

METAL INCORPORATED POLYMER AS CATALYST FOR DEGRADATION OF CONGO RED DYE

Submitted in partial fulfilment of the requirements for the award of

Master of Science in Chemistry

by

A.MAHALAKSHMI

(REGISTER NO.: 40910005)



**DEPARTMENT OF CHEMISTRY
SCHOOL OF SCIENCE AND HUMANITIES**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC | 12B Status by UGC | Approved by AICTE

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **MAHALAKSHMI.A (40910005)** who carried out the project entitled "**METAL INCORPORATED POLYMER AS CATALYST FOR DEGRADATION OF CONGO RED DYE**" under our supervision from November 2021 to May 2022.

Internal Guide

Dr. S.SUPRIYA, M.Sc., Ph.D.,

Head of the Department

Dr. J. KARTHIKEYAN, M.Sc., Ph.D.

Submitted for Viva voce Examination held on _____

Internal Examiner

External Examiner

DECLARATION

I **MAHALAKSHMI.A (40910005)**, hereby declare that the Project Report entitled “**METAL INCORPORATED POLYMER AS CATALYST FOR DEGRADATION OF CONGO RED DYE**” done by me under the guidance of **Dr. S.SUPRIYA, M.Sc., Ph.D.**, Associate professor, Department of Chemistry at **Sathyabama Institute of Science and Technology**, Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai – 600119 is submitted in partial fulfillment of the requirements for the award of Master of Science degree in Chemistry.

DATE:

A.MAHALAKSHMI

PLACE:

SIGNATURE OF THE CANDIDATE

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ABSTRACT

Water pollution is a threatening environmental concern on these days; hence it requires a serious attention. Pure water is contaminated by the heavy discharge of industrial effluents. These wastewaters cause a rise in organic matter content, a change in chemical oxygen demand, and eventually the demise of aquatic organisms. Herein, this research work focused on the demand for overcoming water pollution utilizing metal (copper) incorporated polymer as catalyst to degrade the industrial water waste pollutant Congo red dye. Because Congo red can also be converted to benzidine, which is a proven human carcinogen. Hence, Congo red must be removed from the industrial wastes. In this study, a PVA-Cu catalyst with good reusable capacity was successfully prepared by chemical method. The properties of this were assessed by employing different characterization techniques such as Ultraviolet-Visible spectroscopy, X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FT-IR), scanning electron microscope (SEM). This catalyst when added to the industrially released Congo red dye pollutant in water bodies. The Congo red dye will undergo degradation and turns the water bodies clean and also brings back the normal neutral pH of the water from basic pH which is pH 9 from pH 7.

The results showed that PVA-Cu catalytic films are promising as a suitable candidate for the efficient removal of Congo red dye from solution.

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LIST OF ABBREVIATIONS

PVA	Polyvinyl Alcohol
CRD	Congo Red Dye
Cr	Congo Red
Cu	Copper
CuSO ₄	Copper Sulphate
HCl	Hydrochloric acid
NaOH	Sodium Hydroxide
g/mL	Gram Per Millilitre
pH	Potential of Hydrogen
mL	Millilitre
UV-Vis	Ultraviolet Visible
FTIR	Fourier Transform Infrared
XRD	X-Ray Diffraction
SEM	Scanning Electron Microscope

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CHAPTER 1

INTRODUCTION

1.1 POLYVINYL ALCOHOL:

Polyvinyl alcohol was 1st prepared by Hermann and Haehnel in 1924 by hydrolysing polyvinyl acetate in ethanol with potassium hydroxide. Polyvinyl alcohol (PVA), which is also one of the most important polymers used in the industry, is the most well-known water-soluble polymer utilised for various optoelectronic devices and applications that is both environmentally benign and cost effective. PVA is a semicrystalline polymer with excellent optical characteristics and a high dielectric constant. strength, great physical qualities, and exceptional transparency. Even if the best low isn't available, polymer glasses with the lowest refractive index ($n = 1.3\text{--}1.4$) for light scattering loss. Amorphous polymers (perfluoropolymer-0.3 dB/km, at 1.3 m) have a high transmission rate. PVA has been extensively studied due to its huge size (similar to silica fibre). Due to its chemical flexibility and good optical properties, it has a wide range of potential applications. [27].

It is commercially produced from polyvinyl acetate by continuous process. The acetate groups are hydrolyzed by ester interchange with methanol in the presence of anhydrous sodium methylate or aqueous sodium hydroxide. The physical characteristics and its specific functional uses depend on degree of polymerization and degree of hydrolysis. Polyvinyl alcohol is classified into two main classes they are namely partially hydrolyzed and fully hydrolyzed. Partially hydrolyzed PVA is used in the food. It is utilized as a dampness hindrance film for food supplement tablets and for food varieties that contain considerations or dry food with incorporations that should be shielded from dampness take-up. Poly (vinyl liquor) (PVOH or PVA) is a water-soluble synthetic polymer. It has the admired formula $[\text{CH}_2\text{CH}(\text{OH})]_n$. It is utilized in papermaking, material twist measuring, as a thickener and emulsion stabilizer in PVAc cement details, in an assortment of coatings, and 3D printing. It is dull or colourless (white) and scentless or odourless, translucent, white or cream coloured granular powder. It is regularly provided as beads or as solutions in water. It is not a naturally occurring product.

Without a remotely added crosslinking agent, PVA solution can be gelled through continued freezing-thawing, yielding strong, ultrapure, biocompatible hydrogels which have been utilized for an assortment of utilizations like vascular stents, ligaments, contact focal points, and etc...

1.1.1 DESCRIPTION AND MANUFACTURING OF PVA:

The solubility of the PVA is fully soluble in water, slightly soluble in ethanol, The solubility of the PVA is fully soluble in water, slightly soluble in ethanol, but insoluble in other organic solvents. A 5% solution of polyvinyl alcohol exhibits a pH in the range of 5.0 to 6.5. Polyvinyl alcohol has a melting point of 180 to 190°C. It has a molecular weight of between 26,300 and 30,000, and a degree of hydrolysis of 86.5 to 89%.

Vinyl acetate monomer is the principal raw material used in the production of polyvinyl alcohol. It is created by polymerizing vinyl acetate and then partially hydrolysing it. The hydrolysis process works by partially replacing the ester group in vinyl acetate with a hydroxyl group, and in the presence of aqueous sodium hydroxide, the process is completed. The aqueous solution was gradually added after that. Agent of saponification Precipitated polyvinyl alcohol is cleaned and dried. The degree of hydrolysis is determined by the time point at which the saponification reaction has been stopped [33].

The structure of polyvinyl alcohol (partially hydrolysed) is

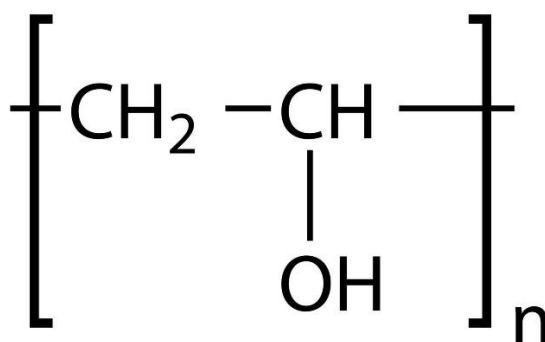


Fig 1.1 Structure of PVA

1.1.2 APPLICATION AND USES OF PVA:

Because of its biocompatibility, low tendency for protein adhesion, and low toxicity, PVA is used in a variety of medical applications. Cartilage replacements, contact lenses, and eye drops are all examples of specific applications. In suspension polymerizations, polyvinyl alcohol is utilised as a helper. In China, the most common application is as a protective colloid in polyvinyl acetate dispersions. Its primary application in Japan is the manufacture of Vinyon fibre. North Korea produces this fibre for self-sufficiency reasons because it does not require the usage of oil. Photographic film is another application. In additive manufacturing, PVA-based polymers are commonly employed. In the pharmaceutical business, 3D printed oral dose formulations, for example, show considerable promise. It's feasible to make drug-loaded tablets with different drug-release mechanisms [45].

Poly (vinyl alcohol) is utilised in the coatings industry (for example, as a thickening agent for aqueous systems), adhesives, paper and cardboard finishing, paper coating, strippable coatings, and as a protective colloid for dispersions.

Ceramics, leather, cloth, nonwoven textiles and paper, paper coatings, grease-proofing paper, emulsifying agent, thickening and stabiliser, textile warp and yarn size photosensitive films, cements and mortars, intermediate for other polyvinyls, imitation sponges and printing inks (glass).

PVA polymer is utilised in a variety of applications. Many medications contain it as a primary ingredient. Its sticky property is used in a variety of applications. PVA stands for polyvinyl alcohol, and it's a form of synthetic adhesive. PVA glue is used in a variety of applications. A glue or fixative made of polyvinyl alcohol is known as PVA glue. PVA glue is water soluble and can be used to make emulsions. It's mostly used to secure porous materials. It's used to glue wood, paper, and cloth together. PVA is an excellent absorbent.

PVA's property is quite important in the textile business. PVA is utilised in the textile sector because of this PVA cloth dries quickly. [46].

1.2 HEAVY METAL POLLUTANTS:

In the earth's crust, numerous metals can be found in trace amounts. Heavy metals like Pb, Hg, Zn, and Cd. In small amounts, some heavy metals are advantageous to organisms. However, if excessive levels of heavy metals reach the environment as a result of human activity, they harm human and other organisms health and survival.

A heavy metal is defined as a substance with a density of more than 5g cm^{-3} . Lead, cadmium, mercury, arsenic, selenium, iron, copper, manganese, selenium, zinc, and other heavy metals are examples.

The atomic number of all of these metals is greater than 20. Metals like iron, copper, zinc, and a few others, in low amounts, are necessary for organisms. They're known as 'trace metals'. Metals such as lead, mercury, cadmium, and others, on the other hand, are hazardous to organisms above a specific concentration. A trace metal is one that occurs in the earth's crust in concentrations of 1000 ppm (parts per million or mg/litre) or less [16].

Human civilization is always evolving and progressing, and natural resources play an important role in this development and progression. Biotic (living organisms and their products) and abiotic (air, water, and soil) resources are combined to suit civilization's needs.

We have been exploiting resources in the period of fast progress without considering the time it takes for the resources to recover. Injudicious resource consumption not only results in a scarcity of resources for future use, but it also leads to the introduction of compounds into our environment that were not previously there or were present in little quantities. The phenomena of unwanted substance addition to the environment are known as "pollution," and the compounds added are known as "pollutants." [31]

These pollutants, which are released into the environment as a result of numerous development activities, endanger ecosystems in general and human lives in particular. Various historical events, such as the Bhopal gas tragedy, the Minamata Bay disaster, the London smog, and others, have demonstrated the dangers that pollutants pose. Pollutants might be in the form of a gas, a liquid, or a

solid. They can be formed and released as a result of human activities, or they can occur in the biosphere as a result of resource over-exploitation, which causes contaminants to be exposed from deeper soil crusts. Heavy metals, among the various types of contaminants, have piqued the scientific community's interest due to the substantial health risks they pose.

Metals have always been a part of nature, but over-exploitation of resources and other anthropogenic activities have increased the biosphere's background concentration of these metals. For example, increasing levels of arsenic in groundwater in many locations are the result of over-exploitation of subsurface water resources, which results in mineral disintegration. Heavy metals generated by any activity last a long period in the environment since they cannot be eliminated. Although several of these heavy metals are required in minute amounts for plant and animal physiological metabolism, they are hazardous at higher doses [3].

