WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A Review on Nano-Particles as Catalyst in Degrading Organic Dyes

Sarvaree Bano [a]*, Manisha Agrawal [b]

[a] *Research Scholar, Department of Chemistry, Rungta College of Engineering & Technology, Bhilai-490024, Chhattisgarh, India*
[b] *Professor & Dean,, Department of Chemistry, Krishna's Vikash Institute of Technology,, Raipur-492099, India*
**Sarvaree1985@gmail.com*[1], *dr.manisha.9000@gmail.com*[2]
DOI : https://doi.org/10.55248/gengpi.6.0325.1163

A B S T R A C T

Nanotechnology flourished in twenty-first century, offering possible solutions to numerous environmental concerns. Nanoparticles are a part of nanotechnology and have a wide spectrum of applications. It has been demonstrated that a catalyst can be made using nanoparticles of different elements. Nano-catalysts are chosen over conventional catalysts because of their high surface area to volume ratio.

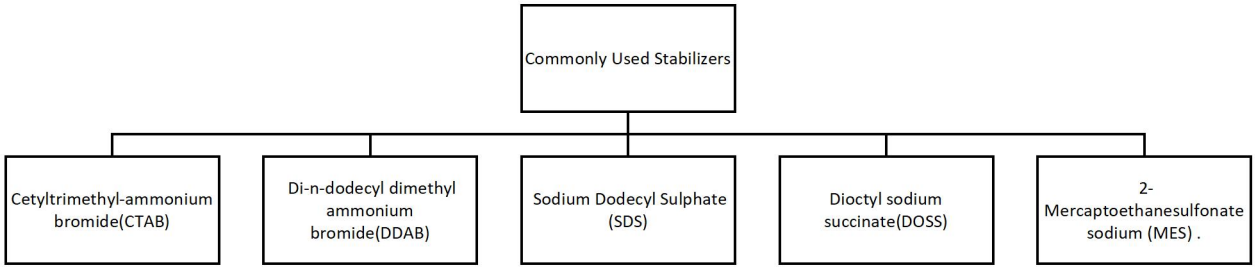
The use of nanoparticles (NPs) as catalysts over several organic transformations including coupling, reduction, and multicomponent reactions has massively increased recently. Nanoparticles can be synthesised using Physical, Chemical, or Biological Method of Synthesis. NPs are utilised in the detection and degradation of dyes in contaminated water as a result of their great efficiency in detecting and destroying pollutants due to their surface atoms, which are very active. Nano-catalysts exhibit unique reactivity, selectivity, stability, recyclability in catalytic reactions, in addition to the features of catalysts.

The several ways for synthesizing NPs, observing their catalytic activity, and characterising them are all covered in this paper. Dye pollutants are among the most prevalent and challenging to eliminate from water. When NPs containing NaBH4 were utilised, it was discovered that the dyes were converted to a less dangerous substance. The most of NPs are recyclable and can be used 4-5 times.

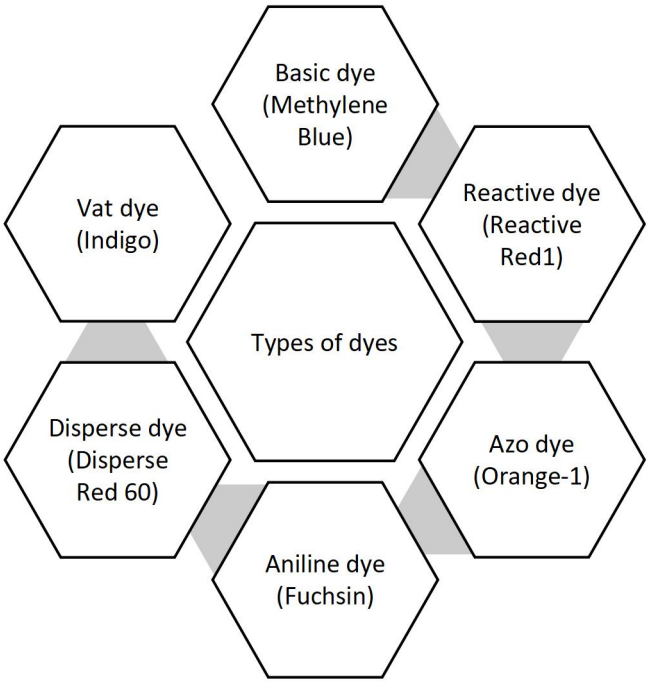
Keywords: Nano-Catalyst, Nanoparticle, $NaBH_4$, Dyes, Water pollution.

