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GREEN SYNTHESIS OF SILVER NANOPARTICLES FROM TETLEY TEA WASTE FOR Fe^{3+} DETECTION, PHOTO CATALYTIC DYE DEGRADATION, AND ANTIBACTERIAL APPLICATIONS

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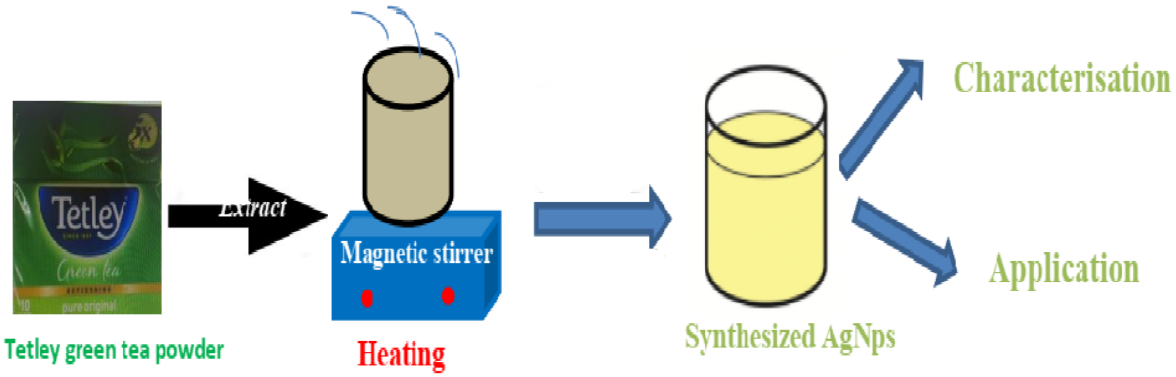
ABSTRACT

Green synthesis of silver nanoparticles (Ag-NPs) has emerged as an environmentally sustainable alternative to conventional chemical methods due to its simplicity, safety, and cost-effectiveness. In the present study, silver nanoparticles were successfully synthesized using **Tetley tea powder waste extract** as a natural reducing and stabilizing agent without the use of any additional chemical reagents. The developed method is rapid, non-toxic, economical, and suitable for sustainable large-scale production while promoting the reutilization of tea waste. The formation of Ag-NPs was confirmed by the appearance of a characteristic surface plasmon resonance (SPR) absorption peak at approximately **420 nm** in the UV–Visible spectrum. The synthesized nanoparticles were comprehensively characterized using FTIR, XRD, DLS, SEM, and TEM techniques. FTIR analysis confirmed the involvement of phytochemicals present in the tea extract during nanoparticle synthesis and stabilization, while XRD analysis established the crystalline nature of the Ag-NPs. SEM and TEM images revealed predominantly spherical nanoparticles with sizes ranging from **10 to 30 nm**, and DLS analysis indicated good colloidal stability. The synthesized Ag-NPs exhibited selective colorimetric sensing toward **Fe^{3+} ions**, demonstrating their potential for monitoring iron contamination in water samples. In addition, the nanoparticles showed efficient

photocatalytic degradation of crystal violet dye under irradiation and significant antibacterial activity against both *Bacillus subtilis* and *Escherichia coli*, with comparatively higher efficacy against the Gram-positive strain. These findings demonstrate that Tetley tea powder waste-derived AgNPs are multifunctional nanomaterials with promising applications in environmental monitoring, wastewater treatment, and antimicrobial technologies.

KEYWORDS: Green synthesis; Silver nanoparticles; Tetley tea powder waste; Surface plasmon resonance; Fe^{3+} ion detection; Photocatalytic degradation; Crystal violet dye; Antibacterial activity; Environmental remediation.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Nanotechnology has emerged as a rapidly advancing field of research owing to the unique physicochemical properties exhibited by materials at the nanoscale. Among various nanomaterials, silver nanoparticles (Ag-NPs) have attracted considerable attention because of their remarkable optical, catalytic, antimicrobial, and electronic properties, leading to their extensive applications in medicine, environmental remediation, food packaging, catalysis, sensing, electronics, and water treatment. Green synthesis of Ag-NPs has become an attractive alternative to conventional chemical and physical methods as it is environmentally friendly, economical, and eliminates the use of hazardous chemicals. In the present study, **Tetley tea powder waste extract** was utilized as a natural reducing and stabilizing agent for the synthesis of Ag-NPs. The extract contains abundant bioactive phytochemicals, including polyphenols, flavonoids, tannins, antioxidants, and phenolic compounds, which facilitate the reduction of Ag^{+} ions into stable silver nanoparticles while simultaneously acting as capping agents. The reutilization of discarded tea powder not only offers a sustainable and cost-