1.2.1 COPPER:

Copper is a chemical element its symbol is **Cu** (It is derived from Latin: *cuprum*) and atomic number is 29. It is a soft, malleable, and ductile metal and it has very high thermal and electrical conductivity. A freshly exposed surface of the pure copper has a pinkish-orange colour [47]. Copper (Cu), a reddish, very ductile metal of Group 11 (Ib) of the periodic table that is an especially strong conductor of electricity and heat, is a chemical element. Copper is found in its free metallic condition in nature. Copper is commercially produced primarily through smelting or leaching, with electrodeposition from sulphate solutions commonly following. The electrical industries consume the majority of copper produced worldwide; the remainder is mixed with other metals to generate alloys. [48].

- Atomic number (number of protons in the nucleus): 29
- Atomic symbol (on the periodic table of elements): Cu
- Atomic weight (average mass of the atom): 63.55
- Density: 8.92 grams per cubic centimetre.
- Phase at room temperature: solid
- Melting point: 1,984.32 degrees Fahrenheit (1,084.62 degrees Celsius)

- Boiling point: 5,301 F (2,927 C)
- Number of isotopes (atoms of the same element with a different number of neutrons): 35; 2 stables
- Most common isotopes: Cu-63 (69.15% natural abundance) and Cu-65 (30.85% natural abundance) [42].

1.2.2 PHYSICAL PROPERTIES:

Copper is a noble metal like gold and silver, and it is found in Group IB of the periodic table between nickel and zinc. Copper's desirable physical qualities, such as appearance, alloying ability, minimal corrosion, malleability, and high thermal and electrical conductivity, contribute to its industrial importance. Copper does not dissolve in acidic conditions unless an oxidising agent is present, and the metal is protected from further oxidation by the creation of a green layer of copper carbonate on top of it.

1.2.3 CHEMICAL PROPERTIES:

Cuprous ions (I) dissociate fast into cupric (II) and metallic copper in aqueous solutions (0). In water, only the insoluble cuprous compounds (CuCl) are stable. The colour of cupric compounds is blue or green. They are commonly found in water and are typically highly soluble in aqueous solutions. Cu (III) is a strong oxidising agent that has little industrial or environmental significance.

Copper makes up roughly a quarter of the mass of copper sulphate (CuSO₄ 5H₂O). The amount of copper leached from copper piping increases as water becomes more acidic [9].

1.2.4 USES:

Copper is used as a heat and electricity conductor, a building material, and a component of various metal alloys, including sterling silver for jewellery, cupronickel for marine hardware and coins, and constantan for strain gauges and thermocouples for temperature measurement [47] . Copper is mostly utilised in electrical equipment like wire and motors. This is due to the fact that it transmits heat and electricity more efficiently and can be dragged into wires. It is also used in the building (for example, roofing and plumbing) and industrial machines (such as

heat exchangers). Chemical assays for sugar detection use copper compounds like Fehling's solution.

For the manufacture of bridges and dental crowns, copper-based alloys (aluminium, cobalt, manganese, nickel, zinc) have been introduced. Small amounts have recently been discovered. High-copper alloys have been infused with platinum or palladium. To decrease tarnish and boost durability, amalgams are used. Copper amalgam corrosion products include oxides, chloride oxides or hydroxides, chlorides, and sulphides of copper after exposure to saliva [9].

1.2.5 COPPER AS HEAVY METAL:

Copper toxicity (also known as Copperiedus) is a form of metal poisoning caused by a build-up of copper in the body. Copperiedus can be caused by eating acidic meals cooked in uncoated copper cookware, wearing an IUD, being exposed to excessive copper in drinking water and other environmental sources, or having Wilson's disease, which is a genetic illness.

Copper toxicity can be acquired from a variety of ways. It can be caused by consuming copper salts (copper sulfate). Unused cooking or food storage devices, such as pots and pans, can develop these blue-colored salts. They can occur within water pipes as well. Copper salts can contaminate water if they develop in water pipes. Copper poisoning can be caused by eating too much copper-rich food or taking too many dietary supplements. Copper can also be ingested by drinking an acidic beverage or eating food that has been stored for a long time in a copper container. Copper poisoning is possible if you consume too much of it. Ingesting high amounts of copper salts through your skin could cause serious poisoning. Copper can accumulate in your brain, liver, and lungs as it passes through your internal organs. Even persons with a healthy liver can be poisoned by large dosages of copper-containing substances like copper sulphate. However, some persons are more susceptible to copper toxicity than others. Copper toxicity is more common in patients with specific liver illnesses and those who have a genetic inability to metabolise copper, such as those who have Menkes disease, hereditary aceruloplasminemia, or Wilson's disease. Acute gastrointestinal sickness is caused by copper exposure in food and beverages. Copper poisoning can be caused by vending machine beverages, copper or brass vessels, and, in rare cases, drinking

water. Copper is a prevalent suicidal substance in India. Because of its toxicity, copper was no longer used as an emetic in medicine.

People who live near or work in copper-producing facilities, such as mines, smelters, or refineries, or in copper manufacture, are at a higher risk of excessive copper exposure. Copper dust and fumes can be inhaled, resulting in exposure. There are some copper sources in the environment that can be harmful to your health. Copper is reported to be present in over half of the hazardous waste sites on the EPA's National Priorities List. Copper levels in the air and soil near copper processing plants, such as smelters, are often substantially higher than in other locations. Copper-based insecticides can be found in agricultural runoff. These can be harmful to humans' health. Copper, on the other hand, readily bonds to molecules in soil and water, lowering its bioavailability in people [31].

Here we use copper sulphate for the reaction. Copper sulphate molecular formula is CuSO_4 . CuSO_4 molecular weight is 159.609 g/mol. Valency is +2. Boiling point is 650°C . Melting point is less than 200°C . Density is 3.603. And water solubility(g/mol) is 14.3 (0°C). Copper sulfate is used widely as an agricultural poison and as an algicide in water purification [47].

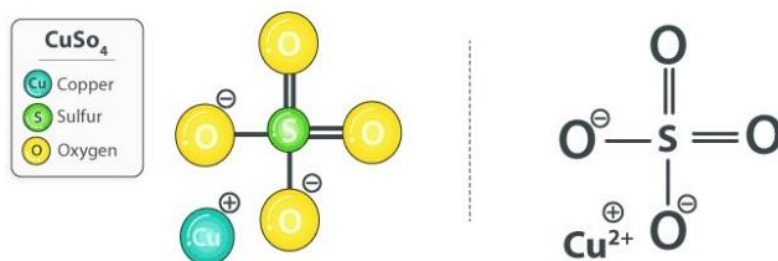


Fig 1.2 Structure of copper sulphate

1.3 POLYVINYL ALCOHOL WITH METAL:

PVA is a water-soluble polymer. So, we are dissolving in the Copper Sulphate solution in certain amount. On continuous stirring the Copper in the Copper sulphate solution gets doped into the polymer.

1.4 CATALYST:

Catalysts are chemicals that change the reaction's rate by changing the reaction's course. To speed up or raise the rate of a reaction, a catalyst is usually used. Catalysts, on the other hand, are employed to break or rebuild chemical connections between atoms in molecules of various elements or compounds at a deeper level. Catalysts, in essence, stimulate molecules to react, making the entire reaction process simpler and more efficient.

Catalysts have a number of key characteristics, some of them are listed below,

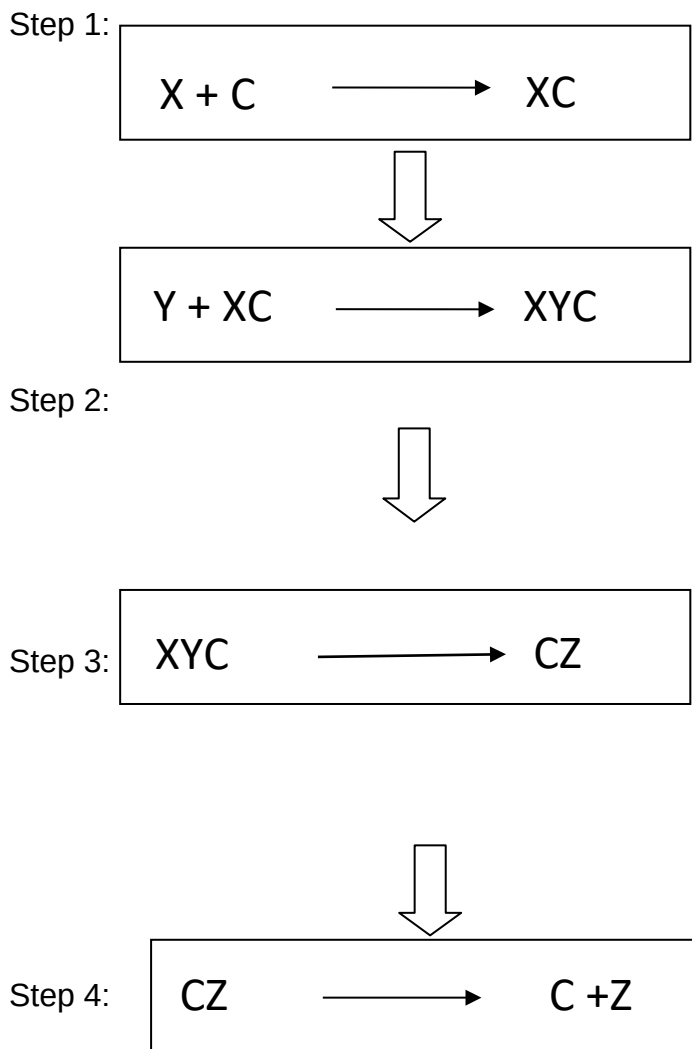
1. A catalyst isn't the one who initiates a chemical reaction.
2. A catalyst does not be consumed in the reaction.
3. Catalysts tend to combine with reactants to make intermediates while also making the final reaction product easier to produce. A catalyst can regenerate after the entire procedure.

1.4.1 MECHANISM OF CATALYST:

The basic principle behind catalysis is that in the presence of a catalyst, lesser free energy is required to reach the transition state, and the total free energy from reactants to products does not change. So, catalyzed reactions have a lower activation energy than an uncatalyzed reaction, resulting in a higher reaction rate at the same temperature and for the same reactant concentrations. Typically, the catalyst enters into chemical combination with the reactants but is eventually regenerated, so the amount of catalyst remains unaffected. Since the catalyst is not consumed, each catalyst molecule may persuade the conversion of many molecules of reactant. For an active catalyst, the number of molecules transformed per minute by one molecule of catalyst may be as large as several million. By choosing the appropriate catalyst, a particular reaction can be made to occur to the extent of practically excluding another. Many important applications of catalysis are based on this kind of selectivity.

Catalysts react with one or more reactants to form intermediates that subsequently produce the final reaction product, in the process regenerating the catalyst. The

following is a typical reaction scheme, where C represents the catalyst, X and Y are reactants, and Z is the product of the reaction between X and Y:



Hence, the overall reaction is: $X + Y \longrightarrow Z$

Since the catalyst is consumed in step 1 and regenerated in step 4, it does not appear in the overall reaction. As it is regenerated, it is only required in small quantities in the reaction. Also, it can be noted that a catalyst does not affect the position of equilibrium of a chemical reaction; it affects only the rate at which equilibrium is attained. Apparent exceptions to this generalization are those reactions in which one of the products is also a catalyst for the reaction (autocatalytic reactions).