1. Introduction

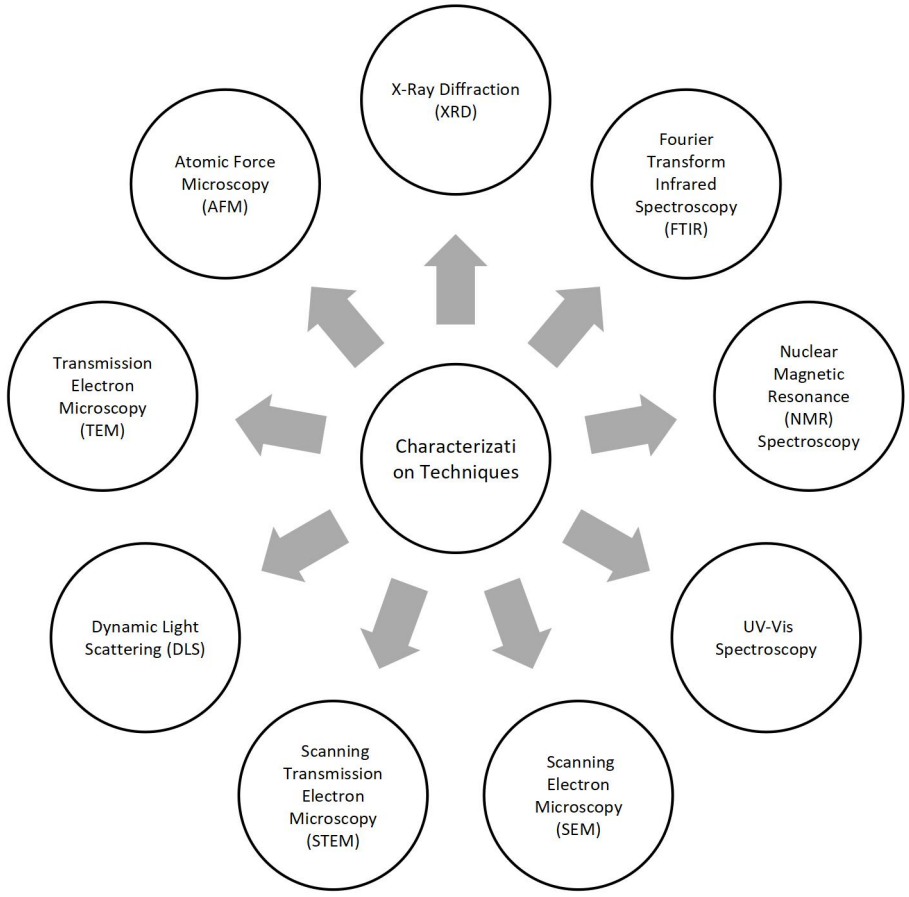
The majority of fields employ nanoparticles because of their tiny size and substantial surface area. Distinctive particles that lie between microscopic and mesoscopic sizes are called nanoparticles. Beyene, H. D. et al. [1] Nanoparticles exhibit unambiguous traits like catalytic activity, Iqbal, S. et al. [2] Antimicrobial activity, Ayala Valencia, G., et al. [3] Optical activity, Fahmy, H. M., et al. [4] And many more. Due to their potential to serve as catalysts, metallic nanoparticles have been the subject of extensive research recently. Venkatesham, M. et al. [5] And, because of its numerous distinct characteristics, particularly its strong antibacterial and catalytic activity, Silver is a very alluring metal to analyse at the nanoscale. Rostami-Vartooni, A. et al. [6] Ag has been fabricated into nanoparticles with sizes ranging from 1 to 100 nm. As particle size decreases, nanoparticles have a larger surface area to volume ratio. The catalytic activity is dependent on specific surface area. Gurunathan, S. et al. [7] Due to the wide range of industries in which they are used, several methods of fabricating silver nanoparticles have been researched. Some of these include: chemical reduction Mostafa, A. A., et al. [8] Physical method, Natsuki, J. et al. [9] and biological reduction. Dahoumane, S. A. et al. [10] Since, the activity of NPs is reliant on their size and varies with size range as discussed above, attaining required size and stable structure during nanoparticle manufacturing is quite challenging and crucial. As previously noted, many stabiliser types have been utilised in the manufacture of silver nanoparticles to provide the best control over their size, distribution, shape, stability, and solubility. Vijayan, R. et al. [11] Some of the most commonly used Stabilizers are: Cetyltrimethyl-ammonium bromide(CTAB), di-n-dodecyl dimethyl ammonium bromide(DDAB), Sodium Dodecyl Sulphate (SDS),dioctyl sodium succinate(DOSS), 2-mercaptoethanesulfonate sodium (MES) . Mahmood, M. et al. [12]

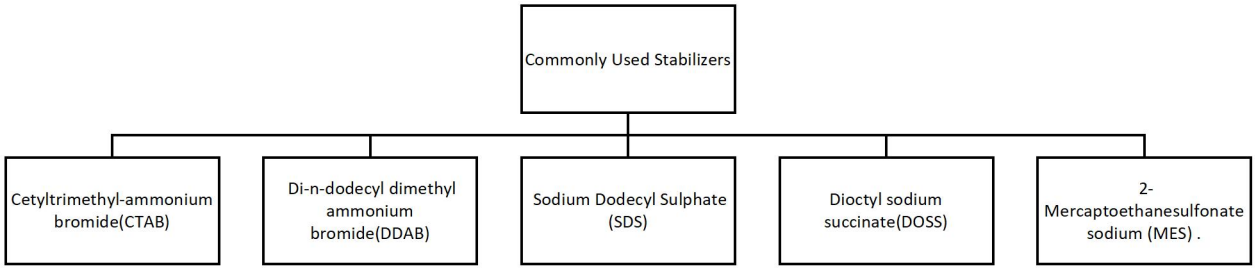


Chemical and physical processes are costly and pollute the environment. To evade these problems, a biological process, also known as green synthesis, has been practiced. It has assets that other construction methods do not have, such as being inexpensive, environmental friendly, and being a one-step construction method. Saha, J., et al. [13] Synthesis of silver nanoparticles from plants and plant extracts represent an important breakthrough biotechnology that can explore the hidden mysteries of nature. Mashwani, Z. U. et al. [14] Plants have diverse biomolecules that trim metal ions to nano-size and also act as stabilizers. Khan, M., et al. [15] Due to their excellent catalytic activity, silver nanoparticles are used to degrade organic dyes Rostami-Vartooni, A., et al. [16] released from different industries like food, paper and textile, directly into water without any pre-treatment. David, L., et al. [17] There are many structural variants, such as acidic, basic, disperse, azo, diazo, anthroquinone and metal complex dyes.



Discoloration of textile dye effluent does not occur when treated aerobically by municipal sewage systems. These are very difficult to remove. Robinson, T., et al. [18] Various depigmentation methods have now been established with countless research projects claiming successful depigmentation. There are various applicable dye removal techniques, but not all are successful or suitable for practice due to their drawbacks. Katheresan, V. et al. [19] This review focuses on the degradation of organic dyes such as Methyl Orange, Methylene Blue and Eosin Y by the catalytic activity of AgNPs. The silver nanoparticles were characterized by different techniques such as X-Ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), Nuclear Magnetic Resonance (NMR) Spectroscopy, UV-Vis Spectroscopy, Scanning Electron Microscopy (SEM), Scanning Transmission Electron Microscopy (STEM), Dynamic Light Scattering (DLS), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), etc.And the reduction of the dye in water was also observed by UV spectroscopy.