effective synthesis route but also supports waste valorization and the principles of green chemistry. Owing to their broad-spectrum antimicrobial activity and relatively low production cost, Ag-NPs constitute a significant proportion of commercially available nanotechnology-based products; however, their increasing production and widespread applications have also raised concerns regarding their release into aquatic environments, emphasizing the need for sustainable synthesis strategies and environmentally beneficial applications. The physicochemical properties of Ag-NPs are strongly influenced by their size, shape, morphology, and surface characteristics; therefore, the synthesized nanoparticles were comprehensively characterized using UV–Visible spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), Dynamic Light Scattering (DLS), Scanning Electron Microscopy coupled with Energy Dispersive X-ray spectroscopy (SEM–EDX), and Transmission Electron Microscopy (TEM) to confirm their formation, crystallinity, morphology, particle size, elemental composition, and colloidal stability. Furthermore, the synthesized Ag-NPs were investigated for selective Fe^{3+} ion detection, photocatalytic degradation of crystal violet dye, and antibacterial activity against Gram-positive and Gram-negative bacteria, demonstrating their potential as sustainable multifunctional nanomaterials for environmental monitoring, wastewater treatment, and biomedical applications.

2. MATERIALS AND METHODS

$AgNO_3$, HNO_3, $FeCl_2$, $Zncl_2$, $BaSO_4$, Na-cl, $MgCl_2$, $SnCl_2$, $CuSO_4$, $CdCl_2$, $NiCl_2$, $FeSO_4$, $PbNO_3$, $SrCl_2$, $MnCl_2$, KCl and $CaCl_2$ were bought from aura chemicals for reliable grade of purity without further purification. The Tetley tea (which consists of higher medicinal values), powder are purchased from the local market of Osmania university Hyderabad.

2.1 PREPARATION OF TETLEY TEA POWDER EXTRACT

The Tetley tea powder was grinded into fine powder and nearly 5gm of powder was mixed in to 100 ml of deionized water and then subjected to high volte centrifugation for the removal of un soluble material for 30 min at 1500 rpm. The solution was separated by utilizing Whatman′s filter paper pore size is 0.22 micron to get a clear and pure solution. This solution was put away in cooler at 10ºC for further uses.

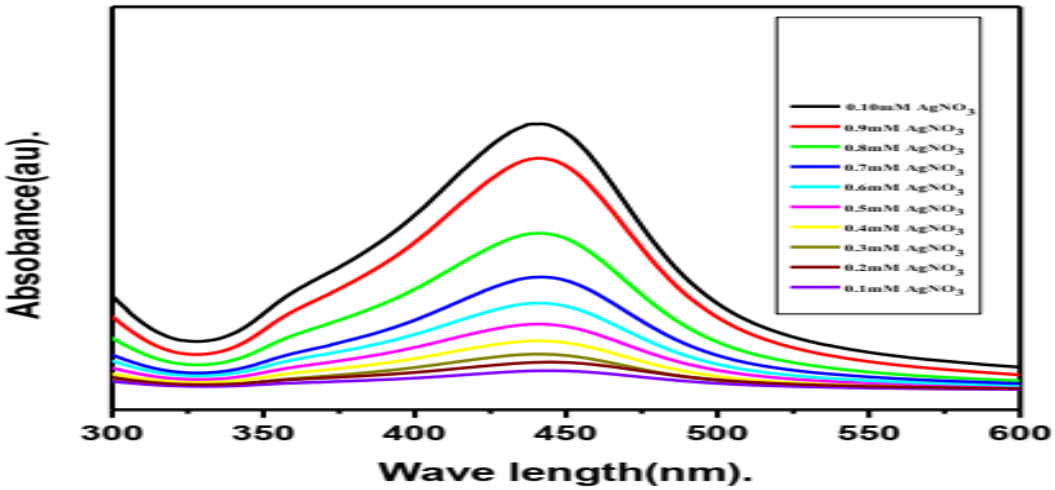
2.2 PROCEDURE FOR SYNTHESIS OF SILVER NANOPARTICLES