TYPES OF CATALYST: -

Mainly catalyst are four types,

- ✓ Homogeneous
- ✓ Heterogeneous
- ✓ Heterogenized homogeneous catalyst
- ✓ Biocatalyst

HOMOGENEOUS CATALYST:

In homogeneous catalysis reaction mixture and catalyst both are in same state. Both catalyst and reactant have high homogeneity which results in high interaction among them.

Some of the examples homogeneous catalyst are Lewis's acids, transition metals, organometallic complexes.

Some important chemical process that occurs through homogenous catalysis are carbonylation oxidation and hydrogenation.

HETEROGENEOUS CATALYST:

Heterogenous catalysis is a catalysis that the reactant or product and catalyst differ from the states.

Example of heterogenous catalyst is Haber- Bosch process for the synthesis of ammonia.

Heterogenous catalyst are widely used in industrial process because of the easy separation of product and recovery of catalyst.

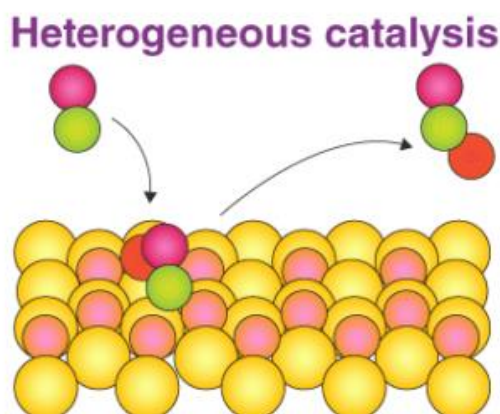


Fig 1.3 Heterogenous catalyst

HETEROGENIZED HOMOGENEOUS CATALYSTS: -

Heterogeneous catalyst in variance to their homogeneous counterpart are much more difficult to develop practically because of their complexity.

BIOCATALYST: -

Some specific chemical reactions are carried out side the living cells by catalysis using natural proteins or nucleic acid is called bio catalysis. Enzymes are obtained from the animal tissues, plant and microbes. They are high selectivity, high efficiency and eco- friendly and gentle response conditions are the main impetuses for their huge scope use and making biocatalysts an option in contrast to ordinary industrial catalyst.

1.5 CONGO RED DYE:

Congo red is the first synthetic dyestuff of the direct kind, which means it doesn't need to be mordanted (a substance such as tannin or alum used to fix the colour to cotton fibres). Congo red is a kind of azo dye made from benzidine that was first introduced in 1884. Congo red was once used to colour cotton, but it has since been replaced with dyes that are more light and washing resistant. It's still used in histology to stain tissues for microscopic study and as an acid-base indicator since it becomes red when exposed to alkalies and blue when exposed to acids. [50].

Congo red is the sodium salt of 3,3'-([1,1'-biphenyl]-4,4'-diyl)bis(4-aminonaphthalene-1-sulfonic acid). It's a kind of azo dye. Congo red is water soluble, resulting in a crimson colloidal solution; however, its solubility in organic solvents is higher. Congo red is water-soluble, yielding a red colloidal solution; its solubility is greater in organic solvents. However, the use of Congo red has long been abandoned, primarily because of its carcinogenic properties. Congo red is an acid-base indicator dye. Congo Red is an azo dye, it is toxic to many organisms it is a pollutant in the environment and is a suspected carcinogen and mutagen [51].

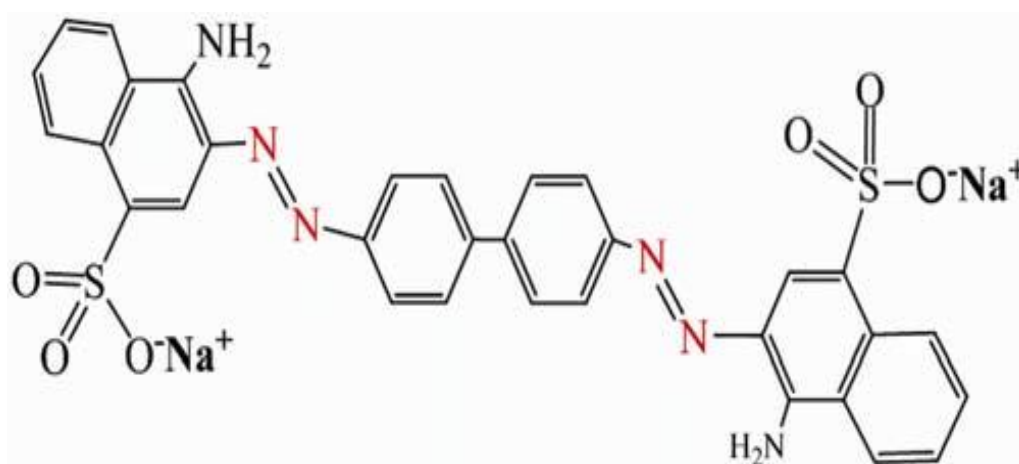


Fig 1.4 Structure of CRD

1.5.1 POLLUTION AND POLLUTANT:

Pollution is defined as the introduction of contaminants into the natural environment that have a negative impact. Any substance (solid, liquid, or gas) or energy can be polluted (such as radioactivity, heat, sound, or light).

There are four main types of pollution namely air pollution, water pollution, land pollution and noise pollution.

A pollutant is a substance or energy that has unfavourable impacts on the environment or reduces the utility of a resource. By altering the growth rate of plant or animal species, or interfering with human amenities, comfort, health, or property values, a pollutant can inflict long- or short-term damage. Some pollutants are biodegradable, meaning they won't last long in the environment. Pollution is defined

as the introduction of contaminants into the natural environment that have a negative impact. Any substance (solid, liquid, or gas) or energy can be polluted (such as radioactivity, heat, sound, or light) [52].

1.5.2 INDUSTRIAL WATER POLLUTION:

Pollution of industrial waste water caused by the release of hazardous chemicals and substances into the water, rendering it unfit for human consumption and other uses. Despite the fact that 60–70% of the land is used for agriculture, Lakes, ponds, and rivers are examples of water bodies. Fresh water is supplied via reservoirs and watercourses, which should be kept clean [36].

Greater population has resulted in increased demand for commodities, resulting in rapid industrialization. As a result of the growing number of industrial setups, there has been an increase in the generation of industrial waste. These industrial wastes pollute the water, air, and soil, causing considerable environmental damage. The type of industry determines the quality and quantity of wastewater produced: it may contain non-biodegradable waste such as heavy metals, pesticides, plastic, and other non-biodegradable compounds, as well as biodegradable compounds such as paper, leather, and wool. Toxic, reactive, carcinogenic, and ignitable industrial wastewater exist. As a result, dumping waste into bodies of water without suitable treatment and management procedures can have disastrous environmental and health consequences [18].

1.5.2 CRD as industrial waste water pollutant:

Enterprises in the printing, dyeing, and paint industries have grown quickly in recent years, resulting in a substantial amount of wastewater containing colours. These companies' untreated effluents have a negative impact on the environment as well as the health of those who live in their catchment areas. These wastewaters cause a rise in organic matter content, a change in chemical oxygen demand, and eventually the demise of aquatic organisms. Nitro and amino chemicals, as well as heavy metal components like copper, zinc, and arsenic, have been found in dyes. These pollutants reach the groundwater system via water circulation and have the ability to bioaccumulate in organisms, resulting in increased toxicity. Because of this problem with dyes, it is critical to cleanse dye-containing wastewater before releasing it into the environment. CR discharged into wastewater has the potential

to harm the environment. CR can also be converted to benzidine, which is a proven human carcinogen. As a result, CR must be removed from the solution [20].

Hence the removal of CRD, because of its harmful effects is taken as the main theme in this project. Generating catalyst by utilizing the waste products to treat the waste in the environment.

CHAPTER 2

LITERATURE SURVEY

1.Title: Adsorption of Congo red from solution by iron doped PVA-chitosan composite film.

Authors: Kang Wen, Yi Li, Shuxing Zhang, Xiaoting Zhang, Runping Han.

Journal and year: Desalination and Water Treatment, 18 January 2020.

Inference: Changes in adsorption conditions (temperature, pH, salt) and characterisation were used to explore the adsorption mechanism of Congo red (CR) on composite films (isoelectric point, infrared spectroscopy, photoelectric spectroscopy, scanning electron microscopy). The results showed that the composite film had a 450 mg g⁻¹ adsorption capacity at pH 5.0, and that CR adsorption by high concentration salt had only a minor detrimental effect.

2.Title: Efficient removal of Congo red dye from aqueous solution by adsorbent films of polyvinyl alcohol/melamine-formaldehyde composite and bactericidal effects.

Authors : Shahnawaz Ahmad Bhat , Fahmina Zafar ,Aftab Hossain Mondal , Azar Ullah Mirza , Qazi Mohd Rizwanul Haq , Nahid Nishat

Journal and year: Journal of Cleaner Production, 10 January 2020.

Inference: One of the highest priorities in both environmental and industrial applications is the removal of hazardous dyes and the inhabitation of bacterial growth. We developed environmentally friendly and sustainable dye adsorbent films in response to rising industrial discharge and fresh water scarcity. The production of melamine-formaldehyde (MF) and cross-linking of polyvinyl alcohol (PVA) with MF were used to create biodegradable composite films in this study. FTIR, XRD, TGA, DSC, and SEM were used to characterise the PVA and PVA/MF composite films. PVA is a water-soluble polymer that has been treated with MF (13 percent, 23 percent, 33 percent, and 43 percent) to increase hydrophobicity, as measured by contact angle (500 to 910).

3.Title: Sono catalytic rapid degradation of Congo red dye from aqueous solution using magnetic Fe₀ /polyaniline nanofibers

Authors: Raghunath Dasa, Madhumita Bhaumik, Somnath Giria , Arjun Maitya.

Journal and year: Ultrasonics Sonochemistry, 16 February 2017.

Inference: For sonocatalytic degradation of organic anionic Congo red (CR) dye, nano-sized magnetic FeO /polyaniline (FeO /PANI) nanofibers were used as an effective material. At room temperature, nano-FeO was reductively deposited onto PANI nanofibers to produce FeO /PANI. HR-TEM, FE-SEM, XRD, and FTIR equipment were used to characterise the catalyst.

4.Title: Photocatalytic degradation of Congo red using Carissa edulis extract capped zinc oxide nanoparticles.

Authors: J. Fowsiya, G. Madhumitha, Naif Abdullah Al-Dhabi , Mariadhas Valan Arasu

Journal and year: Photochemistry & Photobiology, 11 July 2016.

Inference: The secondary metabolites were extracted using microwave assisted extraction of Carissa edulis (C. edulis) at 70 °C and 400 W in this study. To make ZnO nanoparticles, the metabolites were utilised as a capping agent and Zn (NO₃)₂ as a metal precursor (ZnO NPs). Nanoparticles were characterised by UV–Vis spectroscopy, FT-IR, XRD, SEM, and HR-TEM.

5.Title: Oxidative degradation of Congo red using zeolite Y as a support for Co(II), Ni(II) and Cu(II) ions

Authors: Smita Chowdhury. Krishna G. Bhattacharyya

Journal and year: Applied Sciences,16 September 2019.