2. Methodology

2.1 Physical Method

Physical method of Nanoparticle synthesis is seldom used on industrial level due to their large size distribution, high energy consumption, lower yield of productivity and also due to their insignificance in large scale synthesis. Kaabipour, S., et al.[21] Using a furnace processing chamber, to vaporize metal of interest to a low-density gas phase and then it is condensed to form nuclei which further grow into nanoparticle. The whole process is known as evaporation-condensation process and AgNP synthesized using this technique were in size range of 7 to 55 nm and of crystalline shape. Simchi, A. et al. [22] Inert gasses like Helium are generally used in this process. Raffi, M., et al. [23] Silver electrodes are dipped in deionized water and under high DC current and Ag gets vaporized from electrode further resulting in formation of AgNP from Silver condensates. Zhang, H. [24] AgNPs may also be

synthesised using inert metals like Titanium as electrodes and $AgNO_3$ as precursor. During electron exchange in plasma region Silver ion is reduced and thus forming AgNP. Ashkarran, A. A. et al. [25]

2.2 Chemical Method

Chemical synthesis of AgNPs is highly dependent on the capping agent selected, as it helps in determination of shape, size and structure of the nanoparticle. The wet chemical Synthesis method of Ag nanorod and nanowire is simple to perform and requires no nanoporous membrane. Jana, N. R., et al. [26]. For wet chemical synthesis of quasi-spherical AgNPs, $AgNO_3$ was used as a precursor of Ag ions and $NaBH_4$ was used as reducing agent. The $AgNO_3$ and capping agent are mixed at room temperature maintaining the concentration of each surfactant i.e., CTAB (2.0 mM), DDAB (0.3 mM), SDS (9.0 mM), DOSS (3.0 mM) and MES (1.0 mM) above their respective critical micelle concentration (CMC) values. Mahmood, M. et al. [12]. CTAB is also used as capping agent in synthesis of CuO nanoparticles along with other capping agents such as Poly ethylene glycol (PEG). Siddiqui, H., et al. [27].Yet another method in chemical synthesis is seed mediated growth approach in rodlike micellar media. A preformed Silver Seed is used to promote silver growth in solution, by reduction of a silver salt. $AgNO_3$ is reduced by $NaBH_4$ and stabilizing agent, Trisodium citrate is added in order to prepare Ag seeds. For preparation of nanorods and nanowires, $AgNO_3$ is reduced by ascorbic acid in presence of Ag seeds and micellar template (CTAB) is added along with NaOH. The separation of rod and wire is done by centrifugation. Jana, N. R., et al. [26].

The strategy involved in previously discussed method is surfactant assisted, as these involved either use of harder template or softer directing agents. These also included use of surfactants and polymers. The problems associated were:

1.) Removal of the template or directing agent from the nanoparticle surface can require harsh conditions or multiple washings to remove unwanted materials.

2.) Presence of residue from synthesis on nanoparticle surface act as interferent in process that require sensing application (e.g.: surface enhanced Raman scattering).

3.) Surface bound residue also create a hinderance in surface chemical activities (such as rational linking of metallic nanoscale object).

These problems were dealt by using a Seedless and Surfactant less process of Synthesis for Silver Nanowires. The solutions were prepared in 3 steps, Solution A consisted of 100 mL of deionized H_2O, 1.5-2 µL of 1 M NaOH (Fisher), and 40 µL of 0.1 M $AgNO_3$ (Sigma). Solution B was made by mixing 150 mL of deionized H_2O and 1.5-2 µL of 1 M NaOH with 20 µL of 0.1 M $AgNO_3$ and bringing this to a boil. In the final step, Solution B was added to A, the neck of the flask was covered with an inverted 50 mL beaker, and the mixture was allowed to boil for 60 min while stirring rapidly. Final pH of solution came out in range of 7.0 to 7.1. It was also observed that the yield of Silver Nanowire highly depended on concentration of NaOH. Caswell, K. K., et al.[28].

2.3 Biological Method

In biological synthesis, we use plant extracts as stabilizing agent. This kind of synthesis is less expensive and produces effective results. In one of such synthesis method, *Manihot esculenta* (Tapioca) starch was mixed with 0.35 g of NaOH platelets to produce Ag-NPs. Then, certain amount of ($AgNO_3$) is dissolved in 5 ml of water along with 3 ml isopropyl alcohol to volatile easily during the synthesis of Ag-NPs. The reaction temperature was set to 80°C and allowed to react for several hours. At the end of reaction, the system colour turns to dark brown which confirms the synthesis of Ag-NP Kalantari, K., et al. [29]. Another such synthesis involved addition of 10 mL *Duranta erecta* leave extract to 90 mL of aqueous 20mM $AgNO_3$ solution at room temperature. Change in colour of solution and UV-vis spectrophotometer readings confirmed the formation of AgNP. Albukhari, S. M., et al. [30] . In Biosynthesis of AgNP using *Eriobotrya japonica*, 1mM $AgNO_3$ solution was slowly mixed with leaf extract in a magnetic stirrer. The reduction was indicated by change in color of the solution from light yellow to dark brown within 5 minutes. The effect of different preparation conditions like temperature, pH, leaf extract and Ag salt solution were noted. Yu, C., et al. [31]. AgNPs were also synthesized using *Ocimum tenuiflorum* leaves(Tulsi leaves). For this, 1 g of *Ocimum tenuiflorum* leaves were washed with water and were then air dried. The dried leaves were cut and boiled in 100ml distilled water for 1 hour. A light greenish yellow solution was obtained. 5mL of $AgNO_3$ solution was added to 10 mL leaf extract and was exposed to sunlight with mild stirring, in order to prepare AgNPs. The colour change from light greenish yellow to reddish brown after an hour indicated successful formation of AgNPs. Singh, J., et al. [32]. It is to be noted that in paper reviewed for biosynthesis, we have been considering leave extracts, but biosynthesis is not only limited to use of leave extracts, it also includes use of green algae extract and fruit extract. For green synthesis of AgNPs from *Botryococcus braunii*, the algal biomass was cultivated and after successful cultivation it was shade-dried. 5g of this dried content was boiled with 100 mL distilled water for 5 minutes and then it was filtered and was used as a reducing agent for nanoparticle synthesis. 5mL algal extract was mixed with 45 mL 1mM $AgNO_3$ solution in a 100mL flask and was placed on a magnetic stirrer for 3 hours. The progress was continuously monitored by observing the colour change and recording UV-visible Spectrum. Arya, A., et al. [33].