The Autoclave process of green synthesis, (eco-accommodating method) is utilized for the synthesis of Ag-NPs by utilizing $AgNO_3$ and Tetley tea powder extract, which undergo reducing and stabilizing agent without adding any outer reagents/synthetic substances. A

combination containing 1 ml of $AgNO_3$ and 20ml of Tetley tea powder extract was heated under Autoclave. The shade of the response combination changed gradually from white to brown yellow shading which shows the formation of Ag-NPs. The arrangement of Ag-NPs is additionally confined by UV-visible spectroscopy. The Ag-NPs were integrated from response blends arranged utilizing 0.1mM to 0.10mM concentration of $AgNO_3$. Furthermore, each reacted with single level of Tetley tea powder extract (0.5 %). The Autoclave, which is naturally protected, is utilized for the rapid production of nano-particles inside couple of moments by utilizing pressure heat.

2.3 UV-VISIBLE SPECTROSCOPY

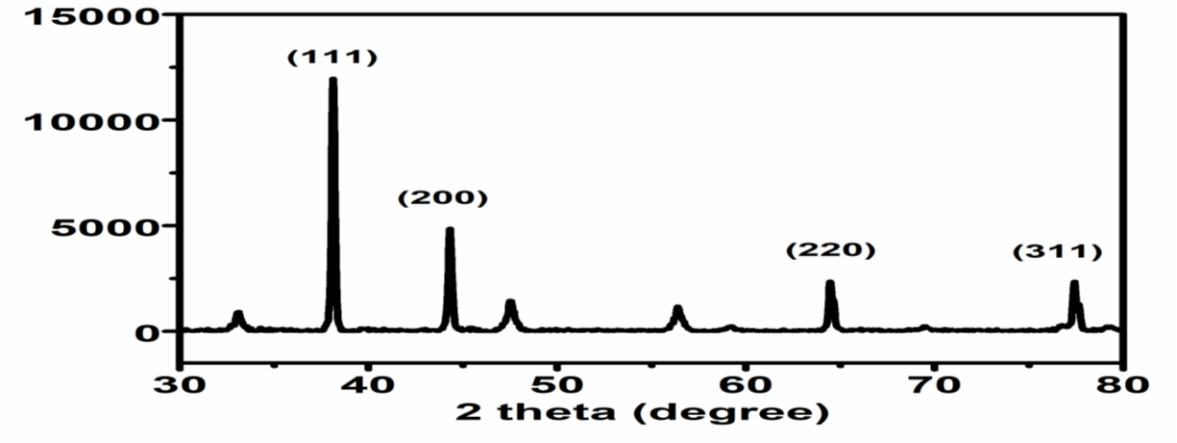
The Autoclave process of green synthesis of silver nanoparticles were synthesized using Tetley tea powder extract. The ingestion top in UV–Visible absorption range for integrated silver nanoparticles was seen at 445 nm. The nanoparticles are circular fit with a normal size range from 10 to 30 nm. Figure Shows the SPR tops for the synthesis of silver nano-particles, framed from arrangements prepared using $AgNO_3$. (0.1mM to 0.10 mM of Conc.). Also, each mixed with single level of Tetley tea powder extract (0.5 %). The expansion in SPR peaks demonstrates the increment in the peaks of Ag-NPs, which are expanded with the increment in the concentration of $AgNO_3$. Since the increment in number of silver particles with the increment fixation of $AgNO_3$.



2.4 X-RAY DIFFRACTION

The X-ray diffraction analysis is one of the most useful techniques for the determination of crystallographic structure of synthesized silver nanoparticles. By Bruker D_8 advanced instruments using Cukα radiation (=1.5406A^o), 40 kv-40Ma, 2θ/θ scanning mode and 2θ

values started from 30-80^{o}. In these diffractogram studies, mainly four peaks are absorbed at 38.4812, 44.11, 64.919 and 78.448, In the experimental studies of crystallographic structure were determined.