Inference: In Catalytic wet air oxidation of Congo red, the potential of Co(II), Ni(II), and Cu(II) integrated zeolite Y produced via wet impregnation technique was investigated. AAS, FTIR, XRD, SEM, BET Surface area, and cation exchange capacity measurements were used to characterise the catalysts.

6.Title : Polymer Nanocomposites for Photocatalytic Degradation and Photoinduced Utilizations of Azo-Dyes.

Authors : Emily Z. Wang , Yigui Wang and Dequan Xiao.

Journal and year : Polymer Nanocomposites, 9 April 2021.

Inference : Designed polymer nanocomposites can photo-catalytically destroy azo dyes in wastewater and textile effluents, with TiO₂-based nanocomposites standing out as particularly promising and well-studied.

7.Title : An Experimental Study of Photocatalytic Degradation of Congo Red Using Polymer Nanocomposite Films.

Authors : Mashael Nasser Alshabanat and Murefah M. AL-Anazy.

Journal and year : Polymer, 2 December 2018.

Inference : Biodegradable polymers of chitosan and polyvinyl alcohol as polymeric matrices and carbon black nanoparticles as reinforcement were used to make eco-friendly polymer nanocomposite films. These films were investigated for their suitability for industrial wastewater purification as a photocatalyst for the degradation of Congo red as a target pollutant, as well as the effect of the films' polymeric matrix types on their performance as a semiconductor photocatalyst. The films were characterised using Fourier-transform infrared (FTIR) spectra and X-ray diffraction (XRD).

8. Title: Congo Red Azo Dye Removal and Study of Its Kinetics by Aloe Vera Mediated Copper Oxide Nanoparticles

Authors: Madiha Batool, Muhammad Qureshi, Farwa Hashmi, Nida Mehboob and Abdul Salam Shah.

Journal and Year: Indonesian Journal of Chemistry, May 2019

Inference: The goal of this research is to investigate the tracing of an object using green manufacture of copper oxide nanoparticles in conjunction with the interaction of leaves extract and copper salt, as well as the dye removal effectiveness. The results show that copper oxide nanoparticles are effective at removing Congo red (CR) dye. Congo red dye was eliminated by nanoparticles in this work, and the influence of nanoparticle concentration, pH, and contact duration was detected, which was satisfactory.

9.Title : Stabilized nanofibers of polyvinyl alcohol (PVA) crosslinked by unique method for efficient removal of heavy metal ions

Authors: Sana Ullaha, Motahira Hashmia, Nadir Hussaina, Azeem Ullaha, Muhammad Nauman Sarwara, Yusuke Saitoa, Seong Hun Kimb, Ick Soo Kim

Journal and year: Journal of Water Process Engineering, February 2020

Inference: Removal of heavy metal ions is vital in water purification system. We developed a novel approach for crosslinking polyvinyl alcohol (PVA) nanofibers to improve their adsorption ability against metal ions such as Copper (Cu^{2+}) and Lead (Pb^{2+}) in this paper. By maintaining PVA nanofibers in a crosslinking solution, we were able to successfully crosslink them. Unlike uncrosslinked PVA nanofibers, the morphology of nanofibers did not disintegrate in solution. When vapour crosslinked PVA nanofibers were compared to solution crosslinked PVA nanofibers, the adsorption capacity of copper and lead ions was significantly improved.

10. Title: Tuning optical properties of polyvinyl alcohol doped with different metal oxide nanoparticles.

Authors: M.Rashad

Journal and year: Optical materials and 10 April 2020.

Inference: Using the casting procedure, pure and doped polyvinyl alcohol (PVA) with 1% Fe_2O_3 or NiO nanoparticles (NPs) were created. The optical and structural characteristics of pure and doped PVA were investigated. Pure PVA has a semi-crystalline structure with crystalline and amorphous phases, as revealed by X-ray diffraction. Doping with different NPs materials changed the amorphous character of the doped PVA. The predicted optical band gap of pure PVA is 4.9 eV. The single oscillator and dispersion energy characteristics of optical dispersion were determined. The nonlinear optical sensitivity and nonlinear refractive index were also determined to be doping dependent.

11. Title: Removal of anionic dye Congo red from aqueous environment using polyvinyl alcohol/sodium alginate/ ZSM-5 zeolite membrane

Authors: Sabarish Radoor, Jasila Karayil, Jyotishkumar Parameswaranpillai and Suchart Siengchin.

Journal and year: Scientific Reports, 2020

Inference: The majority of companies discharged untreated water into bodies of water, poisoning them with harmful metals, dyes, herbicides, and insecticides. Water pollution is becoming increasingly severe, making it one of the most pressing concerns facing the metropolitan world. We have successfully created an environmentally friendly adsorbent for the removal of the hazardous anionic dye Congo red from aqueous medium in this study. The adsorption isotherm and kinetics analyses demonstrated that the Freundlich and PSO models can best represent the adsorption, respectively. Antibacterial properties and recyclability are also evident in the produced membrane. However, based on the current research, the PVA/SA/ZSM-5 zeolite membrane appears to be a potential contender for removing Congo red from contaminated water.

CHAPTER 3

AIM AND SCOPE

3.1 AIM OF THE PRESENT WORK:

To study the catalytic efficiency of the newly synthesized catalyst PVA-Cu.

3.1.1 OBJECTIVE OF THE PRESENT WORK:

- To incorporate heavy metal in the polymer and to use it as the catalyst to study its efficiency.
- To characterize the catalyst using Fourier transform infrared spectroscopy (FTIR), Ultraviolet-Visible spectroscopy, Scanning Electron Microscope (SEM).
- To study the molecular structure of the compound using single crystal X-ray diffraction studies.
- To degrade the Congo red dye.

3.2 SCOPE OF THE PRESENT WORK:

- To reduce the industrial water pollution.
- To degrade the pollutant Congo red dye from the industrial waste water pollution.
- To improve the efficiency of the catalyst by doping it with other heavy metals such as Cadmium, Cobalt, Nickel, Lead, Zinc, Iron, Mercury etc.,
- By improving the efficiency of the catalyst by doping with others metals can increase the rate of degradation of Congo red dye (pollutant) even more faster.

CHAPTER 4

MATERIALS AND METHODS

4.1 MATERIALS:

The materials used in this project are Polyvinyl alcohol, Copper sulphate, Congo red dye, Acetone, Sodium chloride, Hydrochloric acid, Sodium hydroxide pellets, beaker, measuring cylinder, Glass rod, Watch glass, Magnetic stirrer, Shaker, Hot air oven, pH paper.

4.2 METHODS:

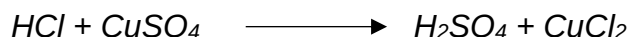
4.2.1 SYNTHESIS OF CATALYST:

Metal incorporated polymer is used as catalyst in this project. Metal incorporated polymer has prepared in three conditions. They are

- Acidic condition
- Basic condition
- Neutral condition

ACIDIC CONDITION:

1g of Copper Sulphate is weighed and dissolved in 20mL of distilled water. Then this solution is made upto 25mL by adding HCL drop by drop and maintaining the acidic condition of pH=3.



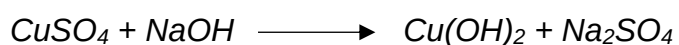
Then 2g of Polyvinyl alcohol (PVA) is weighed and powdered and added with constant stirring. Then it is kept in shaker for constant stirring for time period of 24hours. Then the metal is separated out in the form of polymer by removing it with 25mL of acetone.



Fig 4.1 Acidic Condition PVA-Cu

BASIC CONDITION:

1g of Copper Sulphate is weighed and dissolved in 20mL of distilled water. Then this solution is made upto 25mL by adding Sodium hydroxide drop by drop and maintaining the acidic condition of pH=8.



Then 2g of Polyvinyl alcohol (PVA) is weighed and powdered and added with constant stirring. Then it is kept in shaker for constant stirring for time period of 24hours. Then the metal is separated out in the form of polymer by removing it with 25mL of acetone.



Fig 4.2 Basic Condition PVA-Cu

NEUTRAL CONDITION:

1g of Copper Sulphate is weighed and dissolved in 20mL of distilled water. This solution is made upto 25ml of distilled water. Then 2g of Polyvinyl alcohol (PVA) is weighed and powdered and added with constant stirring. Then it is kept in shaker for constant stirring for time period of 24hours. Then the metal is separated out in the form of polymer by removing it with 25mL of acetone.

Here from all the above-mentioned conditions, in neutral condition the absorption of heavy metal into the polymer is more while compared with other conditions.

Hence, we are proceeding with neutral conditions.

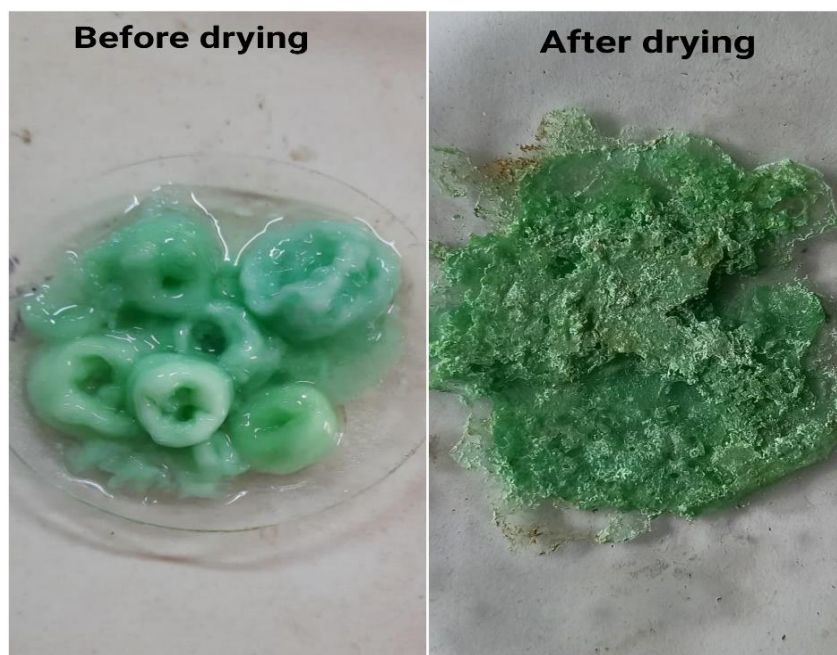
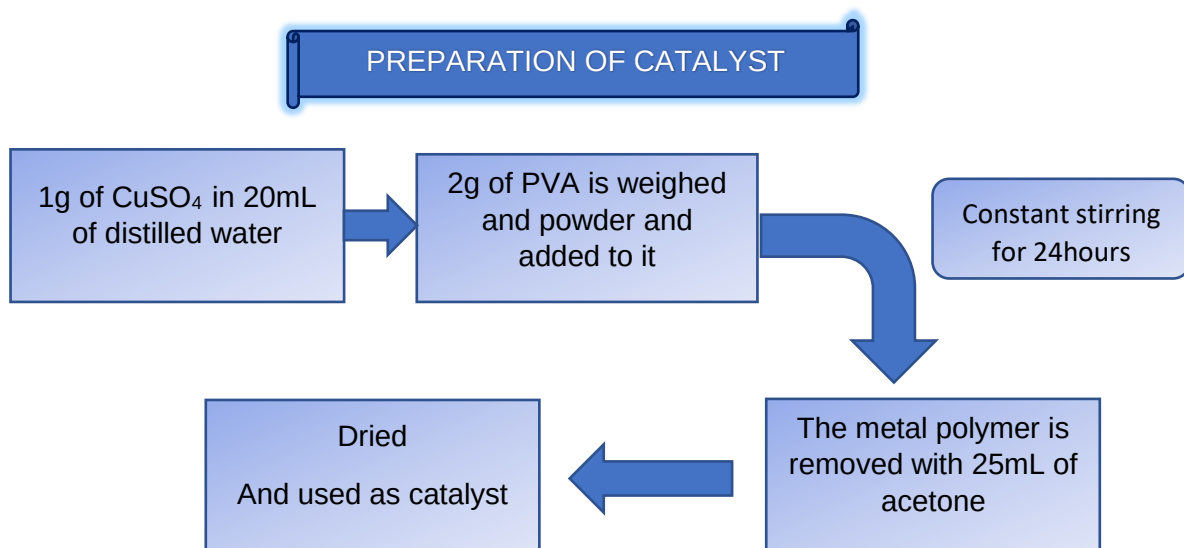


Fig 4.3 Neutral Condition PVA-Cu

Then the metal incorporated polymer is transferred in watch glass and kept in Hot air oven for drying. After removing that it is used as catalyst for degradation of Congo red dye.



