SINCE 2010

NAAS Rating
2012:1.3; 2013-16: 2.69
2017-2020: 3.98

IMPACT FACTOR
2019-20: 2.40; 2021:1.09

IPI Value 2.74
SJIF 6.783

Received on:
20rd June 2022
Revised on:
25th June 2022
Accepted on:
30th June 2022
Published on:
1st July 2022

Volume No.
Online & Print
149 (2022)

Page No.
11 to 31

Life Sciences Leaflets is an international open access print & e journal, peer reviewed, worldwide abstract listed, published every month with ISSN, RNI Free- membership, downloads and access.

A REVIEW ON SYNTHESIS OF NANOPARTICLES AND THEIR APPLICATION IN DYE DEGRADATION

RIYA SHAH[1*], NIRMAL KUMAR J.I[1], RITA N KUMAR[2] AND NIRALI GOSWAMI[1]

[1]P.G. DEPARTMENT OF ENVIRONMENTAL SCIENCE AND TECHNOLOGY (EST), INSTITUTE OF SCIENCE AND TECHNOLOGY FOR ADVANCED STUDIES AND RESEARCH (ISTAR) –A CONSTITUENT COLLEGE OF CVM UNIVERSITY, VALLABH VIDYANAGAR- 388 120, GUJARAT, INDIA.

[2]DEPARTMENT OF BIOLOGICAL AND ENVIRONMENTAL SCIENCE, NV PATEL COLLEGE- A CONSTITUENT COLLEGE OF CVM UNIVERSITY, VALLABH VIDYANAGAR- 388 120, GUJARAT, INDIA.

***Corresponding author's e-mail*: shahriya1015@gmail.com**

ABSTRACT:

In recent studies, nanomaterials and nanotechnologies have acquired a lot of attention. With the advancement of nanoscience, new physical properties and methods in sample preparation and device fabrication emerged. This research work carried out by physicists, chemists, material scientists, and mechanical and electrical engineers from several domains. The developments of nanomaterials are equivalent to quantum confined atoms which is a significant step forward in the quest for quantum confinement. Materials scientists and engineers have made considerable advances in the development of nanomaterial solids synthesis technologies. This review includes various methods of preparing nanomaterials including ball milling, chemical vapor deposition, pulse-laser method, as precipitation, co-precipitation method, mixture methods, solvothermal, and sol-gel processing, water-oil microemulsions method, hydrothermal and biological synthesis and applications of nanomaterial in dye degradation from industrial -wastewaters.

KEYWORDS: *Environmental Nanotechnology, Nanoparticle Synthesis, Water pollution, Wastewater treatment.*

INTRODUCTION:

Wastewater problem: Water is a valuable natural resource that exists on earth, without which life wouldn't be possible. The earth's surface is composed of more than 70 % water, out of which about 97% is salt water which is technically not suitable for human consumption; the other 2 % is glacier ice, which is very far away from the locations where people dwell. The remaining 1% is the surface water which we use for drinking, washing, irrigation, industrial purposes and many more **(Shiklomanov, 1993)**. Unfortunately, water is not a renewable resource and in future it might get worse due to climate change, industrialization and human activities **(Bell and Buckley, 2003)**. Wastewaters are producing gradually with rapid development in different type of industries such as textile, leather, pulp and paper, printing, photographs, cosmetics, pharmaceutical etc., commerce, hospital and health-care services. Water is the primary medium for eliminating impurities, applying dyes, and applying finishing products in the business. As a result, the main source of concern is wastewater discharge. Significant quantities of toxic and hazardous chemicals are being generated as an industrial waste. At present, there are thousands of types of toxic chemicals commercially generated. Their virulence, firmness to natural disintegration and prolong accumulation in the environment are a source of great concern for society and regulatory bodies all around the world. The most hazardous pollutants in liquid waste include production of dyes, heavy metal, pesticides, petrochemicals, pharmaceuticals, antibiotics, an inorganic pollutant, heavy metals, microbes. These chemicals that are used in industrial processes are worth mentioning for their prospective negative effects on the environment, threat to the aquatic life and risk factor for human health **(Patil and Shinde, 1988)**.

Environmental issues have become increasingly important at the global level over the last two decades. Industrial growth has resulted in significant pollution and deterioration of water quality, which directly affect the people and human health. Among the industries, the textiles effluents are highly charged with a large quantity of organic dyes which are toxic and often hardly biodegradable to date, there are approximately 1,000,000 tons of different dyes produced around the world. The azo dyes are among the most important class of synthetic dyes (~ 60%). They represent half of all commercial dyes used in different types of industries such as textiles, papers, laser prints and others. Several types of dyes are very toxic and resistant to biodegradation due to their complex chemical structure and some of them can be carcinogenic. Azo Dyes Azo dyes make up 60-70 percent of all dyes and are used in a variety of applications. This group of dyes produces vibrant colours in a wide range of hues. Although the majority of commercially available azo dyes are red, orange, and yellow, and the complete spectrum can theoretically be generated. More azo dyes will be developed as study proceeds.

Textile dyes have been causing diseases like dermatitis, respiratory illnesses, eye allergies, and skin irritation. Large amounts inorganic nutrients (phosphate, sulphate and nitrate) not only cause eutrophication but can lead to respiratory tract irritation, coughing, sore throat, shortness of breath, or even suffocation. These dyes are generally made of aromatic compounds and exposure to heavy metals and Polycyclic Aromatic Hydrocarbons (PAHs) can become a source to range of neurological health threats such as memory loss, loss of coordination, reduced speed of response to stimuli, reduced visual ability, such as increased salivation and perspiration, narrowing of the pupils. Over the decades, the release of waste into the environment was the only way to eliminate it. The permitted discharge levels have been immensely exceeded, causing alteration in water characteristics and creates environmental contamination that our natural resources cannot be reused for many purposes. The possibilities to conquer these problems, i.e., usual prevention and control by adopting various strategies to reduce the waste production by different treatment methods.