Table 1: AgNPs Biosynthesis Parameter. **[Reference Yu, C., et al. [31]]**

S. No.	Colloid	Temperature(°C)	Proportion ratio of $AgNO_3$ and leave extract (v:v) (mL)	pH
1	G-L1	20	10:1	7.0
2	G-L2	20	2:1	7.5
3	G-L3	20	1:1	8.0
4	G-M1	50	10:1	7.5
5	G-M2	50	2:1	8.0
6	G-M3	50	1:1	7.0
7	G-H1	80	10:1	8.0
8	G-H2	80	2:1	7.0
9	G-H3	80	1:1	7.5

Here G is grouping experiments, G-L represents experiments conducted at lower temperature, G-M represents experiments conducted at medium temperature, G-H represents experiments conducted at higher temperature.

Table 2: List of Analytical techniques used for Characterization in various articles **[Reference no. 2, 17,30,32,34,3536,37]**

S.No.	Composite	Size of AgNPs	Characterization of AgNPs	Reference
1	Sun dried Tulsi leaves	5–10 nm	HR-TEM	Singh, J., et al. [32]
2	Sepolite		XRF, XRD, XPS	Zhang, J., et al. [34]
3	TPHH-COF		PXRD, TEM, XPS	Wang, R. L., et al.[35]
4	Viburnum opulus fruits	7-26 nm	TEM, FTIR, XRD, PXRD, DSC, DTG, TGA	David, L., et al. [17]
5	Salvia officinalis leaf	25 nm.	FTIR, XRD, TEM, EDX, TGA, DTG	Albeladi, S. S. R., et al.[36]
6	p(NMA) polymer microgel	12-20 nm	FTIR, UV-vis spectra, Laser Light Scattering Spectrophotometer, XRD	Iqbal, S. et al. [2]
7	Duranta erecta leaf, cellulose acetate filter paper	25nm	UV–vis spectrophotometer, XRD, FE-SEM	Albukhari, S. M., et al. [30]
8	thiol-modified magnetite nanoparticles (Fe_3O_4/SiO_2-Pr-S Ag)	30-40 nm	EDX, WDX, FE-SEM, HRTEM, XPS, FTIR, VSM, ICP	Veisi, H., et al. [37]

3. Characterization

Complete characterization of a nanoparticle's dimensions, surface characteristics, morphology, and dispersion are essential. Carvalho, P. M., et al. [38]. It is essential to characterize these nanoparticles for their several physical, chemical, and biological properties given the nature of their applications. Reddy LH, et al. [39].While characterization is essential for resolving worries about environmental health and safety (EHS) and assessing the safety of nanoparticles for inadvertent exposure to check whether nanoparticles are more hazardous than their larger counterparts. McNeil, S. E. [40]. The knowledge of the surface characteristics of metal NPs facilitates the selection of the appropriate application and the identification of the functional groups for surface functionalization. The principal characteristics that can be easily determined by means of various characterization techniques are surface charge, shape, and size. Bhatia, S., et al. [41]. Three components make up a logical characterization strategy for biomedical nanoparticles: physicochemical characterization, in vitro tests, and in vivo research. Each of these is necessary for a thorough comprehension of the effectiveness and safety of nanoparticles. For instance, effective interpretation of in vitro or in vivo biological data or interlaboratory comparison cannot be achieved without physicochemical characterization. McNeil, S. E. [40].

By assessing the storage stability of materials, the zeta potential (ZP), an indirect way of measuring surface charge, aids in the prediction of colloidal material stability. ZP helps ensure stability to avoid aggregation of MNP. Pal, S. L., et al. [42]. This section presents techniques for measuring surface charge using zeta potential measurement, molecular weight using mass spectrometry, topology using atomic force microscopy (AFM), and nanoparticle size in solution using dynamic light scattering (DLS). Moreover, techniques are provided for the inspection of nanoparticle samples using TEM and SEM as well as for the identification of elements using energy dispersive X-ray spectroscopy (EDX). McNeil, S. E. [40]. These instruments provide in-depth details on the chemical and physical properties of nanoparticles. Bajaj S, et al. [43].

3.1 X-ray diffraction (XRD)

X-ray diffraction (XRD) is one of the most popular techniques for characterizing NPs. The lattice parameters, phase, crystalline grain size, and crystalline structure are typically revealed by XRD. By utilizing the Scherrer equation and the broadening of the most intense peak of an XRD measurement for a particular sample, the latter parameter is calculated. The advantage of using XRD techniques is that they produce statistically representative, volume-averaged values. These techniques are frequently used with samples in powder form, typically after drying their respective colloidal solutions. The composition of the particles can be determined by comparing the position and intensity of the peaks with the reference patterns found in the International Centre for Diffraction Data (ICDD, formerly known as Joint Committee on Powder Diffraction Standards, JCPDS) database. The XRD peaks are excessively broad for particles smaller than 3 nm, thus it is not appropriate for amorphous materials. Yan, W., et al., [44], Upadhyay, S., et al., [45], Lu, L. T. et al. [46].

3.2 Fourier transform infrared spectroscopy (FTIR)

Infrared spectroscopy using a Fourier transform (FTIR) or Fourier transform infrared spectroscopy is a technique for determining the absorption of electromagnetic radiation with wavelengths between 400 and 400 cm-1 in the mid-infrared range. A molecule's dipole moment is altered as it absorbs IR light, making it IR active. A recorded spectrum reveals the location of bands related to the type and strength of a bond as well as certain functional groups, offering details on the interactions and molecular structures. Blanco Andujar, C., [47], Shukla, N., et al. [48].