4.2.2 PREPARATION OF CONGO RED DYE:

0.25g of CRD is weighed and dissolved in different volume of distilled water to get different concentrations.

1st concentration of CRD solution:

0.25g of CRD powder is weighed and dissolved in distilled water and made up to 500ml in 500ml standard flask.

2nd concentration of CRD solution:

From 1st concentration solution, 100ml is measured and made up into 500ml in 500ml standard flask.

3rd concentration of CRD solution:

From 2nd concentration, 10ml is pipetted out and made up into 100ml in 100ml standard flask.

4.2.3 DEGRADATION OF CONGO RED DYE:

20mL of CRD solution of 3rd concentration is pipetted out into a clean beaker and 2 drops of NaOH is added into it in order to maintain the pH=9. Then 0.3g of copper (metal) incorporated polymer is used as a catalyst for degradation which is added into it. And kept for stirring. Within 5-7 minutes the CRD solution got degraded.

OBSERVATION: -

- ❖ Precipitation
- ❖ The pH becomes neutral.
- ❖ Filtrate is obtained as clear solution
- ❖ Catalyst can be reused

The same procedure was repeated with 2nd concentration (higher concentration than 3rd concentration). 0.3g of catalyst is added into 20ml of CRD and kept for stirring. After 12-15 minutes degradation of CRD occurs.

In both concentration degradation of CRD takes place but in lower concentration degradation occurs more faster than in higher concentration.

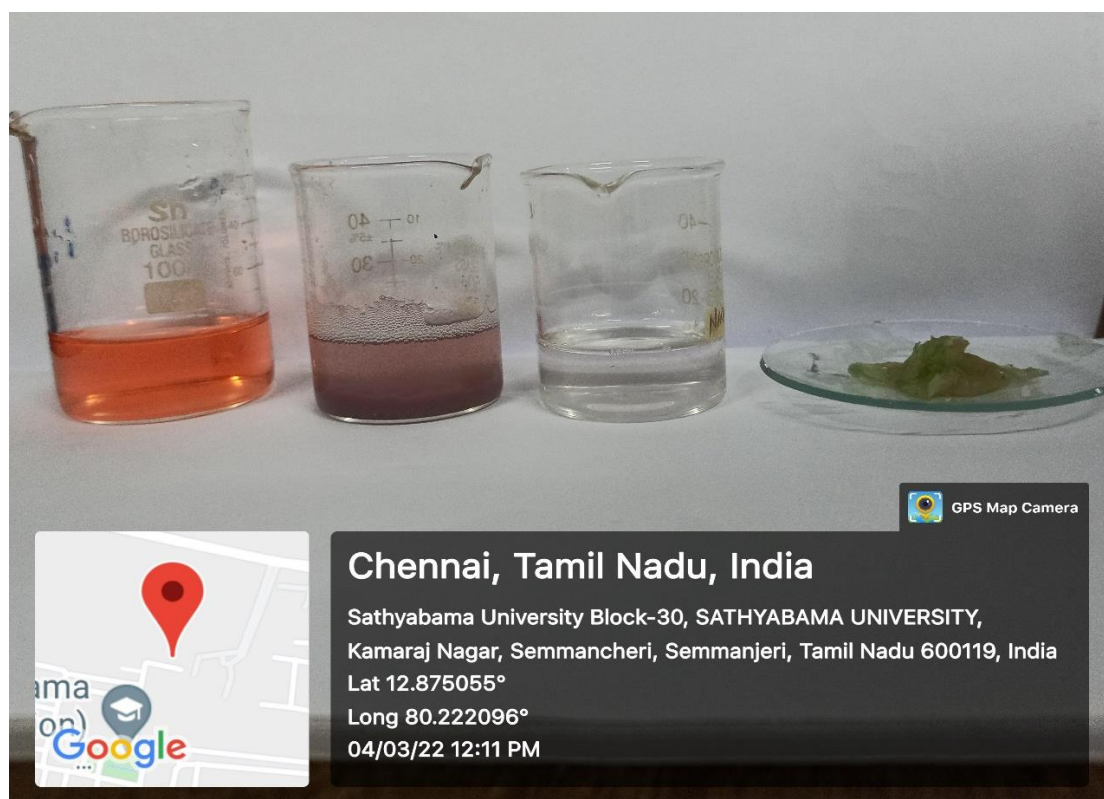
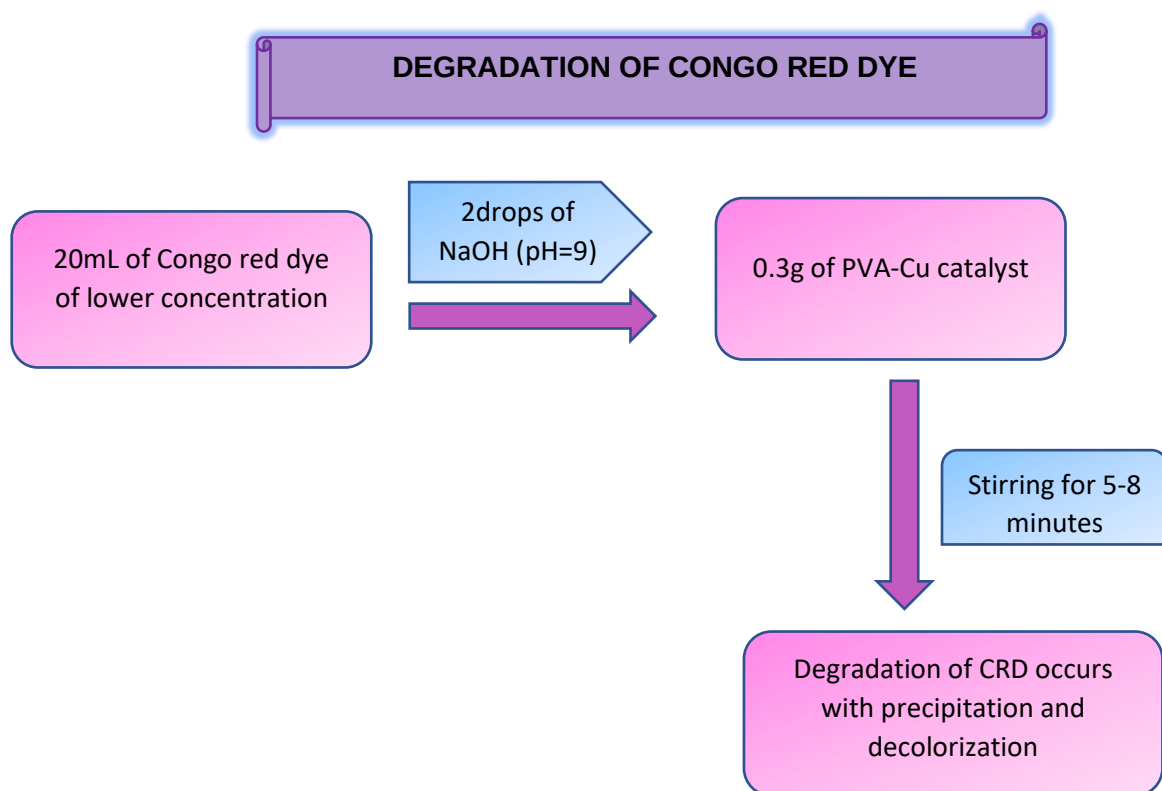


Fig 4.4 Degradation Of CRD

4.3 CHARACTERISATION TECHNIQUES:

4.3.1 UV SPECTROSCOPY:

PRINCIPLE: -

The UV-Visible Spectroscopy is based on the absorption of ultraviolet or visible light by chemical substances, which leads in the production of various spectra. Spectroscopy is based on the interaction of light and matter. When matter absorbs light, it undergoes excitation and de-excitation, resulting in the production of a spectrum. [53]

When matter absorbs ultraviolet light, the electrons inside it get excited. This leads them to leap from a ground state to an excited state (an energy state having a little amount of energy connected with it) (an energy state with a relatively more amount of energy associated with it).

The more easily excited the electrons (i.e., lower energy gap between the HOMO and the LUMO), the longer the absorb energy in the form of ultraviolet or visible light to excite these electrons to higher anti- Molecules containing bonding and non-bonding electrons (n-electrons) can bonding molecular orbitals.

wavelength of light it can absorb. There are four possible types of transitions ($\pi-\pi^*$, $n-\pi^*$, $\sigma-\sigma^*$, and $n-\sigma^*$), and they can be ordered as follows: $\sigma-\sigma^* > n-\sigma^* > \pi-\pi^* > n-\pi^*$

The quantitative determination of different analytes or samples, such as transition metal ions, highly conjugated organic compounds, and biological macromolecules, is regularly done using UV/visible spectroscopy in analytical chemistry. Spectroscopic analysis is most usually performed on solutions, but it can also be done on solids and gases.

- All diluted inorganic solutions are UV active
- Solutions of transition metal ions can be coloured (i.e., absorb visible light) because d electrons within the metal atoms can be excited from one electronic state to another.
- The presence of additional species, such as anions or ligands, has a significant impact on the colour of metal ion solutions. A dilute solution of copper sulphate, for example, is a very faint blue colour; adding ammonia

intensifies the colour and shifts the wavelength of maximum absorption (λ_{max}).

- While charge transfer complexes also give rise to colours, the colours are often too intense to be used for quantitative measurement.
- According to the Beer–Lambert equation, a solution's absorbance is proportional to the concentration of absorbing species in the solution and the route length. UV/Visible spectroscopy may thus be used to determine the concentration of the absorber in a solution for a specific route length. It's crucial to understand how rapidly absorbance varies with concentration. References (tables of molar extinction coefficients) or, more precisely, a calibration curve can be used to calculate this.

This method is most often used in a quantitative way to concentration of absorbing species in solution using Beer-Lamberts law.

where A = absorbance

I = intensity of the incident is the transmitted intensity,

L = the path length

c = concentration of absorbing species

ϵ = molar absorptivity coefficient.