Growing population concern with environmental contaminants is creating escalated interest in evolving novel methods of treating contaminated sites and media. A wide variety of contaminants including organics (e.g., volatile organic compounds, pesticides, polychlorinated biphenyls and derivatives such as dioxin, etc.), heavy metals, and radioactive species, present potential problems, in surface waters, ground waters, sediments, soils, and air. There is an inadequate possibility to increase the supply of freshwater to reach the competing demand of growing population all over the world, (Vörösmarty et al., 2000). Using improved purification technology, reuse of wastewater can be achieved which, in turn, needs the development of catalysts that are proficient, cost-effective, and reliable (Bowman et al., 2002). (Patil et al., 2014) have documented the efficiency and drawbacks of various available methods for treatment of wastewater. **Rajan et al., (2011)** have stated slow phase out of current expensive and moderately effective soil and groundwater remediation technologies with application of quick and highly efficient approaches. They documented nano-remediation as a new and effective approach for prevention, monitoring and remediation of environmental pollutants.

Available Technologies for wastewater remediation

There are numerous methods for abatement of organic and inorganic compounds from the wastewater such as filtration, electrolysis, precipitation, ion-exchange, coagulation and adsorption processes **(Johnston and Heijnen, 2001; Robins et al., 2001; Twidwell et al., 1999).** Most of these approaches necessitate a significant initial and ongoing investment, making them unsuitable for small businesses. Table 1 shows the benefits and drawbacks of different approaches. Besides, all the above-mentioned methods, photocatalysis is a highly effective and cheap process than the other methods **(Barakat, 2011)**.

The search for novel technologies for the remediation and reduction of pollutants has attracted attention to adsorption phenomenon. A solid phase (bio sorbent) and a liquid phase (solvent, usually water) containing dissolved species to be adsorbed are used in the adsorption method (sorbate, metal ions). Because sorbent has a higher affinity for sorbate species, the latter is drawn to it and binds to it through several ways. The main advantage in the process of adsorption, is the utilization of non-living biomaterials which minimizes the prerequisite for remarkable care and maintenance as well as it acts as inducer in remediating toxic high levels of contaminants **(Basso et al., 2002)**. Study presented by **(Crane and Scott 2012)** have highlighted the potentiality of nanotechnology for environmental clean-up.

The idea of nanotechnology was inspired after the talk "There's Plenty of Room at the Bottom" by Richard Feynman at the California Institute of Technology in 1959 **(Gribbin and Gribbin 2018)** where they discussed the concept about handling molecules and atoms individually. The word "nanotechnology" was then first delivered and used by Professor Norio in 1974 **(Taniguchi 1974)** where he stated "nanotechnology" mainly includes "the process of consolidation, separation and deformation of any substances via one molecule or one atom". In principle, NMs are described as components with size of 1–1000 nm in at least one dimension; however, they are in many instances described to be of diameter which can fluctuate of 1 to 100 nm. According to National science Foundation and NNI Nanotechnology referred as the functionality to understand, manipulate and control matter at the degree of individual molecule and atoms.

The most important traits of nanoparticles that make them so attractive in chemical engineering and material chemistry are majorly related to the following properties:

(i) high surface area- volume ratio, High activity, Catalytic surface, Adsorbent, Prone to agglomeration

(ii) different physical properties with respect to the bulk material. Here, the melting point and the surface energy are specifically sensitive to nanoparticle sizes,

(iii) Unique light scattering properties and surface plasmon resonance effect; This element is essentially necessary for photocatalytic degradation and optical purposes. **(Iskandar et al., 2009)**

(iv) Novel chemical properties include low coordination sites with high number at the surface with respect to the bulk material, including remarkable effects on catalytic properties which is further enhanced in case of nanoparticles with hollow or porous core **(Tao et al., 2014)**

Ease of functionalization.

Nanotechnology is advanced as a general-purpose technology due to its advanced version such as doping significantly improve some key characteristics and enhances the activity, stability and resistance of materials **(Arabatzis et al., 2003)** which have prominent impact on almost all different sector of society and industries. In recent years, doping metals on the surface of nanoparticles is one of the common methods applied to increase the photocatalytic activity. Among the metals, silver has attracted intense attention to increase photocatalytic activity and stability and can act as electron traps aiding electron–hole separation. The search for novel technologies for the remediation and reduction of pollutants has attracted attention to adsorption phenomenon.

Need and Scope of the Study

According to a recent study, the annual worldwide market for products incorporating nanotechnology is expected to reach US $3.3 trillion. According to the National Nanotechnology Infrastructure Network, the need for technology professionals working in nanotechnology will increase to 1 million employees. Nanotechnology is the new word for chemistry, it is a great term for creating public interest and for collaborative research, where we can now do things more efficiently and with higher performance by making use of nanoscale scientific principles. This technology has enabled advances in computer memory, storage capacity, reduced power consumption, and increased speed, Semiconductors applications everything else combined in this. At present, the number of labs working with nanomaterials is growing dramatically and they are looking for all kinds of new nano properties, for applications ranging from catalysts to energy conversion to deal with issues such as cleanliness and nanofabrication quality control. The main objective of this paper is to provide the reader with brief insight on synthesis and characterisation of nanoparticles with a comprehensive summary of the successful application of various nanoparticles in industries.