Using infrared light to scan the samples, FTIR analysis is used to identify organic, inorganic, and polymeric components. A change in the material composition is indicated by changes to the characteristic pattern of absorption bands. A material's impurities, unexplained components, additions, decomposition, oxidation, and decomposition can all be found using FTIR. Taha, M., et al. [49].

3.3 Nuclear magnetic resonance (NMR) spectroscopy

Another crucial analytical method in the quantitative and structural evaluation of nanoscale materials is nuclear magnetic resonance (NMR) spectroscopy. It is based on the NMR phenomenon that occurs when strongly magnetic fields are applied to nuclei with non-zero spin, which results in a minor energy difference between the "spin-up" and "spin-down" states. Electromagnetic radiation in the radio wave region can be used to study the transitions between these states. The interaction or coordination between the ligand and the surface of diamagnetic or antiferromagnetic NPs is frequently investigated using NMR. However, it is not appropriate for ferri- or ferromagnetic material characterization. Lu, L. T. et al. [46].

3.4 UV-Vis spectroscopy (UV-Vis)

Another relatively simple and inexpensive characterisation technique that is frequently employed for the investigation of nanoscale materials is UV-Vis spectroscopy (UV-Vis). It calculates the light reflection intensity from a sample and contrasts it with the light reflection intensity from a reference material. In order to identify, characterize, and investigate these materials as well as assess the stability of NP colloidal solutions, UV-Vis spectroscopy is a crucial tool. Size, shape, concentration, aggregation state, and the refractive index close to the NP surface all affect the optical properties of NPs. Bindhu, M. R., et al. [50].

3.5 Scanning electron microscopy (SEM)

In scanning electron microscopy (SEM), an electron beams rather than a light beam is pointed at the specimen as in an optical microscope. An electron gun fires a highly focused electron stream. High-energy electron beams from the SEM are used to scan the sample's surface. SEMs use light waves to produce a magnified image, which makes them different from traditional light microscopes. Joshi, M., et al. [51].

3.6 Scanning Transmission Electron Microscopy (STEM)

Scanning transmission electron microscopy are essential for describing flaws and interfaces in nanodevices, nanoparticles, and other nano systems. The adaptability of a STEM instrument is its key quality; from the same part of the specimen, atomic resolution pictures, diffraction patterns from nanometer regions, and nanometer-scale spectroscopy data can all be produced concurrently or sequentially. Liu, J. [52].

3.7 Dynamic Light Scattering (DLS)

DLS is used to characterise colloidal fluids and nanoparticles. DLS measures the amount of laser light that is scattered as it passes through the colloidal solution. We can determine the particle size from the analysis of the time-dependent modulation of the scattered light's intensity. Stetefeld, J., et al. [53].

3.8 Transmission Electron Microscopy (TEM)

Although TEM and SEM operate on separate principles, they frequently produce the same kinds of data. Because samples must be extremely thin in order for them to transfer electrons, the sample preparation for TEM is difficult and time-consuming. The dispersion of nanoparticles is applied on support grids or films. To make nanoparticles resistant to the instrument vacuum and easier to handle, they are either fixed using a negative staining material, such as phosphotungstic acid or derivatives, uranyl acetate, etc., or by plastic embedding. An alternative method is to subject the sample to liquid nitrogen temperatures after vitreous ice embedding. When a beam of electrons passes through an incredibly thin sample and interacts with it as it does so, the surface features of the sample are discovered. Molpeceres, J., et al. [54].

3.9 Atomic force microscopy (AFM)

Microscopy using atomic forces is known as Atomic Force Microscopy (AFM). Very high resolution in particle size evaluation is provided by atomic force microscopy (AFM), which is based on the physical scanning of materials at the sub-micron level utilizing a probe tip of atomic scale. The instrument creates a topographical map of the sample based on forces between the tip and the sample surface. Depending on their characteristics, samples are often scanned in either contact or non-contact mode. AFM, which doesn't require any mathematical processing, offers the most accurate representation of size and size distribution. Also, the AFM technique's analysis of particle size creates a real-time image that aids in comprehending the effects of various biological situations. Pal, S. L., et al. [42].

3.10 Catalytic Behaviour of AgNPs

Due to its low solubility in water and high chemical stability, it is difficult to transform Organic Dyes into non-hazardous substances. Nakagawa, M., et al.[55]. Organic dyes can currently be disposed of in water in an effective and environmentally favourable manner by reducing them over noble metal nanoparticles in the presence of $NaBH_4$ Saha, S., et al.[56]. It is well known that AgNP size plays a key role in catalysis and that smaller AgNPs typically exhibit greater catalytic activity. Dong, Z., et al.[57]. By performing the catalytic degradation of dye in the presence of sodium borohydride (NaBH4) as a Reducing agent at ambient temperature, the catalytic activity of silver nanoparticles was examined. Albeladi, S. S. R., et al. [58]. The nanoparticles were created using various methods and hybrid materials. NaBH4 was used to dissolve the nanoparticles in water, and at regular periods, UV-Vis spectroscopy was used to track the reduction reactions. Veisi, H., et al. [59]. It was observed that after some time the dyes were reduced and their intensities decreased with the increase of reaction time. Due to the formation of reduced

compound and sometimes change in colour of the solution was also observed.

