.

5.2. Swelling study

50 mg of freeze-dried PAA/Chitosan hydrogel was dissolved in 100 mL of deionized water to determine the hydrogel swelling ratio. The deionized water was removed from the growing hydrogel when it reached equilibrium, and any remaining surface water was drained off before it was weighed. Equation was used to compute the swelling ratio (SR).

$$SR = m_s – m_d / m_d$$

Where the weights of the PAA/Chitosan hydrogel in the swollen and dry stages, respectively, are m_s (g) and m_d (g). It was determined that the swelling ratio was 270%.

5.3. UV-Vis Spectroscopy

UV-Vis Spectroscopy (also known as Spectrophotometry) is a quantitative method for calculating how much light an individual molecule absorbs. This is accomplished by comparing the amount of light that passes through a sample to the amount of light that goes through a reference sample or a blank. Glass, liquids, solids, thin films, and other sample types can all be employed with this method.[27]

Both Congo red and methylene blue dyes were very well absorbed by the chitosan-PAA hydrogel. Chitosan-PAA hydrogel beads were prepared for the adsorption studies and submerged in dye solutions with various starting concentrations. After agitating the solutions for a predetermined amount of time, the equilibrium concentrations were measured. The calibration curves for each dye were then built using the data that had been collected.

5.3.1. Calibration curve of Methylene blue

Several standard solutions with known concentrations of methylene blue were created to build the calibration curve.

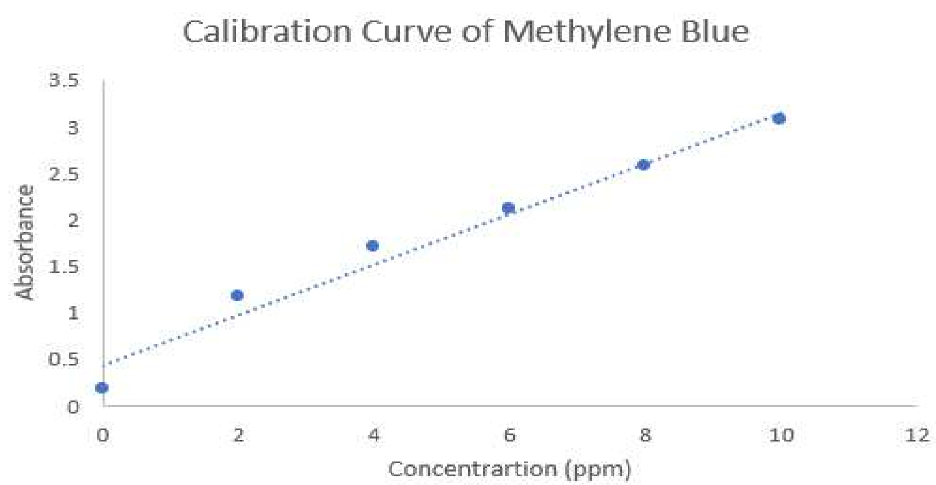


Figure 11 Calibration Curve of MB

Using a spectrophotometer, the absorbance of each solution was determined at a particular wavelength that corresponded to the maximum absorbance of the matching dye.

5.3.2. Calibration curve of Cango red

Numerous widespread answers with acknowledged concentrations of Cango red have been created to construct the calibration curve.

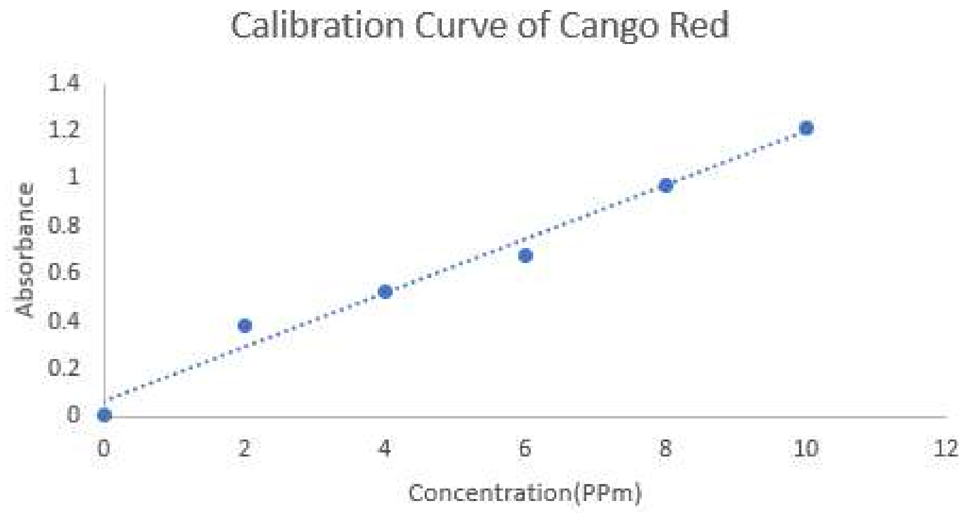


Figure 12 Calibration Curve of CR

The use of a spectrophotometer, the absorbance of each solution was decided at a selected wavelength that corresponded to the most absorbance of the matching dye.