Methods for Synthesis of Nanoparticles

Nanotechnology employs two main techniques: The first is a "bottom-up" approach, in which materials and devices are built up atom by atom, whereas the second is a "top-down" approach (Fig.1), in which materials and devices are synthesised or produced by removing existing material from larger entities **(Nasrollahzadeh et al., 2019).** Nano-scale things are created via a top-down strategy, which involves processing larger items. A bulk material is treated and reduced in size to a nanoscale pattern using diverse techniques such as lithography, mechanical, and chemical manipulation tools, whereas the bottom-up methodology creates or grows larger structures atom by atom or molecule by molecule **(Yang et al., 2021)**. These methods include: Self-assembly, Positional assembly, and Chemical synthesis **(Thiruvengadathan et al., 2013).**

Physical, chemical, and biological processes are the three types of synthesis. Physical synthesis includes ball milling, chemical vapour deposition, and the pulse-laser method. Chemical synthesis is separated into liquid-phase synthesis and gas-phase synthesis. Precipitation, co-precipitation, mixture methods, solvothermal, and sol-gel processing, water-oil microemulsions method, and hydrothermal synthesis are examples of liquid-phase fabrication methodologies. Pyrolysis and inert gas condensation fabrication processes are examples of vapour-phase fabrication methodologies. Plant and microbial mediate, as well as waste material, are used in the biological synthesis of nanoparticles.

Top-down approaches:

Ball- milling Method: This is a mechanical attrition method that creates nanostructures as a result of plastic deformation caused by structural disintegration of coarser grained structures. It is utilised for nanoparticle milling and post-annealing (Yadav et al., 2012). It is a physical approach for synthesis of nanoparticles in which the structural degradation of a metal source is achieved by a mechanical attrition process. Here High-energy ball mills are used to make metal element powders. Mechanical alloying is a one-of-a-kind procedure that can be performed at room temperature. Nanomaterials can be made using a variety of fabrication techniques. The effect of the ball on the powder charge. High energy mills, such as Attrition Ball Mills, Planetary Ball Mills, Vibrating Ball Mills, and Low Energy Tumbling Mills, are the most often used ball mill processes (Konrad et al., 2001; Rostislav et al., 1994; Sharma et al., 2009). High-energy ball milling is the most common method for commercial nanomaterial manufacturing. It is a cost-effective approach with the main goal of blending particles into a new phase by lowering particle size. A mixture of metal elemental powders is deposited in a high-energy mill in conjunction with a suitable milling medium. It is made out of a chamber with a number of parallel layers down which the ball slides. Mechanical millings are more cost-effective for large-scale manufacturing of nano-sized grain. A ball mill is a cylindrical drum that contains grinding balls inside and is used to grind materials. Steel or tungsten carbide are commonly used in the construction of the balls. The technology is particularly well suited to laboratory research purposes.

Laser ablation: Laser ablation is a technique for making semiconductor quantum dots, carbon nanotubes, nanowires, and core shell nanoparticles (Kim et al., 2017). The nucleation and development of laser-vaporized species in a background gas are used to create nanoparticles in this process. The ability to produce high purity nanoparticles in the quantum size range (10 nm) is aided by vapour quenching that is exceptionally fast.

Sputtering: Sputtering is the process of depositing nanoparticles on a surface by ejecting particles from the surface when they collide with ions (Shah et al., 2006). Sputtering is the process of depositing a thin coating of nanoparticles and then annealing them. The form and size of the nanoparticles are determined by the layer thickness, annealing temperature and time, substrate type, and other f\actors (Lugscheider et al., 1998).

Bottom-up approaches:

Physical Vapor deposition (PVD): Different surfaces are required for thin films of various metal depositions in this deposition procedure (Powell et al., 1966). It's a three-part procedure: a) Vaporization of a solid-state material using high-temperature vacuum or gaseous plasma. b) Vacuum transports the vapour to the substrate surface. c) thin film formation by vapour condensation on the substrate PVD is further classified into Laser ablation, Sputtering, Spray route pyrolysis, and Inert gas condensation methods, depending on the evaporation source employed. PVD is a high-temperature, vacuum-process that is used to make materials with high melting points and low vapour pressure (Ferrari et al., 2014).

Gas condensation: The first method for creating Nano-crystalline metals and alloys was gas condensation. In this process, a metallic or inorganic substance is evaporated in a 1-50 m bar atmosphere utilising thermal evaporation sources such as Joule heated refractory crucibles and electron beam evaporation devices. By gas phase collision, a high residual gas pressure causes ultra-fine particles (100 nm) to develop during gas evaporation. Collisions of evaporated atoms with remaining gas molecules produce ultra-fine particles. It's necessary to have a gas pressure of at least 3 mPa (10 torr) (Tissue et al., 2003).

Pyrolysis: Pyrolysis is the most widely utilised method in industry for producing nanoparticles on a big scale. It entails the use of flame to burn a precursor. The precursor is either a liquid or a vapour that is injected into the furnace under high pressure through a small hole and burns (Kammler et al., 2001). To recover the nanoparticles, the combustion or by-product gases are air categorised. To create high temperatures for easy evaporation, some of the furnaces use laser plasma instead of flame. Pyrolysis has the benefits of being a simple, efficient, cost-effective, and continuous process with a high yield.

Chemical vapor deposition (CVD): In this process, which includes deposition of solid on a heated surface by a chemical reaction from the vapour or gas phase, the source material is usually mixed with a volatile precursor that functions as a carrier (Bhaviripudi et al., 2007). In a CVD reactor, the vaporised precursors are added to a substance that is kept at a high temperature and allowed to adsorb. These precursors degrade on the substrate, forming a deposit. With the help of the gas flow, the by-product is removed. In the breakdown process, heat, plasma, and other mechanisms can all be utilised. The necessity for specialised equipment and the extreme toxicity of the gaseous by-products are both disadvantages of CVD (Adachi et al., 2003).