Table 3: Used synthesized catalyst and its observed band before catalyst and after catalyst. **[Reference no. 2, 30,32,34,3536,37, 60]** (1)

S. No.	**Catalyst**	**Absorption band before catalyst**	**Absorption band after catalyst**	**Dye Reduced**	**Characterization**	**References**
1	AgNP of sun dried tulsi	400 nm	298 nm	4 Nitro Phenol	UV spectroscopy	Singh, J., et al. [32]
2	Ag/NH_2-ASep	400 nm	300 nm	4 Nitro Phenol	UV spectroscopy	Zhang, J., et al. [34]
3	AgTPHH-COF	400 nm	300 nm	4 Nitro Phenol	UV spectroscopy	Wang, R. L., et al.[35]
4	AgNP of Salvia officinalis leaf extract	492 nm	250 nm	Congo Red	UV spectroscopy	Albeladi, S. S. R., et al.[36]
5	Ag-p(NMA) hybrid microgel	492 nm	288 nm - 249 nm	Congo Red	UV spectroscopy	Iqbal, S. et al. [2]
6	AgCAF & $AgTiO_2$	402 nm	303 nm	4 Nitro Phenol	UV spectroscopy	Albukhari, S. M., et al. [30]
		411 nm	290 nm	2 Nitro Phenol		
		395 nm	303 nm	Picric Acid		

7	Fe_3O_4/SiO_2-Pr-SH/Ag	400 nm	298 nm	4 Nitro Phenol	UV spectroscopy	Veisi, H., et al. [37]
8	Taro rhizome AgNP	402 nm	301 nm	4 Nitro Phenol	UV spectroscopy	Ismail, M., et al. [60]
		419 nm	294 nm	2 Nitro Phenol		
		394 nm	234 nm	Picric Acid		
		492 nm & 337 nm	275 nm & 249 nm	Congo Red		
		479 and 329 nm	286 and 252 nm	MR		
		555 nm	241 nm	RhB		

4. Conclusion

The behaviour exhibited by Silver Nanoparticles (AgNPs) highly depends on the selection of method of synthesis, as each method of synthesis has its own set of positive and negative attributes. Physical method of synthesis is generally insignificant for large scale industrial production mainly due to their wide range of size distribution and high energy consumption. In few cases, the equipment was also very expensive. Particle size of the synthesized nanoparticle depended on metal chosen as electrode. When Silver was used as electrodes the size of the particle ranged from 5 to 45 nm. On the other hand, particle size varied from 7 to 55 nm and were of crystalline shape in evaporation-condensation process. Chemical method of synthesis on the other hand are simple and provides narrow size distribution. Despite ample of benefits presented by Chemical method, use of hazardous and highly toxic substances like hydrazine and sodium borohydride limits its biomedical and industrial application. CTAB is one of the most used capping agents. In Chemical Method of synthesis, it was observed that size of Silver nanoparticle highly depends on the capping agent selected. Based on this, the particle size varies from 4.50 ± 0.50 nm to 11.30 ± 0.40 nm. Biological method of synthesis also known as green synthesis are environment-friendly and low cost. It provides us with definite morphology and narrow size distribution. Plant extracts acts as reducing agent as well as capping agent and require low temperature for reaction. Colour change in solution is the general indication of successful formation of silver nanoparticle. The particle size generally ranged from 5 to 25 nm. $NaBH_4$ is generally used as reducing agent for organic dyes like methyl orange, but it cannot completely reduce the dye. By using Nanoparticle as a catalyst, we are speeding the reduction time and decomposing harmful organic dyes to less harmful inorganic substances. Degradation of dyes are indicated by decolourization of the solution. The study on variation in reaction kinetics based on particle size emphasize that catalytic activity is inversely proportional to particle size.

Acknowledgements

The authors are thankful to Chhattisgarh Swami Vivekanand Technical University (CSVTU) and Rungta College of Engineering & Technology, Bhilai and Krishna's Vikash Institute of Technology, Raipur for providing the help in this work.

References

Beyene, H. D., Werkneh, A. A., Bezabh, H. K., & Ambaye, T. G. (2017). Synthesis paradigm and applications of silver nanoparticles (AgNPs), a review. *Sustainable materials and technologies*, *13*, 18-23.

Iqbal, S., Zahoor, C., Musaddiq, S., Hussain, M., Begum, R., Irfan, A., ... & Farooqi, Z. H. (2020). Silver nanoparticles stabilized in polymer hydrogels for catalytic degradation of azo dyes. *Ecotoxicology and Environmental Safety*, *202*, 110924.

Ayala Valencia, G., Cristina de Oliveira Vercik, L., Ferrari, R., & Vercik, A. (2013). Synthesis and characterization of silver nanoparticles using water-soluble starch and its antibacterial activity on Staphylococcus aureus. *Starch-Stärke*, *65*(11-12), 931-937.

Fahmy, H. M., Mosleh, A. M., Abd Elghany, A., Shams-Eldin, E., Serea, E. S. A., Ali, S. A., & Shalan, A. E. (2019). Coated silver nanoparticles: Synthesis, cytotoxicity, and optical properties. *RSC advances*, *9*(35), 20118-20136.

Venkatesham, M., Ayodhya, D., Madhusudhan, A. *et al.* A novel green one-step synthesis of silver nanoparticles using chitosan: catalytic activity and antimicrobial studies. *Appl Nanosci* 4, 113–119 (2014). https://doi.org/10.1007/s13204-012-0180-y

Rostami-Vartooni, A., Nasrollahzadeh, M., & Alizadeh, M. (2016). Green synthesis of seashell supported silver nanoparticles using Bunium persicum seeds extract: application of the particles for catalytic reduction of organic dyes. *Journal of colloid and interface science*, *470*, 268-275.

Gurunathan, S., Kalishwaralal, K., Vaidyanathan, R., Venkataraman, D., Pandian, S. R. K., Muniyandi, J., ... & Eom, S. H. (2009). Biosynthesis, purification and characterization of silver nanoparticles using Escherichia coli. Colloids and Surfaces B: Biointerfaces, 74(1), 328-335.

Mostafa, A. A., Sayed, S. R., Solkamy, E. N., Khan, M., Shaik, M. R., Al-Warthan, A., & Adil, S. F. (2015). Evaluation of biological activities of chemically synthesized silver nanoparticles. Journal of Nanomaterials, 16(1), 443-443.

Natsuki, J., Natsuki, T., & Hashimoto, Y. (2015). A review of silver nanoparticles: synthesis methods, properties and applications. Int. J. Mater. Sci. Appl, 4(5), 325-332.

Dahoumane, S. A., Mechouet, M., Wijesekera, K., Filipe, C. D., Sicard, C., Bazylinski, D. A., & Jeffryes, C. (2017). Algae-mediated biosynthesis of inorganic nanomaterials as a promising route in nanobiotechnology–a review. Green Chemistry, 19(3), 552-587.