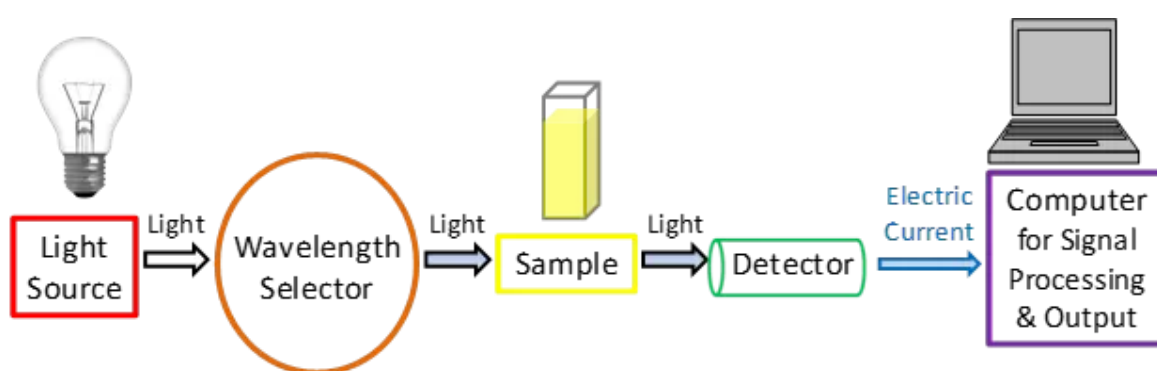


Fig 4.5: schematic working of UV-Visible spectroscopy



Fig 4.6: UV INSTRUMENT

4.3.2 FOURIER-TRANSFORM INFRARED SPECTROSCOPY:

PRINCIPLE:

When molecules containing either permanent dipole moment or dipole moment arising due to vibration of atoms in molecules are subjected to IR radiation of particular frequency, it induces an oscillating dipole moment and excite them to undergo vibrational transitions. Vibrational transition is produced by the absorption of energy (suitable IR radiation).

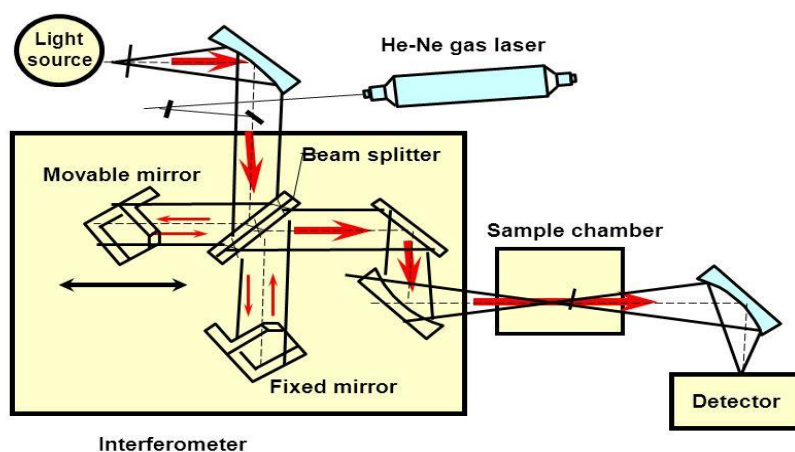
Infrared light from the light source flows via a Michelson interferometer along the optical path in FTIR analysis.

A beam splitter, moving mirror, and fixed mirror make up the Michelson interferometer. The beam splitter splits the light beam into two, which is reflected by the moving and fixed mirrors before being recombined by the beam splitter. The optical path difference between the moving and stationary mirrors changes as the moving mirror reciprocates, causing the phase difference to fluctuate over time. In the Michelson interferometer, the light beams are recombined to produce interference light. An interferogram is used to record the intensity of interference light, with the optical path difference recorded along the horizontal axis.

WORKING:

The FTIR device delivers infrared radiation in the range of 10,000 to 100 cm^{-1} through a material, with part of it absorbed and some of it passing through. The sample molecules transform the absorbed light into rotational and/or vibratory energy. The resulting signal appears as a spectrum at the detector, typically ranging from 4000 cm^{-1} to 400 cm^{-1} , and represents the sample's molecular fingerprint. FTIR analysis is a great tool for chemical identification because each molecule or chemical structure produces a unique spectral fingerprint.

FTIR Instrumentation



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Fig 4.7: Schematic working of FTIR



Fig 4.8: FTIR INSTRUMENT

4.3.3 X-RAY DIFFRACTION (XRD) :-

XRD is one the characterisation technique that reveals the structural properties of nanoparticles. It provides information on the phase, chemical composition, symmetry of unit cells, crystallinity, lattice constant and properties of the nanoparticles. This technique is employed for the identification of both single and multiphase nanoparticles.

XRD is considered as one of the oldest non-destructive methods for the analysis of nanoparticles. The XRD pattern is influenced by the size and shape of the unit cell of the crystal. Consequently, properties of a material are dependent on their structure of about 90% solid materials are crystalline in nature and each crystalline has a significant X-ray diffraction pattern which can be used as fingerprint to detect the material.

Diffraction pattern is obtained only when the X-rays are interacted with the crystal. Information like symmetry of the unit cell, stress, strain, size of crystallite and growth orientation etc. are obtained from the diffraction patterns.

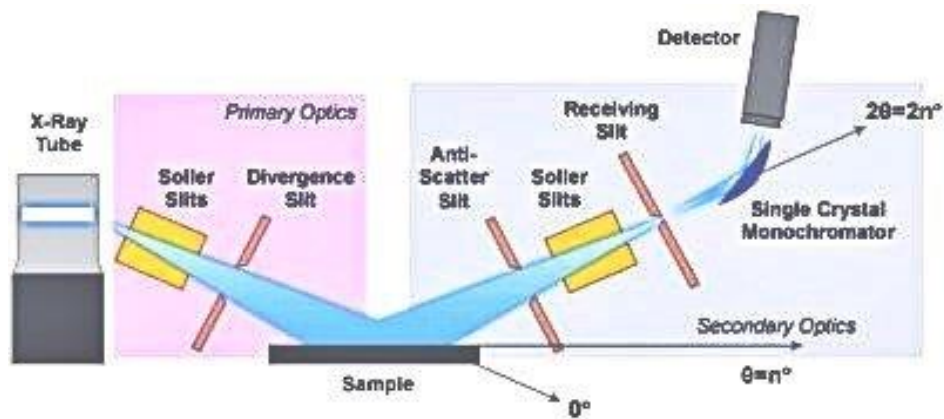


Fig 4.9: SCHEMATIC WORKING OF XRD



Fig 4.10 XRD Instrumentation

4.3.4 SCANNING ELECTRON MICROSCOPE (SEM):

SEM (Scanning Electron Microscope) is a type of electron microscope which scans the surfaces of microorganisms using a low-energy electron beam to focus and scan specimens.

PRINCIPLE:

The scanning electron microscope, unlike the transmission electron microscope, employs released electrons instead of transmitted electrons. The Scanning Electron Microscope (SEM) operates on the premise of using kinetic energy to generate signals from electron interactions. Secondary electrons,

backscattered electrons, and diffracted backscattered electrons are all types of electrons used to observe crystalline elements and photons. An picture is created using secondary and backscattered electrons. The major purpose of the secondary electrons generated by the specimen is to detect the shape and topography of the specimen, whereas the backscattered electrons exhibit contrast in the composition of the specimen's constituents.

WORKING:

A scanning electron microscope (SEM) is a type of electron microscope that uses a concentrated beam of electrons to scan the surface of a sample to obtain pictures. When electrons contact with atoms in a sample, they produce a variety of signals that carry information about the sample's surface topography and composition. A raster scan pattern is used to scan the electron beam, and the position of the beam is coupled with the intensity of the received signal to create a picture. Secondary electrons generated by atoms stimulated by the electron beam are detected by a secondary electron detector (Everhart–Thornley detector) in the most common SEM mode. The quantity of secondary electrons that may be detected, and hence the signal strength, is influenced by specimen topography, among other factors [12].

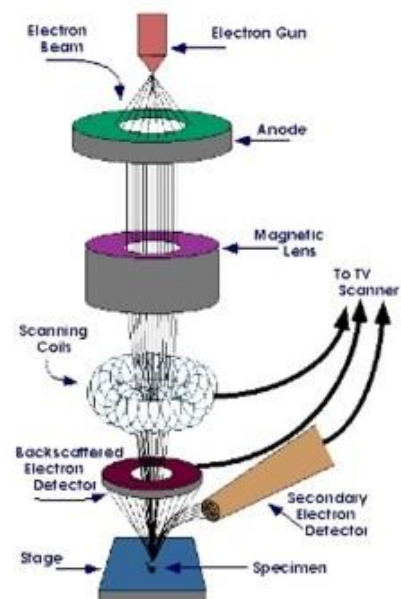


Fig 4.11: Scanning Electron Microscope

CHAPTER 5

RESULTS AND DISCUSSION

Crystal structure, morphology, structural composition and functional group analysis of the given catalyst PVA-Cu nanofibre have been confirmed by the following characteristic techniques. they XRD, SEM, UV-Vis spectroscopy and FTIR.

5.1 X-RAY DIFFRACTION (XRD)

PVA-Cu nanofibers were elaborated with different ratios to form a homogeneous nanocomposite. X-ray diffraction (XRD) was used for detecting the crystalline phases represented which is given in the below figure.

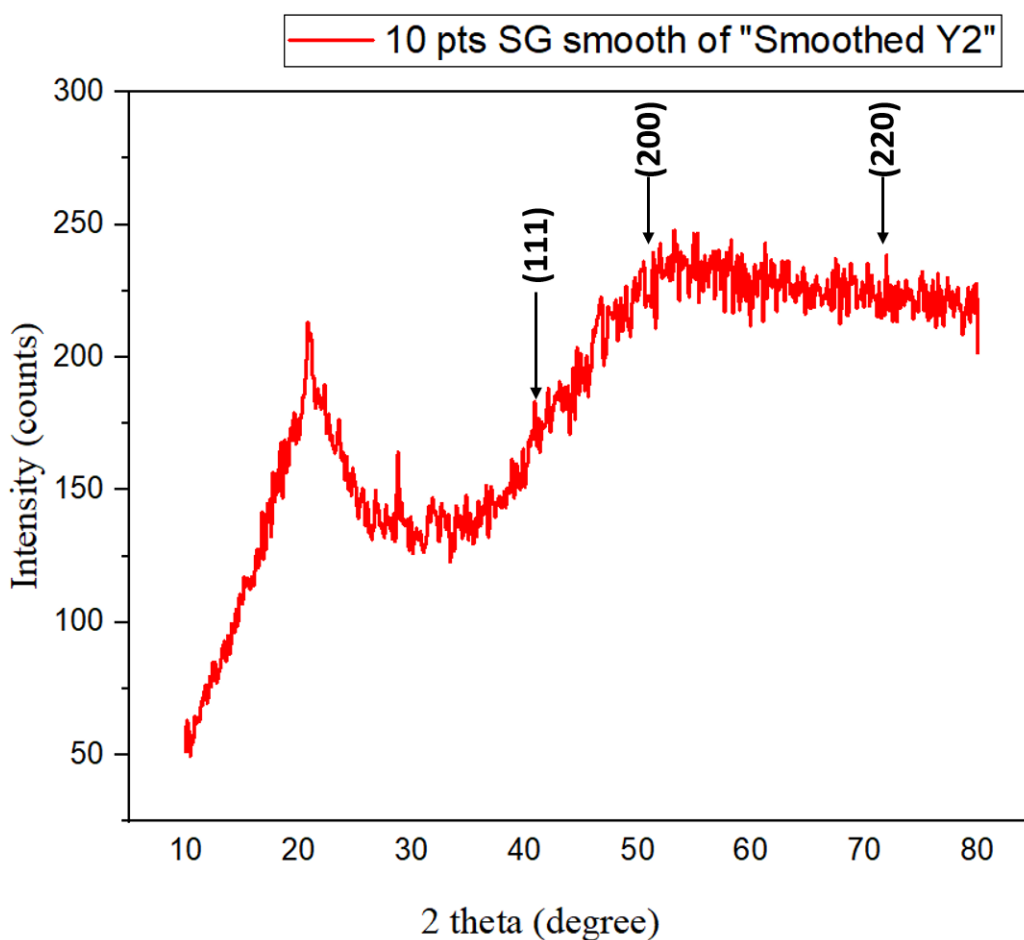


Fig 5.1: Graphical representation of XRD

The given set PVA-Cu Nanofibers phase with diffraction peaks at 42, 53 and 73 corresponding to Miller indices (111), (200) and (220), respectively. These peaks are attributed to the PVA-Cu catalyst.