Co-precipitation method: The precipitate of substances is transported down and soluble at the conditions used in co-precipitation. Physical changes such as aggregation of small crystallites can be avoided because the modification can take place in the same liquid media. This synthesis necessitates the reaction of constituent materials at low temperatures in the presence of a suitable solvent. The key limiting factors of this process include pH, concentration, temperature, surfactants, and so on. Separation of synthesised nanocrystals is followed by washing and vacuum drying. The dried material was then exposed to UV light to see if the surfactant capping coating on the surface of the nano cluster might polymerize, resulting in true quantum confinement. (Konrad et al., 2001; Rostislav et al., 1994; Sharma et al., 2009)

Solvothermal and Hydrothermal Synthesis: The solvent is utilised under moderate to high pressure (1-10,000 atm) and temperature (100°C 1000°C) in the “Solvothermal synthesis” procedure, which improves the interaction with precursors during the synthesis process. “Hydrothermal synthesis” is a process that uses water as a solvent and is often carried out below the water's supercritical temperature (374°C). Crystal morphological alteration sphere (3D), rod (2D), or wire (1D) with various solvent saturations, chemical of interest concentration, and kinetic control.

Micro emulsion synthesis: In this method of nanoparticle creation, two immiscible liquids are disseminated, one of which is stabilised by an interfacial coating of surface-active molecules, while the other is immiscible and covers minute sized domains of one or both liquids. Two micro emulsions containing metal salt and a reducing agent are blended together in this procedure. When two micro emulsions are mixed, reactants are exchanged between micelles. As water drops colloids, Brownian motion is induced, resulting in repulsive osmotic and elastic forces as well as attractive van der Waals forces. Metallic nuclei are formed as a result of this process. (Bönnemann and Richards, 2001).

Sol-Gel Synthesis: In this method, an inorganic network of colloidal suspension (sol) is created, followed by the gelation of the sol, resulting in a continuous liquid phase (gel). Metal alkoxides; compounds in which one or more alkyl groups are linked to metal with an intermediary oxygen atom; and the other precursors such as metal organic compounds, salts of inorganic acids and organic acids, etc. are the most commonly utilised precursors. The precursor is dissolved in a solvent solution in this process. The use of an acid or base catalyst accelerates the process. As the Precursor undergoes hydrolysis and polycondensation processes, M-O-M bonds develop. As it hydrolyses, it acquires a hydroxyl group through a reaction with water. In the Polycondensation process, the hydrolysed species unite and form inorganic polymer-like chains by removing a water molecule. As a result, during continuous polycondensation, the sol transforms into gel, resulting in solid, sol, and solvent. The solvent residue and other chemical traces are removed from the gel before it is further treated. After that, the sol system produces an amorphous solid structure known as xerogel. The xerogel is subsequently sintered in a furnace, transforming it into a solid crystalline substance (Danks et al., 2016).

Biological Synthesis: Plant extracts, microorganisms, and biological components are used in this process of nanoparticle manufacturing. The manufacture of bio metal and bio metal oxide nanoparticles is largely attributed to plants with reducing characteristics phytochemicals with antioxidants or microorganism-based enzymes. Biosynthesis is a nontoxic and biodegradable method for making nanoparticles that is both green and environmentally beneficial. Biosynthesis replaces conventional chemicals with bacteria, plant extracts, fungi, and other precursors to generate nanoparticles for bio reduction and capping (Hassan et al., 2015).

Photocatalytic Removal of dyes

Thousands of dyes and pigments are manufactured in industries today (Wesenberg et al., 2003). The textile industry has reported a significant increase in the usage of synthetic complex organic dyes as a colouring material. Synthetic dyestuffs are utilised in a variety of sectors, including paper, textiles, printing, and dye houses. The loss of colour in the waste stream during the production or processing activities of textile dyes is estimated to be between 10 and 20%. (Daud et al., 2012; Thinakaran et al., 2008). Textile effluent is carcinogenic and genotoxic, and it has an adverse effect on the immunological and reproductive systems. According to reports, the majority of dyes and toxic metals employed in the colour industry are light stable and non-biodegradable (Baran et al., 2008). It is mandatory to treat such trash before dumping it into the environment in order to limit the danger of environmental pollution. For which adsorption technique was shown to be the most effective degrading technique (Kumar et al., 2014) Because of the simplicity and cost-effectiveness, By hydrogen bonding, van der Waals interactions, or hydrophobic forces, dye molecules are adsorbed on the surface of an adsorbent (Kumar et al., 2014). The primary factors controlling the performance of most adsorption procedures include concentration, pH of the solution, temperature, contact time, adsorbent dosage, adsorbent size, and particle interaction affinity. Nanomaterials, which have a high surface-to-volume ratio, have superior qualities and are thought to be the future building blocks of innovative technologies in a variety of fields. (Lattuada and Hatton 2011).

CATIONIC DYES

Methylene Blue: Various nanomaterials have been used to degrade the dye successfully, including ZnSe/graphene nanocomposites (Hsieh et al., 2015), Cu-supported clay nanocomposite (Mekewi et al., 2016), Tio2 (Pandey et al., 2015), Th (IV) nanocomposite (Gupta et al., 2013b), and Ta-d (Kong et al., 2010). The dye was completely removed using Cu-supported organo-treated clay (Mekewi et al., 2016), whereas ZnSe/graphene nanocomposites had a 99.6% degradation efficiency (Hsieh et al., 2015).

Methyl violet: Even though removing methyl violet from wastewater is a critical task, several nano adsorbents have been used, such as a nano graphite/Fe3O4 composite that worked well under basic conditions (pH greater than 10.0) due to increased negative charges that favour the contact between azo dye and negatively charged adsorbent (Li et al. 2014). Under UV exposure, doping ZnS quantum dots with Fe^{3+} ions increased the breakdown process (by more than 95 percent at pH 11.0). (Shamsipur and Rajabi 2014). ZnO nanoparticles produced the best results, with 100 percent breakdown in 60 to 80 minutes (Jeyasubramanian et al. 2015).