5.3.3. Absorbance / time Graph of MB

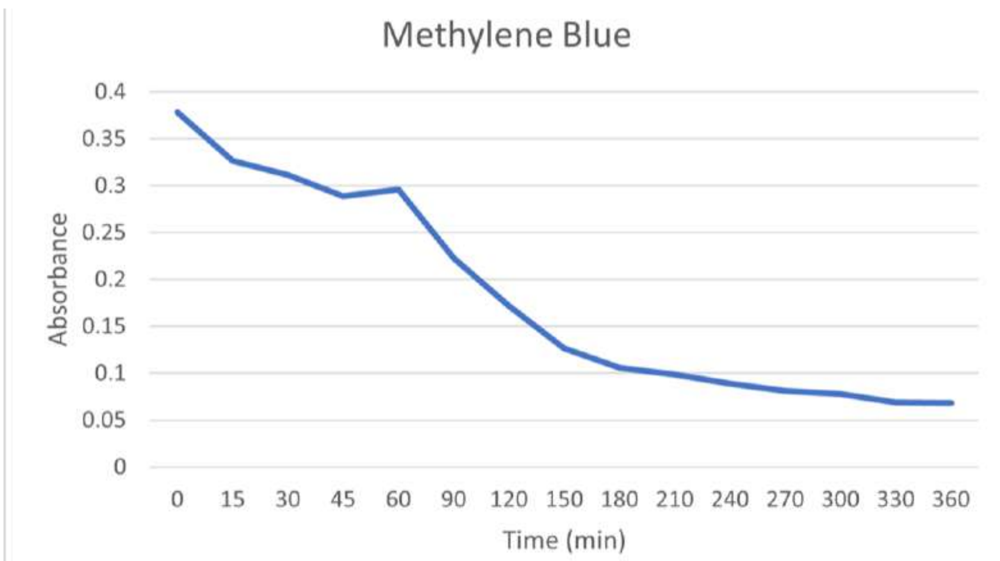


Figure 13 Graph of MB

As shown in the graph, MB absorbance decreases with time, indicating that dye is absorbed by the absorbent (hydrogel).

5.3.4. Absorbance / time Graph of CR

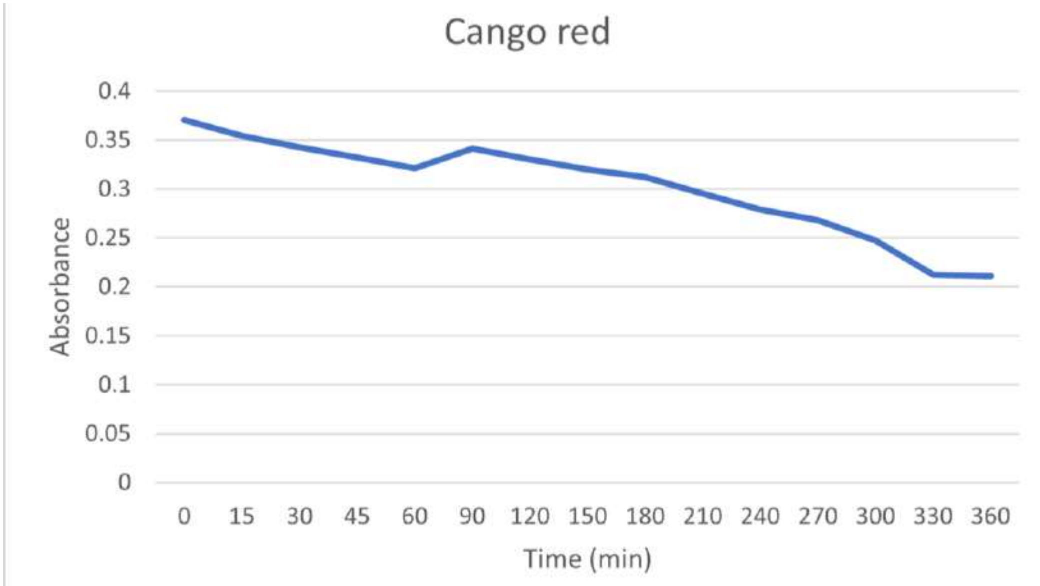


Figure 14 Graph of CR

According to the graph, CR absorbance decreases with time, meaning dye is absorbed by the absorbent (hydrogel).

Chapter: 06

6. Conclusion:

The consequences obtained from the UV-Vis spectrometry and calibration curve analysis confirmed the efficacy of the polymeric hydrogel in getting rid of Cango red and Methylene Blue dyes. The absorbance spectra of the handled solutions exhibited an extensive discount in dye concentration in comparison to the untreated answers, indicating successful dye elimination. The quantitative evaluation discovered high dye removal efficiencies, in addition validating the effectiveness of the polymeric hydrogel.

The development of a polymeric hydrogel for dye removal applications, especially targeting Cango red and Methylene Blue, has proven promising consequences in this task. By utilizing UV-Vis spectrometry and calibration curves, the effectiveness of the hydrogel in doing away with those dyes from aqueous answers turned into evaluated. The received results verified the capacity of the hydrogel to efficaciously do away with the goal dyes, indicating its potential for water purification and environmental remediation programs. In end, the improvement of polymeric hydrogel for dye removal programs, utilizing UV-Vis spectrometry and calibration curves, gives a promising solution to the environmental demanding situations posed through textile and wastewater industries. The successful elimination of Cango red and Methylene Blue dyes, as validated by means of the experimental results, highlights the capability of polymeric hydrogels as efficient and sustainable materials for dye wastewater remedy.

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