No significant peaks corresponding to impurities were detected in the XRD pattern. After mixing PVA and copper(II), peaks of PVA-CU nanofibers are detected. In the nanocomposite, some intensities of the peaks changed due to peak interference.

5.2 SCANNING ELECTRON MICROSCOPE (SEM):-

Scanning electron microscope is especially used for size and shape characterization, because the required sample preparation and image analysis is relatively quick and simple. The scanning Electron Microscopy (SEM) images allowed a detailed study on the morphological structure of the catalyst (PVA-Cu).

The scanning electron microscope operates in the same manner as an optical microscope, but instead of detecting photon, it detects electrons scattered from the sample. The wavelength of electrons can be made shorter than that of photons because electrons can be accelerated by an electric potential. As a result, the SEM will magnify pictures up to 200.000 times.

The morphological variations in the synthesised sample nanoparticles were detected and analysed. The catalyst PVA-Cu were analysed by SEM are shown in figure. PVA-Cu thus synthesised at room temperature was analysed and the images are displayed in the below figure.

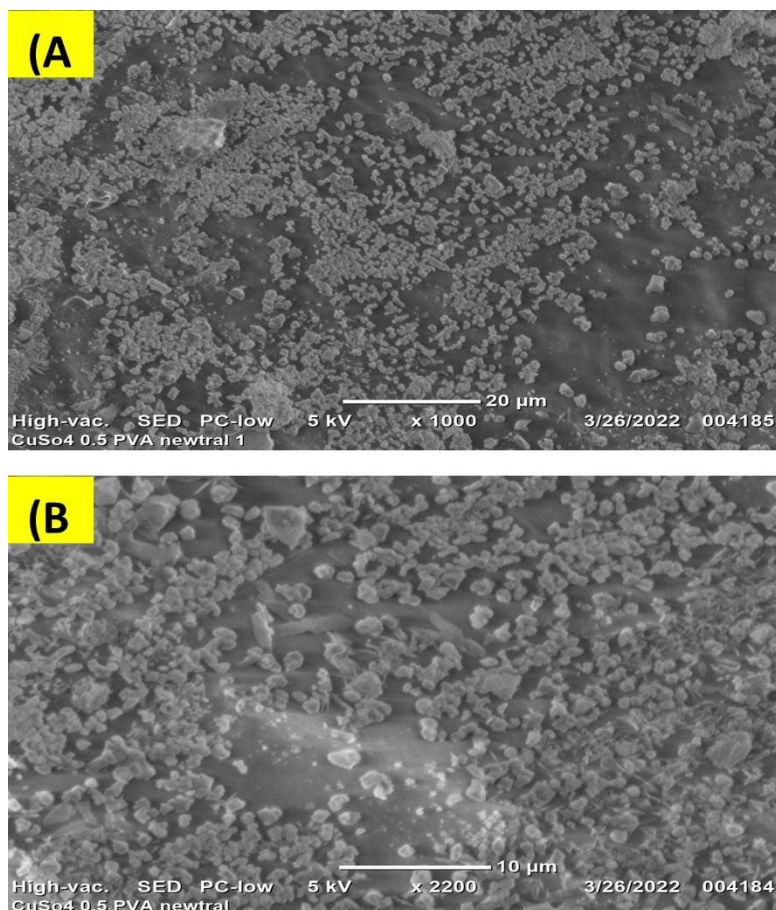


Fig 5.2 SEM image of PVA-Cu Neutral

Scanning electron microscopy was used to examine the apparent designs of the composite films. Fig. 5.2 (a and b) shows SEM images of the PVA-Cu film at 20 μ m and 10 μ m magnifications. It reveals the rough and heterogeneous surface morphology of the composite film. The grooves and non-uniform pores were observed in and on the surface of polymer composite films. The surface morphology of composite shows good compatibility in the film PVA-Cu.

PVA-Cu shows the crystal morphology with average diameter 10.5 to 10.6 nm for PVA-Cu, respectively as the nanofibers structure.

5.3 FOURIER-TRANSFORM INFRARED SPECTROSCOPY

This spectroscopic technique is used to determine the functional groups present in the compound at different frequency levels.

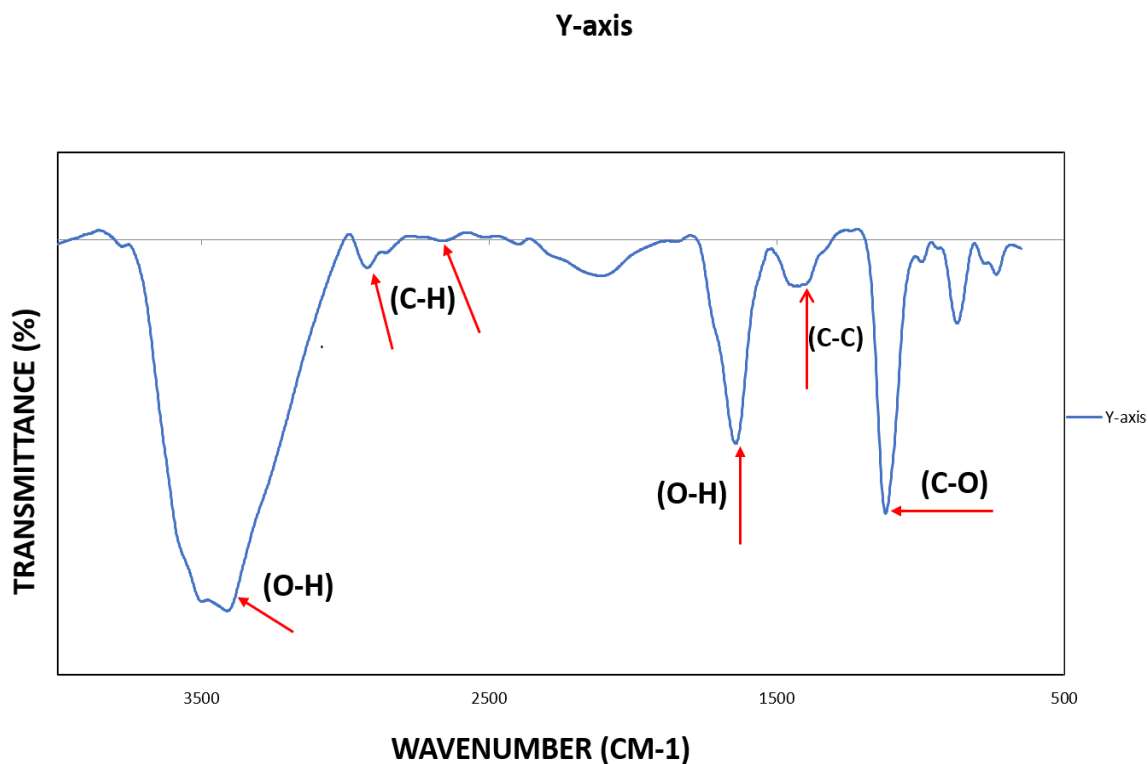


Fig 5.3: Graphical representation of FTIR

S.NO	FUNCTIONAL GROUP	WAVENUMBER (CM ⁻¹)
1	O-H (Stretching vibration)	3293.85
	O-H (Bending vibration)	1660.20
2	C-H	2936.50
		2911.11
3	C-C (Sharp peak)	1100.27
4	C-O	917.30

TABLE 5.1 Spectral Data of FTIR Spectrum

On the IR spectra of given compound, the major peaks observed were as follows: bands at 3293.85 and 1660.20 cm⁻¹ are assigned to the stretching and bending vibrations of (O-H) respectively, two vibration bands at 2936.50 and

2911.11 cm^{-1} are assigned to (C-H), a sharp band at 1100.27 is attributed to the vibration of (C-C), a medium shoulder peak at 917.30 cm^{-1} is linked to the vibration of (C-O)

5.4 UV-Vis SPECTROSCOPY:

Ultraviolet-visible spectroscopy is a widely used technique in many areas of science ranging from bacterial culturing, drug identification and nucleic acid purity checks and quantitation, to quality control in the beverage industry and chemical research.

It is a quantitative technique which is used to measure how much that a chemical substance absorbs light. This is done by measuring the intensity of light that passes through a sample with respect to the intensity of light that passes through a reference sample or blank.

This spectroscopy technique is also used to determine the absorption of the given polymer catalyst PVA-Cu.

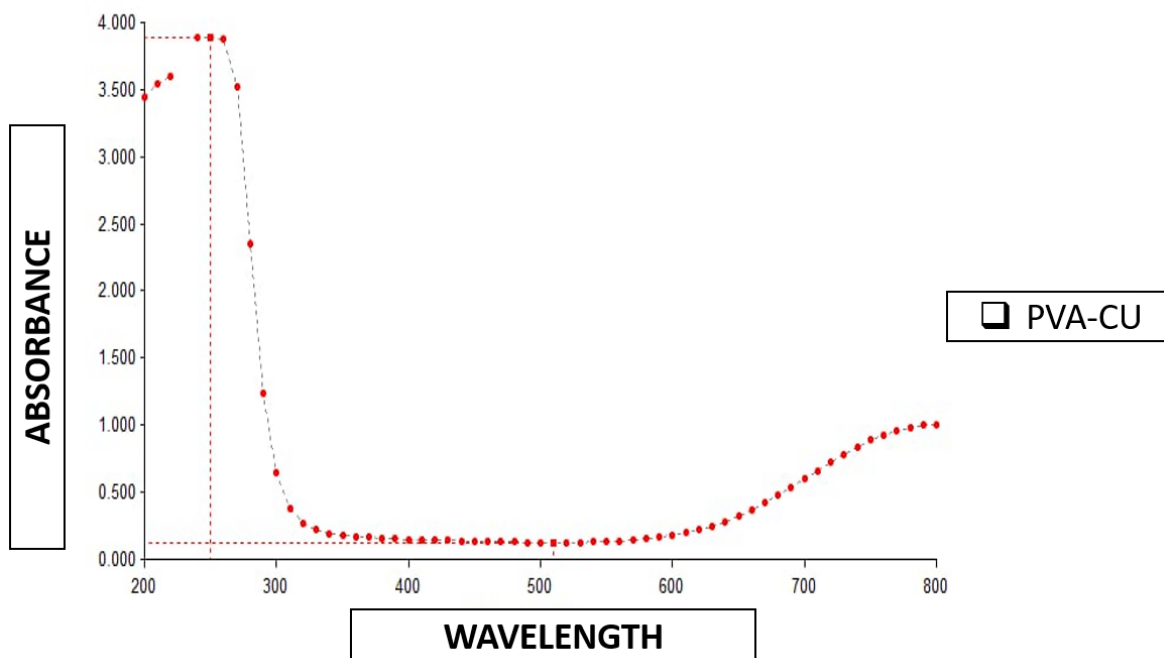


Fig 5.4 UV-Vis spectra of PVA-Cu

S.NO	WAVELENGTH	ABSORBANCE
1	687	0.61
2	693	0.72
3	704	0.78
4	708	0.83
5	722	0.94
6	734	0.98
7	757	1.01
8	763	1.14
9	787	1.23
10	793	1.37

Table 5.2 Spectral data of UV spectrum

This graph shows the absorption of the given compound can be confirmed by the sharp absorption at 693 nm with 0.72 absorption to 793 wavelength with 1.37 absorbance.