Crystal violet: Cadmium Sulfide, cobalt-doped titania, nickel dioxide, and zinc oxide nanorods have all been utilised as adsorbents for successfully removing Crystal violet dye (Dil et al., 2016). Surprisingly, nickel dioxide nanoparticles destroyed 97 percent of the dye within five minutes, resulting in a variety of tiny compounds (He et al., 2010). Because 99.8% of the dye was removed under optimal conditions, zinc oxide nanorods proved to be an excellent catalyst (Dil et al., 2016).

CeO2 nanoparticles were produced and used to photocatalyzed the breakdown of Crystal violet (97.5 percent; 1 hour) using Moringa oleifera peel as a stabilising and reducing agent (Surendra and Roopan 2016).

Basic Fuchsin: Pt-graphene and Pd-graphene nanocomposites' catalytic activity revealed that roughly 55 percent and 58 percent of the dye were destroyed, respectively (Kurt et al., 2016).

Brilliant blue-R: Brilliant blue-R adsorption kinetics were extraordinarily fast for cobalt ferrite nanoparticles. Within one minute, the dye was adsorbed in the range of 65–93%, and equilibrium was reached in 60–120 minutes (Khan et al., 2015). Decolorization of the dye was also achieved using green produced copper oxide nanoparticles and a ZnO/GO nanocomposite (Kashinath et al., 2016). The temperature employed in the method influenced the degradation of brilliant blue-R. In comparison to non-annealed ZnO/GO nanocomposites (90.64 percent degradation), annealed nanocomposites demonstrated improved outcomes (95.4 percent) (Kashinath et al., 2016).

Malachite Green: MnO2 nanosheets were used in aerobic circumstances to achieve maximum oxidative breakdown (99 percent) under ideal conditions (Saha and Pal 2014). Other nanomaterials were also investigated, such as iron-based nanoparticles (Huang et al., 2014) (75.5 percent degradation of dye. (Soni et al., 2016) observed Malachite Green decolouration by TiO anatase nanostructures

ANIONIC DYES

Methyl Orange: There have been several reports on the photocatalytic breakdown of MO dye utilising nanomaterials. For instance, (Lee et al., 2015) employed Al doped ZnO nanoparticles (3 percent Al) photocatalyst to achieve 95 percent degradation in 120 minutes. Silver nanoparticles can likewise reach maximum methyl orange degradation in 12 hours (Kumar et al. 2013). At optimal conditions of 22 minutes, pH 2, and 0.02 g catalyst dosage, lead oxide nanoparticles coated with activated carbon were found to have promise (Ghaedi et al. 2016). The combined action of UV light and ZnO nanoparticles significantly accelerated methyl orange decomposition (complete degradation in 40 minutes (Kumar et al. 2015). Under UV radiation, TiO_2 nanoparticles degraded 98 percent of the dye (Thapa et al., 2012). Using a 5 percent molar solution of Cr^{3+} doped TiO_2 nanoparticles, (Hamadanian et al., 2014) reported that photodegradation of methyl orange was considerably increased. Cr^{3+} on the surface of TiO_2 can capture photogenerated e-, minimising recombination and improving TiO_2's photocatalytic activity when exposed to visible light (Li et al. 2013).

Congo Red: Using diverse nanomaterials, such as magnetic $Sr_5(PO_4)_3(OH)/Fe_3O_4$ nanorods (Zhang et al. 2016), sulfanilic acid-modified P25 TiO2 nanoparticles (Guo et al. 2012), and bimetallic Fe–Zn nanoparticles, several experiments were carried out to successfully remove Congo red (Gautam et al. 2015). Metallic nanoparticles such as Ru operate as an electron mediator in the transport of electrons from the reducing agent to the azo bond, resulting in a two-fold increase in the rate of Congo red degradation (Gupta et al., 2013a). Undoped cobalt ferrite nanoparticles had a capacity of 131 mg g-1 for adsorption or elimination of Congo red. (Zhao et al. 2014) With Gd^{3+}-doped cobalt ferrites, this improved to 161 mg g-1 (CoFe2-xGdxO4). The leaf extract of Amaranthus gangeticus Linn (Chinese spinach) was utilised to make silver nanoparticles with high catalytic effectiveness (greater than 50% within 15 minutes) for decomposing Congo red dye. (Kolya et al. 2015)

Eosin Y: Photodegradation experiments with several nanomaterials for the effective removal of eosin Y have been published (Liu et al. 2014). Within 45 minutes and 160 minutes, two-dimensional CuO nanoleaves and silver–TiO_2 nanocomposites were able to completely destroy the dye (Liu et al. 2014). Hes-TiO_2 nanoparticles (Hesperidin modified TiO_2) also demonstrated great catalytic performance (96%) in an acidic pH (4.0) and a 180-minute irradiation duration. In aqueous solution, dye exists in its anionic form, and the adsorption process is aided by an acidic pH. Due to the highest surface contact between TiO_2 and dye, (Liu et al., 2014) discovered that TiO_2/N-graphene nanocomposite (5 wt%) was successful in degrading the dye. After 3 hours of visible light irradiation, a photodegradation ratio of 63.4 percent was achieved.

Alizarin red S: Under UV light irradiation, ZnO nanoparticles successfully destroyed alizarin red S (77 percent in 90 minutes). The photocatalytic activity of nanoparticles is enhanced by the formation of electron–hole pairs on their surfaces (Kansal et al., 2013). At pH 4.0–5.4, polypyrrole-coated Fe_3O_4 nanoparticles with a quantity of 0.1–0.12 g/100 mL provided maximum Alizarin red S degradation in 1 h. (Gholivand et al., 2015). As a photocatalyst, bismuth vanadate ($BiVO_4$) nanocrystals and gold nanoparticles put on activated carbon successfully degraded 99.6% (180 minutes) and 95% (5 minutes) of the dye, respectively (Abraham et al. 2016; Roosta et al., 2014).