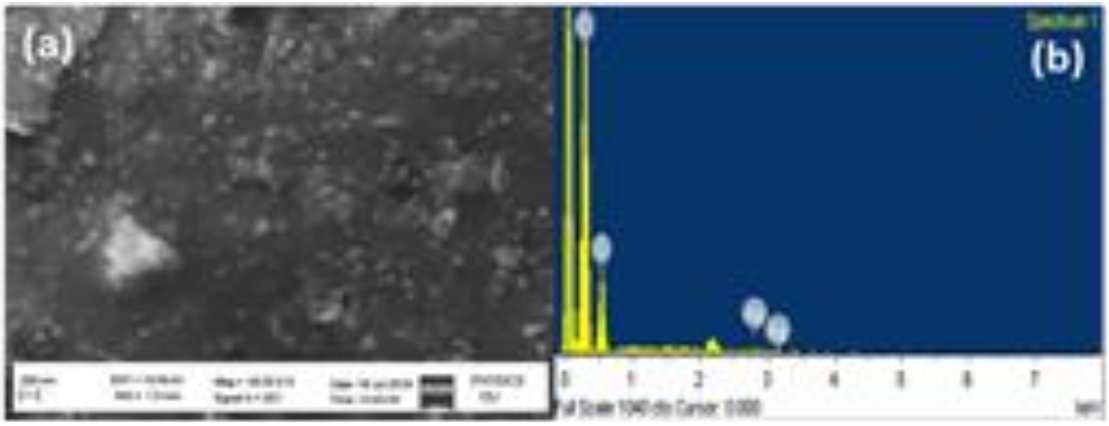
2.5 SEM-EDX

FIGURE a

Morphological and underlying examinations were researched by utilizing Scanning Electron Microscopy (SEM). It was used to characterize the particles and their sizes, shape, and dissemination by taking micrograph from drop covered films of the (Ag-Nps) silver nanoparticles. The filtrate inserted with silver nanoparticle was dried under vacuum and exposed to SEM contemplates. Thin films of the example were prepared on a carbon covered copper grid by dropping a truly hint of the example on the matrix, additional arrangement was taken out utilizing a smudging paper and afterward the film on the SEM lattice were permitted to dry for investigation by putting it under a mercury light for 5 minutes. Scanning electron microscopy gave further understanding into the morphology and insight regarding size of the silver nanoparticles. Correlation of test results showed that the width of arranged nanoparticles in the arrangement was around 10-30 nm.

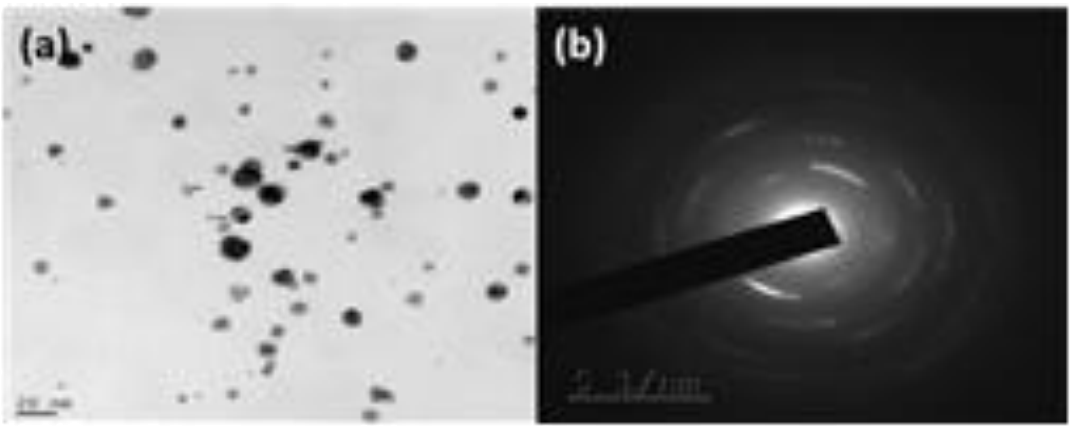
FIGURE b

EDX examination gives subjective just as quantitative status of components that might be present with arrangement of NPs. The basic profile of combined NPs utilizing Tetley tea powder extract shows higher correspond at 3keV because of silver; confirm the arrangement of silver NPs. In general, metallic silver Nano crystals show ordinary optical retention peak roughly at 3keV because of their surface Plasmon resonance. The essential investigation of the silver NPs displayed in uncovered most noteworthy extent of silver followed by Cl and P.