5.5 UV-DRS:

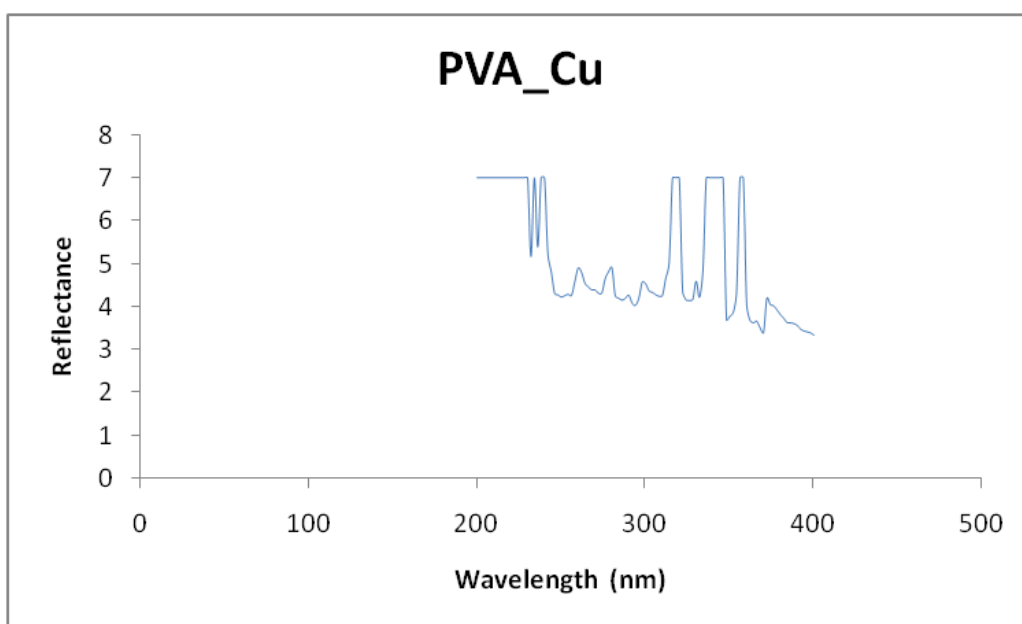


Fig 5.5 Graphical representation of UV-DRS

S.NO	WAVENUMBER	REFLECTANCE
1	211	6.8
2	267	5
3	289	5
4	304	4.3
5	322	7
6	359	7
7	375	7
8	389	4.1

Fig 5.3 Spectral data of UV-DRS

The above figure shows the reflectional spectra of PVA-Cu and the recorded signal peaks were shows the UV-DRS spectrum of PVA-Cu, these peaks are obtained between 200-400nm however in this all the peaks are not equally intensity but one peak shown strong intensity at 375 nm and for this band gap is 3.307 eV, it means this compound shows good electron absorbed substance based on band gap.

5.6 DEGRADATION OF CONGO RED DYE:

Congo red is a carcinogenic anionic dye that is extremely poisonous. Sodium borohydride has been used as a reducing agent in the presence of several nano-catalytic systems to remove it from aqueous medium.

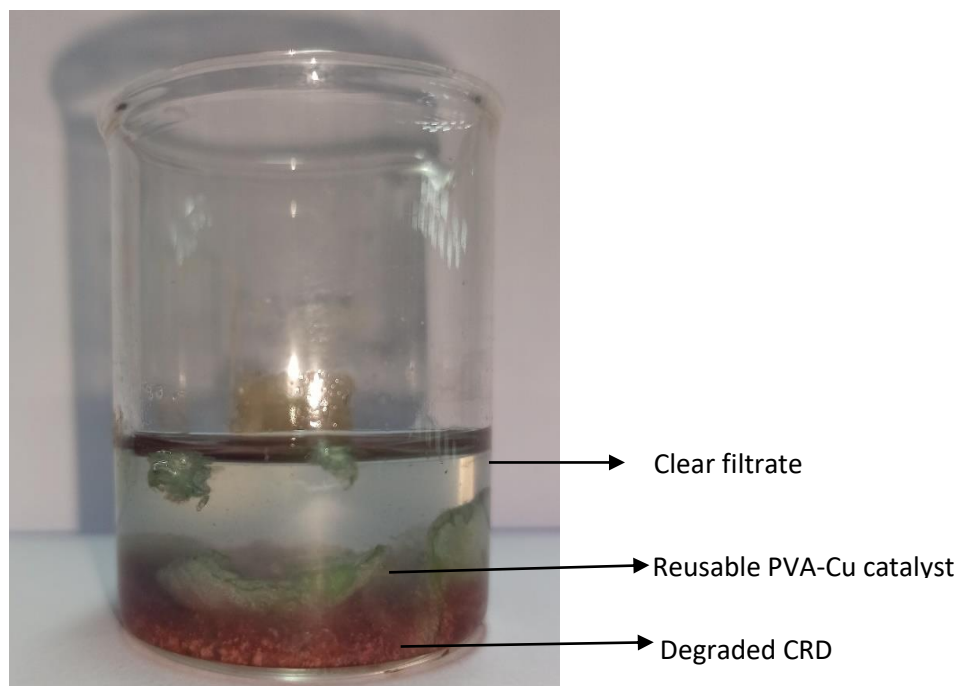


Fig: 5.6: Degradation of CRD

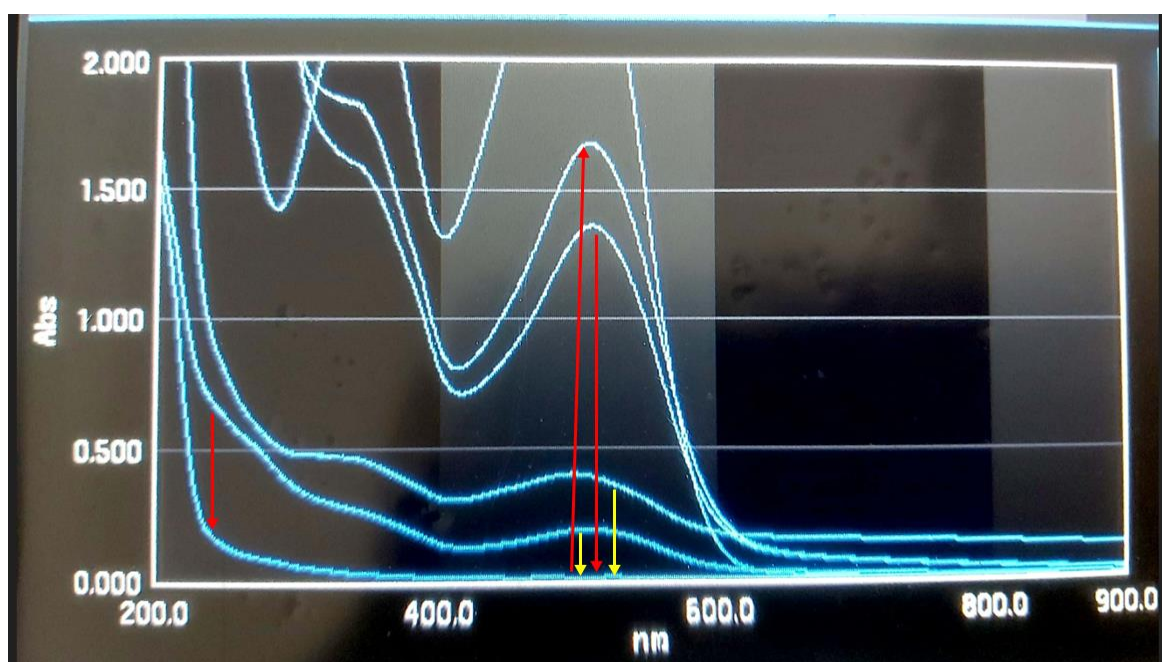


Fig 5.7 Graphical representation of degradation of Congo Red Dye

The Congo red dye has been degraded kinetically in 3 minutes duration time with different intensities and at the wave length of 520nm.

Peak	Absorbance
1	1.63
2	1.41
3	0.33
4	0.27
5	0.22

Table 5.4 Spectral Data of Degradation of CRD

Congo red dye has been kinetically studied under the given conditions, the absorbance the given dye has been observed at very low absorbance due to its degradation. In this kinetical study 87% of Congo red was degraded is confirmed.

The intensity of the dye quite low and its degradation happen when its maintained in the basic pH (pH=8) by adding few drops of NaOH with the solution and polymer. This Congo red dye is used for studies in textile industries mostly combinations of metal oxides.

Surface adsorption and intraparticle diffusion occur simultaneously, according to the kinetics data. The adsorption equilibrium matches the Langmuir isotherm well, showing monolayer adsorption on a homogeneous surface. The healing powers of nanocomposite are supported by a desorption investigation.

The kinetic study of degrade Congo red dye have been observed at different wavelengths, the first peak was observed at 507 nm with 1.63 absorbance then second peak was observed at 523 nm with 1.41 absorbance ,the absorbance difference between these two a peaks are nearly 0.2 absorbance difference.

Then third peak was observed at 545 nm with 0.33 absorbance, after this peak the intensity was decreased gradually, the fourth peak was observed at 511 nm with 0.27 absorbance and the final peak was observed at 245 nm with 0.22 absorbance.

From the above data we come to know that the Congo red dye has been degrade in continuous time period with different intensity and absorbance, finally we come to know that “on the basis of kinetics” the above dye degrade gradually in 3 minutes of duration time with decrease in their intensity.

By the decrease in the colour intensity of the CRD solution and turning from coloured to colourless clear solution we observe the degradation of CRD. And through this spectrum we successfully confirm that the 87% of the Congo red dye got degraded from the solution.

CHAPTER 6

CONCLUSION

In this work, we have successfully developed an efficient catalyst for the removal of toxic Congo red dye from aqueous medium. In many industries Polyvinyl alcohol are generated as waste products utilising it and also using toxic metal which cause heavy metal pollution, we have synthesized an efficient catalyst and characterized using different analytical techniques.

This catalyst will effectively degrade the pollutant Congo red dye from the industrial waste water pollution. The photocatalytic ability of PVA-Cu was evaluated by applying it to the degradation of Congo red dye in the sunlight. The prepared PVA-Cu catalyst was regenerated and reused exhibiting an excellent catalytic activity for many consecutive cycles.

The prepared catalyst also possesses prominent antibacterial property and recyclability. Thus, from the current work, we can conclude that PVA-Cu catalyst could be a promising candidate for the removal of Congo red from polluted water.

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