Indigo Carmine: When compared to commercial Cadmium Sulfide, nanofibers of Cadmium Sulfide demonstrated greater photocatalytic activity when exposed to blue light (Hernandez-Gordillo et al. 2015). Other nanostructured materials, such as palladium-coated zinc sulfide/reduced graphene oxide (Pd– ZnS/rGO) nanomaterials (Agorku et al. 2015), platinum (Pt) and palladium (Pd) nanostructures embellished on graphene sheets (Kurt et al. 2016), and nanometric tin dioxide-based composites, have been successfully used as photocatalysts for Mineralization of the dye was seen using a 60 percent ratio of Sn/Al2O3 (40 min) and Pd–ZnS/rGO nanocomposites (210 min) (Coelho et al.

2010). (Agorku et al. 2015) Utilizing Pt- and Pd-graphene nanomaterials, roughly 75 and 70% of Indigo Carmine were destroyed after 5 minutes, respectively (Kurt et al. 2016)

Eriochrome Black T: Various researchers have investigated the decomposition of Eriochrome Black T utilising various nanomaterials. (Kazeminezhad and Sadollahkhani 2014) discovered that photocatalytic activity of dye with crystalline anatase TiO_2 was accelerated (88%) under basic conditions (pH 11.0), presumably because to larger hydroxyl radical concentrations. Under UV light irradiation, Eriochrome Black T could be efficiently photodegraded (82%) in 90 minutes using Fe^{3+} and Pt^{4+}-impregnated TiO_2 nanostructures of various forms (Kansal et al., 2013b). The dye's likely breakdown mechanism is indicated

In addition to organic dyes Photocatalytic oxidation, nano photocatalyst can degrade most organic and inorganic chemicals in air or water, as well as minimise hazardous inorganic pollutants in water. PAHs are products of natural and human factors, such as incomplete combustion of solid and liquid fuels, trash burning, coke oven, pyrolysis, forest and agricultural fires, or industrial activities (Kumar et al., 2014). According to (Soni et al., 2017), TiO_2 nanoparticles are a viable option for treating PAH-polluted wastewaters in nature Their abundance has been documented in surface waters, sediments, and airborne particulate matter (Casellas et al., 1995; Doong and Lin, 2004). PAHs are poisonous, mutagenic, teratogenic, and carcinogenic by nature because they are hydrophobic, resistant, and bio accumulative (Siebielska, 2014). They adsorb heavily on suspended particles and build up in soil and sediment, causing major soil pollution issues (Manzetti, 2013). Green produced hematite (-Fe_2O_3) and magnesium oxide (MgO) nanoparticles catalyse the degradation of wastewater from the textile and tannery industries (Fouda et al., 2021).

CONCLUSION:

Synthetic dyes are a major source of contamination in the soil and water. When toxic discharge from industry as waste water effluent is mixed with water bodies, it causes an increase in BOD and COD requirements, rendering the water unfit for drinking, as it is damaging to aquatic life, plants, and humans. Physical, chemical, and biological methods have all been explored to remove dyes from waterbodies, but each method has its own set of restrictions. Thus use of nanoparticles for dye degradation has been addressed in this review as It contributes to a cleaner environment by delivering cleaner air and water, as well as clean renewable energy for a more sustainable future. Nanotechnology has received widespread attention, with leading institutions, corporations, and organisations increasing their investment in research and development. Nanotechnology has established itself as a cutting-edge branch of science, with substantial research being conducted to put the concept into practise. It is being tested for a variety of novel applications in order to improve the efficiency and performance of the object or process and, as a result, cut the cost so that it is affordable to everybody. Nanotechnology has a bright future because of its efficiency and environmental friendliness. Nanoparticles are replacing conventional chemicals because they are less expensive, more efficient, and require less treatment volume. Nanofiltration is a relatively new membrane filtration technique for water purification that has found widespread use in the textile industries.

REFERENCES:

Shiklomanov, I. A. (1993). World freshwater resources. Water in crisis: a guide to the world's fresh water resources. Clim. Change, 45, 379-382.

Bell, J., & Buckley, C. A. (2003). Treatment of a textile dye in the anaerobic baffled reactor. Water Sa, 29(2), 129-134.

Patil, S. S., & Shinde, V. M. (1988). Biodegradation studies of aniline and nitrobenzene in aniline plant wastewater by gas chromatography. Environmental science & technology, 22(10), 1160-1165.

Vörösmarty, C. J., Green, P., Salisbury, J., & Lammers, R. B. (2000). Global water resources: vulnerability from climate change and population growth. science, 289(5477), 284-288.

Bowman, J. C., Zhou, J. L., & Readman, J. W. (2002). Sediment–water interactions of natural oestrogens under estuarine conditions. Marine Chemistry, 77(4), 263-276.Brus, L. E. (1984). Electron–electron and electron-hole interactions in small semiconductor crystallites: The size dependence of the lowest excited electronic state. The Journal of chemical physics, 80(9), 4403-4409..

Patil, S. S., Adetutu, E. M., Aburto-Medina, A., Menz, I. R., & Ball, A. S. (2014). Biostimulation of indigenous communities for the successful dechlorination of tetrachloroethene (perchloroethylene)-contaminated groundwater. Biotechnology letters, 36(1), 75-83.

Rajan, C. S. (2011). Nanotechnology in groundwater remediation. International Journal of Environmental Science and Development, 2(3), 182.

Johnston, R., Heijnen, H. and Wurzel, P., 2001. Safe water technology. Technologies for Arsenic Removal from Drinking Water, Matiar Manush, Dhaka, Bangladesh, pp.1-98.

Robins, R. G., Nishimura, T., & Singh, P. (2001, May). Removal of arsenic from drinking water by precipitation, adsorption or cementation. In International Workshop on Technologies for Arsenic Removal from Drinking Water, Dhaka.