2.6 TEM-DLS STUDIES

TEM investigation was done to inspect the molecule shape and size of the Ag-NPs, which are combined by Tetley tea powder extract. TEM examination shows that the size of Ag-NPs goes from **10 to 30 nm**. TEM investigation likewise proposes that the incorporated Tetley tea powder extricate covered Ag-NPs are in spherical fit and the average size of the Ag-NPs is 16±2 nm. They chose space of electron diffraction example (DLS) of concentric rings showed with discontinuous splendid dabs, demonstrating that these Nano particles are exceptionally crystalline in nature.

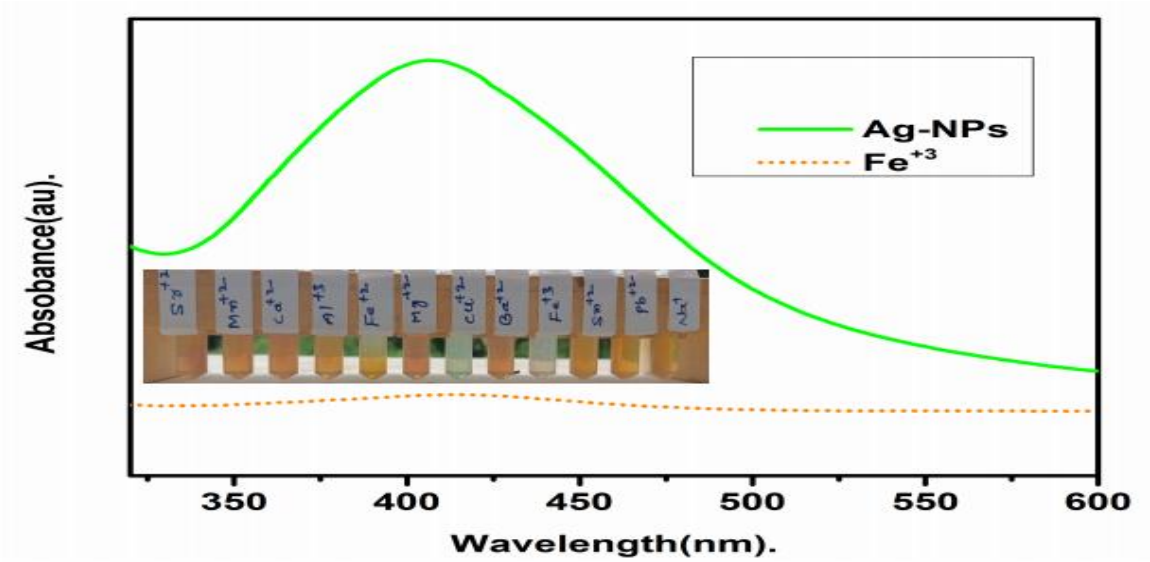


3. APPLICATIONS OF SILVER NANOPARTICLES

3.1 DETECTION OF METAL IONS

The Fe^{+2}, Ba^{+2}, Na^{+}, Mg^{+2}, Sn^{+2}, Cu^{+2}, Ca^{+2}, Al^{+3}, Fe^{+3}, Pb^{+2}, Sr^{+2}, Mn^{+2} of metal solution are (400µl of different metals) mixed each with 2ml of Ag-NPs solution for the detection of metal ion by Ag-NPs. Only ferric **(Fe^{+3})** metal ions are decolorizing the yellow color of Ag-NPs solutions. This may be due to oxidation of silver nanoparticles to silver ions by ferric

ions and simultaneously ferric ion reduced to Fe^{+2}. Hence, it is possible to detect the Fe^{+3} present in waste water/polluted water by the addition of Ag-NPs solution.



3.2 ANTI-BACTERIAL ACTIVITY

Preparations of active cultures

The bacterial cultures were activated by transferring a pure bacterial colony into 50ml nutrient broth media taken in a 150ml conical flask and incubation for 8-12hrs.

Antibacterial assay

The antibacterial assay was carried out by performing pour plate method in which 1ml bacterial active cultures per plate were mixed into agar media before solidifying temperature and poured into plates. Here ***Bacillus subtilis*** and ***E. coli*** were selected as Gram positive and Gram negative bacteria. Wells were made using sterile well borer and samples were loaded 60µl each respectively in ***Gram positive*** and ***Gram negative*** plates. Plates were incubated at 37^0 C for 48 hours.