Vijayan, R., Joseph, S., & Mathew, B. (2018). Eco-friendly synthesis of silver and gold nanoparticles with enhanced antimicrobial, antioxidant, and catalytic activities. IET nanobiotechnology, 12(6), 850-856.

Mahmood, M., Abid, M., Nazar, M. F., Zafar, M. N., Raza, M. A., Ashfaq, M., ... & Zubair, M. (2020). The wet chemical synthesis of surfactant-capped quasi-spherical silver nanoparticles with enhanced antibacterial activity. Materials Advances, 1(7), 2332-2338.

Saha, J., Begum, A., Mukherjee, A., & Kumar, S. (2017). A novel green synthesis of silver nanoparticles and their catalytic action in reduction of Methylene Blue dye. Sustainable Environment Research, 27(5), 245-250.

Mashwani, Z. U. R., Khan, T., Khan, M. A., & Nadhman, A. (2015). Synthesis in plants and plant extracts of silver nanoparticles with potent antimicrobial properties: current status and future prospects. Applied microbiology and biotechnology, 99(23), 9923-9934.

Khan, M., Al-Marri, A. H., Khan, M., Shaik, M. R., Mohri, N., Adil, S. F., ... & Siddiqui, M. R. H. (2015). Green approach for the effective reduction of graphene oxide using Salvadora persica L. root (Miswak) extract. Nanoscale research letters, 10(1), 1-9.

Rostami-Vartooni, A., Nasro llahzadeh, M., & Alizadeh, M. (2016). Green synthesis of seashell supported silver nanoparticles using Bunium persicum seeds extract: application of the particles for catalytic reduction of organic dyes. *Journal of colloid and interface science*, *470*, 268-275.

David, L., & Moldovan, B. (2020). Green synthesis of biogenic silver nanoparticles for efficient catalytic removal of harmful organic dyes. *Nanomaterials*, *10*(2), 202.

Robinson, T., McMullan, G., Marchant, R., & Nigam, P. (2001). Remediation of dyes in textile effluent: a critical review on current treatment technologies with a proposed alternative. *Bioresource technology*, *77*(3), 247-255.

Katheresan, V., Kansedo, J., & Lau, S. Y. (2018). Efficiency of various recent wastewater dye removal methods: A review. *Journal of environmental chemical engineering*, *6*(4), 4676-4697.

Bano, S., Agrawal, M., & Palc, D. (2020). A review on green synthesis of silver nanoparticle through plant extract and its medicinal applications. *J. Indian Chem. Soc*, *97*, 983-988.

Kaabipour, S., & Hemmati, S. (2021). A review on the green and sustainable synthesis of silver nanoparticles and one-dimensional silver nanostructures. Beilstein Journal of Nanotechnology, 12(1), 102-136.

Simchi, A.; Ahmadi, R.; Reihani, S. M. S.; Mahdavi, A. Mater. Des.2007, 28, 850–856. doi:10.1016/j.matdes.2005.10.017

Raffi, M.; Rumaiz, A. K.; Hasan, M. M.; Shah, S. I. J. Mater. Res.2007, 22, 3378–3384. doi:10.1557/jmr.2007.0420

Zhang, H.; Zou, G.; Liu, L.; Tong, H.; Li, Y.; Bai, H.; Wu, A.J. Mater. Sci. 2017, 52, 3375–3387. doi:10.1007/s10853-016-0626-9

Ashkarran, A. A. Curr. Appl. Phys. 2010, 10, 1442–1447. doi:10.1016/j.cap.2010.05.010

Jana, N. R., Gearheart, L., & Murphy, C. J. (2001). Wet chemical synthesis of silver nanorods and nanowires of controllable aspect ratioElectronic supplementary information (ESI) available: UV–VIS spectra of silver nanorods. See http://www. rsc. org/suppdata/cc/b1/b100521i. Chemical Communications, (7), 617-618.

Siddiqui, H., Qureshi, M. S., & Haque, F. Z. (2016). Surfactant assisted wet chemical synthesis of copper oxide (CuO) nanostructures and their spectroscopic analysis. Optik, 127(5), 2740-2747.

Caswell, K. K., Bender, C. M., & Murphy, C. J. (2003). Seedless, surfactantless wet chemical synthesis of silver nanowires. Nano Letters, 3(5), 667-669.

Kalantari, K., Afifi, A. B. M., Bayat, S., Shameli, K., Yousefi, S., Mokhtar, N., & Kalantari, A. (2019). Heterogeneous catalysis in 4-nitrophenol degradation and antioxidant activities of silver nanoparticles embedded in Tapioca starch. Arabian Journal of Chemistry, 12(8), 5246-5252.

Albukhari, S. M., Ismail, M., Akhtar, K., & Danish, E. Y. (2019). Catalytic reduction of nitrophenols and dyes using silver nanoparticles@ cellulose polymer paper for the resolution of waste water treatment challenges. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 577, 548-561.

Yu, C., Tang, J., Liu, X., Ren, X., Zhen, M., & Wang, L. (2019). Green biosynthesis of silver nanoparticles using Eriobotrya japonica (Thunb.) leaf extract for reductive catalysis. Materials, 12(1), 189.

Singh, J., Mehta, A., Rawat, M., & Basu, S. (2018). Green synthesis of silver nanoparticles using sun dried tulsi leaves and its catalytic application for 4-Nitrophenol reduction. Journal of environmental chemical engineering, 6(1), 1468-1474.

Arya, A., Mishra, V., & Chundawat, T. S. (2019). Green synthesis of silver nanoparticles from green algae (Botryococcus braunii) and its catalytic behavior for the synthesis of benzimidazoles. Chemical Data Collections, 20, 100190.

Zhang, J., Yan, Z., Fu, L., Zhang, Y., Yang, H., Ouyang, J., & Chen, D. (2018). Silver nanoparticles assembled on modified sepiolite nanofibers for enhanced catalytic reduction of 4-nitrophenol. Applied Clay Science, 166, 166-173.