Twidwell, L. G., McCloskey, J., Miranda, P., & Gale, M. (1999, September). Technologies and potential technologies for removing selenium from process and mine wastewater. In Proceedings of the TMS Fall Extraction and Processing Conference (Vol. 2, pp. 1645-1656).

Barakat, M. A. (2011). New trends in removing heavy metals from industrial wastewater. Arabian journal of chemistry, 4(4), 361-377.

Basso, A. D., Solit, D. B., Chiosis, G., Giri, B., Tsichlis, P., & Rosen, N. (2002). Akt forms an intracellular complex with heat shock protein 90 (Hsp90) and Cdc37 and is destabilized by inhibitors of Hsp90 function. Journal of Biological Chemistry, 277(42), 39858-39866.

Crane, R. A., & Scott, T. B. (2012). Nanoscale zero-valent iron: future prospects for an emerging water treatment technology. Journal of hazardous materials, 211, 112-125.

Gribbin, J., & Gribbin, M. (2018). Richard Feynman: A life in science. Icon Books.

Taniguchi, N. (1974). On the basic concept of nanotechnology. Proceeding of the ICPE.

Iskandar, F. (2009). Nanoparticle processing for optical applications–A review. Advanced Powder Technology, 20(4), 283-292.

Tao, F. (2014). Metal Nanoparticles for Catalysis: Advances and Applications, RSc Catalysis Series No. 17. ISSN-1757-6725, Royal Society of Chemistry.

Arabatzis, I. M., Stergiopoulos, T., Bernard, M. C., Labou, D., Neophytides, S. G., & Falaras, P. (2003). Silver-modified titanium dioxide thin films for efficient photodegradation of methyl orange. Applied Catalysis B: Environmental, 42(2), 187-201.

Nasrollahzadeh, M., Sajadi, S. M., Sajjadi, M., & Issaabadi, Z. (2019). An introduction to nanotechnology. In Interface science and technology (Vol. 28, pp. 1-27). Elsevier

Yang, Y., Kim, Y., Gwak, J., So, S., Mun, J., Kim, M., ... & Rho, J. (2021). Realization of Artificial Chirality in Micro-/Nano-Scale Three-Dimensional Plasmonic Structures. Chirality, Magnetism and Magnetoelectricity: Separate Phenomena and Joint Effects in Metamaterial Structures, 138, 241-263.

Thiruvengadathan, R., Korampally, V., Ghosh, A., Chanda, N., Gangopadhyay, K., & Gangopadhyay, S. (2013). Nanomaterial processing using self-assembly-bottom-up chemical and biological approaches. Reports on Progress in Physics, 76(6), 066501.

Rawat, R. S. (2015, March). Dense plasma focus-from alternative fusion source to versatile high energy density plasma source for plasma nanotechnology. In Journal of Physics: Conference Series (Vol. 591, No. 1, p. 012021). IOP Publishing.

Yadav, T. P., Yadav, R. M., & Singh, D. P. (2012). Mechanical milling: a top down approach for the synthesis of nanomaterials and nanocomposites. Nanoscience and Nanotechnology, 2(3), 22-48.

Konrad, A., Herr, U., Tidecks, R., Kummer, F., & Samwer, K. (2001). Luminescence of bulk and nanocrystalline cubic yttria. Journal of applied Physics, 90(7), 3516-3523.

Rostislav, R. A. (1994). The synthesis and properties of nanocrystalline refractory compounds. Russian Chemical Reviews, 63(5), 411.

Sharma, A.B., Sharma, M. and Pandey,R.K., (2009). Synthesis, Properties and Potential Applications of Semiconductor Quantum Particles. Asian Journal of Chemistry, 21(10), 033-038

Kim, M., Osone, S., Kim, T., Higashi, H., & Seto, T. (2017). Synthesis of nanoparticles by laser ablation: A review. KONA Powder and Particle Journal, 2017009.

Shah, P., & Gavrin, A. (2006). Synthesis of nanoparticles using high-pressure sputtering for magnetic domain imaging. Journal of magnetism and magnetic materials, 301(1), 118-123.

Lugscheider, E., Bärwulf, S., Barimani, C., Riester, M., & Hilgers, H. (1998). Magnetron-sputtered hard material coatings on thermoplastic polymers for clean room applications. Surface and Coatings Technology, 108, 398-402.

Powell, C. F., Oxley, J. H., Blocher Jr, J. M., & Klerer, J. (1966). Vapor deposition. Journal of The Electrochemical Society, 113(10), 266C.

Ferrari, P., Rojas, S., Diaz-Droguett, D. E., & Cabrera, A. L. (2014). Evaporation of Low-Vapor Pressure Metals Using a Conventional Mini Electron Beam Evaporator. Instrumentation Science & Technology, 42(2), 142-152.

Tissue, B. M., & Yuan, H. B. (2003). Structure, particle size, and annealing of gas phase-condensed Eu3+: Y2O3 nanophosphors. Journal of Solid State Chemistry, 171(1-2), 12-18.

Bhaviripudi, S., Mile, E., Steiner, S. A., Zare, A. T., Dresselhaus, M. S., Belcher, A. M., & Kong, J. (2007). CVD synthesis of single-walled carbon nanotubes from gold nanoparticle catalysts. Journal of the American Chemical Society, 129(6), 1516-1517.

Adachi, M., Tsukui, S., & Okuyama, K. (2003). Nanoparticle synthesis by ionizing source gas in chemical vapor deposition. Japanese journal of applied physics, 42(1A), L77.

Richards, R. M. (2001). Nanoscopic metal particles− synthetic methods and potential applications. European Journal of Inorganic Chemistry, 2001(10), 2455-2480.