INTERPRETATION OF RESULTS

The bacterial plates were observed after 48 hours and following result were noted. The antibacterial activity of Tetley tea powder extract covered Ag nanoparticles are reacted with.

(a) ***Bacillus-subtilis*** (G +ve), whose zone of Inhibitions are (4), (6), (7), (7), (10) mm.

(b) ***Escherichia-coli*** (G -ve), whose zone of inhibition are (4), (6), (6), (8), (9) mm.

(c) Ampicillin (standard drug) whose zone of inhibition is (4) mm. The zone of the hindrance of Ag nanoparticles for the microorganisms demonstrates the positive antibacterial movement

against ***Bacillus subtilis,*** and ***Escherichia-coli***. The antibacterial action results propose that Ag nanoparticles synthesized from Tetley tea powder extract shows the successful antibacterial activity against gram-positive (***Bacillus-subtilis)*** than in Gram-negative (***Escherichia-coli***) pathogens. The zone of inhibition of ***Bacillus-subtilis and Escherichia-coliis increases*** compared to Ampicillin (standard drug).

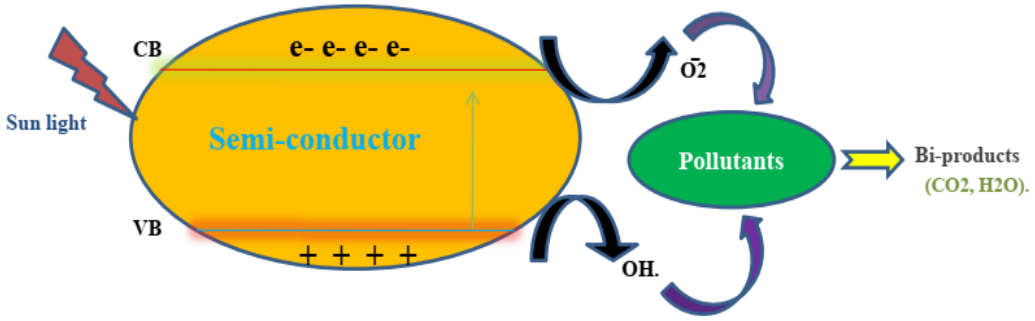
S.NO.	Name of the Samples	*Bacillus subtilis* Gram (+ve)		E-coli Gram -(ve)	
		Sample loaded(µl)	Zone of inhibition in(mm)	Sample loaded(µl)	Zone of inhibition in(mm)
1.	0.1Mm $AgNO_3$	60 (µl)	4(mm)	60 (µl)	4(mm)
2.	0.2Mm $AgNO_3$	60 (µl)	6(mm)	60 (µl)	6(mm)
3.	0.3Mm $AgNO_3$	60 (µl)	7(mm)	60 (µl)	6(mm)
4.	0.4Mm $AgNO_3$	60 (µl)	7(mm)	60 (µl)	8(mm)
5.	0.5Mm $AgNO_3$	60 (µl)	***10(mm)**	60 (µl)	***9(mm)**
6.	**Ampicillin (Standard)**	60 (µl)	**4(mm)**	60 (µl)	**4(mm)**