Wang, R. L., Li, D. P., Wang, L. J., Zhang, X., Zhou, Z. Y., Mu, J. L., & Su, Z. M. (2019). The preparation of new covalent organic framework embedded with silver nanoparticles and its applications in degradation of organic pollutants from waste water. Dalton Transactions, 48(3), 1051-1059.

Albeladi, S. S. R., Malik, M. A., & Al-thabaiti, S. A. (2020). Facile biofabrication of silver nanoparticles using Salvia officinalis leaf extract and its catalytic activity towards Congo red dye degradation. Journal of Materials Research and Technology, 9(5), 10031-10044.

Veisi, H., Razeghi, S., Mohammadi, P., & Hemmati, S. (2019). Silver nanoparticles decorated on thiol-modified magnetite nanoparticles (Fe3O4/SiO2-Pr-S-Ag) as a recyclable nanocatalyst for degradation of organic dyes. Materials Science and Engineering: C, 97, 624-631.

Carvalho, P. M., Felício, M. R., Santos, N. C., Gonçalves, S., & Domingues, M. M. (2018). Application of light scattering techniques to nanoparticle characterization and development. Frontiers in chemistry, 6, 237.

Reddy LH, Arias JL, Nicolas J, Couvreur P. Magnetic nanoparticles: design and characterization, toxicity and biocompatibility, pharmaceutical and biomedical applications. Chem Rev 2012;112:5818e78.

McNeil, S. E. (2011). Challenges for nanoparticle characterization. Characterization of nanoparticles intended for drug delivery, 9-15.

Bhatia, S., & Bhatia, S. (2016). Nanoparticles types, classification, characterization, fabrication methods and drug delivery applications. Natural Polymer Drug Delivery Systems: Nanoparticles, Plants, and Algae, 33-93.

Pal, S. L., Jana, U., Manna, P. K., Mohanta, G. P., & Manavalan, R. (2011). Nanoparticle: An overview of preparation and characterization. Journal of applied pharmaceutical science, (Issue), 228-234.

Bajaj S, Singla D, Sakhuja N. Stability testing of pharmaceutical products. J Appl Pharm Sci 2012

Yan, W., Petkov, V., Mahurin, S. M., Overbury, S. H., & Dai, S. (2005). Powder XRD analysis and catalysis characterization of ultra-small gold nanoparticles deposited on titania-modified SBA-15. Catalysis Communications, 6(6), 404-408.

Upadhyay, S., Parekh, K., & Pandey, B. (2016). Influence of crystallite size on the magnetic properties of Fe3O4 nanoparticles. Journal of Alloys and Compounds, 678, 478-485.

Lu, L. T. (2011). Water-dispersible magnetic nanoparticles for biomedical applications: synthesis and characterisation (Doctoral dissertation, University of Liverpool).

Blanco Andujar, C. (2014). Sodium carbonate mediated synthesis of iron oxide nanoparticles to improve magnetic hyperthermia efficiency and induce apoptosis (Doctoral dissertation, UCL (University College London)).

Shukla, N., Liu, C., Jones, P. M., & Weller, D. (2003). FTIR study of surfactant bonding to FePt nanoparticles. Journal of Magnetism and Magnetic materials, 266(1-2), 178-184.

Taha, M., Hassan, M., Essa, S., & Tartor, Y. (2013). Use of Fourier transform infrared spectroscopy (FTIR) spectroscopy for rapid and accurate identification of Yeasts isolated from human and animals. International journal of veterinary science and medicine, 1(1), 15-20.

Bindhu, M. R., & Umadevi, M. (2013). Synthesis of monodispersed silver nanoparticles using Hibiscus cannabinus leaf extract and its antimicrobial activity. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 101, 184-190.

Joshi, M., Bhattacharyya, A., & Ali, S. W. (2008). Characterization techniques for nanotechnology applications in textiles.

Liu, J. (2005). Scanning transmission electron microscopy and its application to the study of nanoparticles and nanoparticle systems. Microscopy, 54(3), 251-278.

Stetefeld, J., McKenna, S. A., & Patel, T. R. (2016). Dynamic light scattering: a practical guide and applications in biomedical sciences. Biophysical reviews, 8, 409-427.

Molpeceres, J., Aberturas, M. R., & Guzman, M. (2000). Biodegradable nanoparticles as a delivery system for cyclosporine: preparation and characterization. Journal of microencapsulation, 17(5), 599-614.

Nakagawa, M., & Crosby, D. G. (1974). Photodecomposition of nitrofen. Journal of Agricultural and Food Chemistry, 22(5), 849-853.

Saha, S., Pal, A., Kundu, S., Basu, S., & Pal, T. (2010). Photochemical green synthesis of calcium-alginate-stabilized Ag and Au nanoparticles and their catalytic application to 4-nitrophenol reduction. Langmuir, 26(4), 2885-2893.

Dong, Z., Le, X., Li, X., Zhang, W., Dong, C., & Ma, J. (2014). Silver nanoparticles immobilized on fibrous nano-silica as highly efficient and recyclable heterogeneous catalyst for reduction of 4-nitrophenol and 2-nitroaniline. Applied Catalysis B: Environmental, 158, 129-135.

Albeladi, S. S. R., Malik, M. A., & Al-thabaiti, S. A. (2020). Facile biofabrication of silver nanoparticles using Salvia officinalis leaf extract and its catalytic activity towards Congo red dye degradation. Journal of Materials Research and Technology, 9(5), 10031-10044.

Veisi, H., Razeghi, S., Mohammadi, P., & Hemmati, S. (2019). Silver nanoparticles decorated on thiol-modified magnetite nanoparticles (Fe3O4/SiO2-Pr-S-Ag) as a recyclable nanocatalyst for degradation of organic dyes. Materials Science and Engineering: C, 97, 624-631.

Ismail, M., Khan, M. I., Khan, S. B., Akhtar, K., Khan, M. A., & Asiri, A. M. (2018). Catalytic reduction of picric acid, nitrophenols and organic azo dyes via green synthesized plant supported Ag nanoparticles. Journal of Molecular Liquids, 268, 87-101.