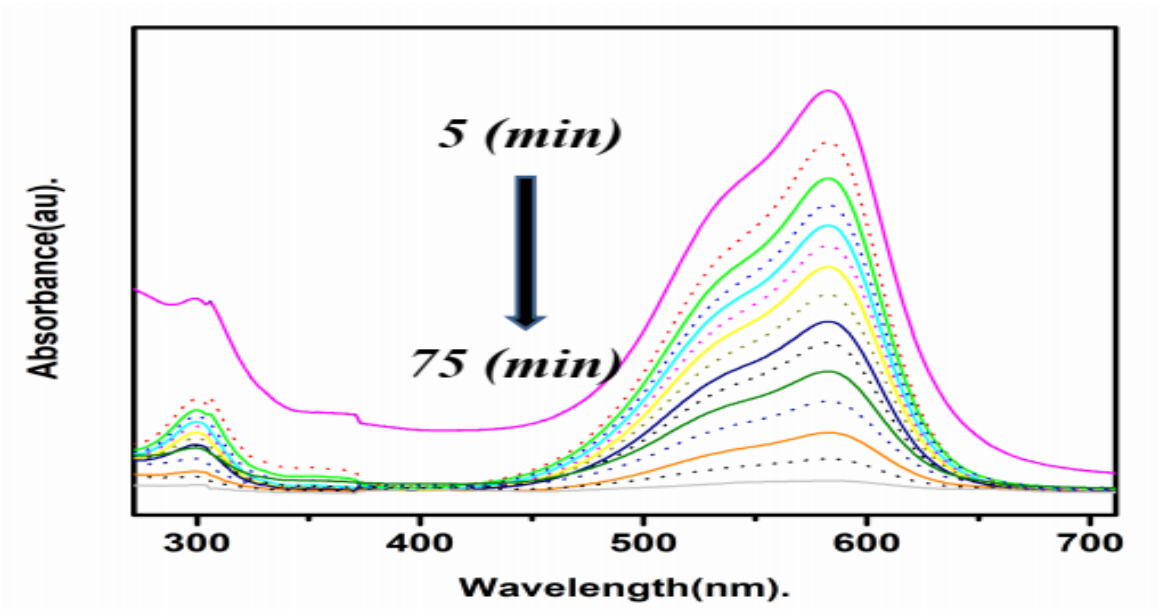
3.3 PHOTO CATALYTIC DEGRADATION OF CRYSTAL VIOLET (CV) DYES

In the present study, CV dyes were investigated for photo catalytic degradation potential of synthesized Ag-NPs under sunlight irradiation. Industrial dyes like CV treated with green synthesized Ag-NPs and the absorbance peaks of the degraded CV were recorded at 596 nm, respectively. The degradation spectra were noted at different time intervals form **(5 min to 75 min)**. The absorbance peaks decreased gradually with an increase in duration of exposure indicating a higher photo catalytic breakdown. In the absence of nano-catalyst (control), there was no progress in the degradation process. The Ag-NPs synthesized using the Tetley Tea powder extract registered a high level of photo-catalytic degradation ability against crystal violet. The possible mechanism for the degradation of dyes is as follows. When the electrons in the biocatalyst are irradiated by sun light, they are excited and move from the valence band to the conduction band. Thus, these high energy electrons form electron hole pairs, which lead to the production of free radicals like hydroxyl and oxygen respectively. Subsequently, these excited free radicals are responsible for the degradation of the dyes. The photo catalytic

degradation of dye depends upon the crystallographic structure, morphology, and size of the synthesized nanoparticles.

Schematic representation Mechanism





4. CONCLUSION

This study presents a rapid, eco-friendly, non-toxic, and cost-effective approach for the green synthesis of spherical silver nanoparticles (Ag-NPs) using Tetley tea powder waste extract without the addition of any external reducing or stabilizing agents. The reuse of discarded tea powder not only minimizes waste generation but also enhances the economic viability and sustainability of the synthesis process, making it suitable for large-scale production. The synthesized Ag-NPs were successfully characterized by various analytical techniques, with TEM analysis confirming uniformly distributed spherical nanoparticles of 10–30 nm in size and DLS analysis indicating good colloidal stability. The Ag-NPs exhibited excellent multifunctional properties, including selective detection of Fe^{3+} ions through a distinct

decrease in UV–Visible absorbance, suggesting their potential application as a simple colorimetric sensor for monitoring iron ions in contaminated water. Furthermore, the nanoparticles demonstrated efficient photocatalytic degradation of crystal violet dye, with a continuous reduction in absorbance at 596 nm over 5–75 min of irradiation, highlighting their applicability in wastewater treatment. In addition, the biosynthesized Ag-NPs showed remarkable antibacterial activity against both *Bacillus subtilis* and *Escherichia coli*, with stronger inhibition observed against the Gram-positive strain and inhibition zones exceeding those of the standard antibiotic ampicillin. Overall, the findings confirm that Tetley tea powder waste-derived Ag-NPs possess significant potential as sustainable multifunctional nanomaterials for environmental remediation, selective metal ion sensing, and antimicrobial applications, providing an effective strategy for converting agricultural waste into value-added products.

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