Danks, A. E., Hall, S. R., & Schnepp, Z. J. M. H. (2016). The evolution of 'sol–gel'chemistry as a technique for materials synthesis. Materials Horizons, 3(2), 91-112.

Hassan, T., Salam, A., Khan, A., Khan, S. U., Khanzada, H., Wasim, M., ... & Kim, I. S. (2021). Functional nanocomposites and their potential applications: A review. Journal of Polymer Research, 28(2), 1-22.

Chen, Y. F., Lee, C. Y., Yeng, M. Y., & Chiu, H. T. (2003). The effect of calcination temperature on the crystallinity of TiO2 nanopowders. Journal of crystal growth, 247(3-4), 363-370.

Praserthdam, P., Phungphadung, J., & Tanakulrungsank, W. (2003). Effect of crystallite size and calcination temperature on the thermal stability of single nanocrystalline chromium oxide: expressed by novel correlation. Materials Research Innovations, 7(2), 118-123.

Soni, H., Kumar, N., Patel, K., & Kumar, R. (2014). UV light induced photocatalytic degradation of malachite GREEN on TiO2 nanoparticles. Int. J. Recent Res. Rev, 7, 10-15.

Soni, H., Kumar, N., Patel, K., & Kumar, R. N. (2017). Investigation on the heterogeneous photocatalytic remediation of pyrene and phenanthrene in solutions using nanometer TiO2 under UV irradiation. Polycyclic Aromatic Compounds.

Yano, F., Hiraoka, A., Itoga, T., Kojima, H., Kanehori, K., & Mitsui, Y. (1996). Influence of ion-implantation on native oxidation of Si in a clean-room atmosphere. Applied surface science, 100, 138-142.

Wesenberg, D., Kyriakides, I., & Agathos, S. N. (2003). White-rot fungi and their enzymes for the treatment of industrial dye effluents. Biotechnology advances, 22(1-2), 161-187.

Daud, N. K., Akpan, U. G., & Hameed, B. H. (2012). Decolorization of Sunzol Black DN conc. in aqueous solution by Fenton oxidation process: effect of system parameters and kinetic study. Desalination and Water Treatment, 37(1-3), 1-7.

Thinakaran, N., Panneerselvam, P., Baskaralingam, P., Elango, D., & Sivanesan, S. (2008). Equilibrium and kinetic studies on the removal of Acid Red 114 from aqueous solutions using activated carbons prepared from seed shells. Journal of hazardous materials, 158(1), 142-150.

Baran, W., Adamek, E., & Makowski, A. (2008). The influence of selected parameters on the photocatalytic degradation of azo-dyes in the presence of TiO2 aqueous suspension. Chemical Engineering Journal, 145(2), 242-248.

Kumar, R., Rashid, J., & Barakat, M. A. (2014). Synthesis and characterization of a starch–AlOOH–FeS 2 nanocomposite for the adsorption of congo red dye from aqueous solution. RSC advances, 4(72), 38334-38340.

Lattuada, M., & Hatton, T. A. (2011). Synthesis, properties and applications of Janus nanoparticles. Nano Today, 6(3), 286-308.

Hsieh, S. H., Chen, W. J., & Yeh, T. H. (2015). Degradation of methylene blue using ZnSe–graphene nanocomposites under visible-light irradiation. Ceramics International, 41(10), 13759-13766.

Mekewi, M. A., Darwish, A. S., Amin, M. S., Eshaq, G., & Bourazan, H. A. (2016). Copper nanoparticles supported onto montmorillonite clays as efficient catalyst for methylene blue dye degradation. Egyptian Journal of Petroleum, 25(2), 269-279.

Pandey, A., Kalal, S., Ameta, C., Ameta, R., Kumar, S., & Punjabi, P. B. (2015). Synthesis, characterization and application of naïve and nano-sized titanium dioxide as a photocatalyst for degradation of methylene blue. Journal of Saudi Chemical Society, 19(5), 528-536.

Gupta, V. K., Agarwal, S., Pathania, D., Kothiyal, N. C., & Sharma, G. (2013). Use of pectin–thorium (IV) tungstomolybdate nanocomposite for photocatalytic degradation of methylene blue. Carbohydrate polymers, 96(1), 277-283.

Kong, J. Z., Li, A. D., Li, X. Y., Zhai, H. F., Zhang, W. Q., Gong, Y. P., ... & Wu, D. (2010). Photo-degradation of methylene blue using Ta-doped ZnO nanoparticle. Journal of solid state chemistry, 183(6), 1359-1364.

Mekewi, M. A., Darwish, A. S., Amin, M. S., Eshaq, G., & Bourazan, H. A. (2016). Copper nanoparticles supported onto montmorillonite clays as efficient catalyst for methylene blue dye degradation. Egyptian Journal of Petroleum, 25(2), 269-279.

Li, C., Dong, Y., Yang, J., Li, Y., & Huang, C. (2014). Modified nano-graphite/Fe3O4 composite as efficient adsorbent for the removal of methyl violet from aqueous solution. Journal of Molecular Liquids, 196, 348-356.

Shamsipur, M., & Rajabi, H. R. (2014). Study of photocatalytic activity of ZnS quantum dots as efficient nanoparticles for removal of methyl violet: effect of ferric ion doping. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 122, 260-267.

Jeyasubramanian, K., Hikku, G. S., & Sharma, R. K. (2015). Photo-catalytic degradation of methyl violet dye using zinc oxide nano particles prepared by a novel precipitation method and its anti-bacterial activities. Journal of water process engineering, 8, 35-44.

Dil, E. A., Ghaedi, M., Ghaedi, A., Asfaram, A., Jamshidi, M., & Purkait, M. K. (2016). Application of artificial neural network and response surface methodology for the removal of crystal violet by zinc oxide nanorods loaded on activate carbon: kinetics and equilibrium study. Journal of the Taiwan Institute of Chemical Engineers, 59, 210-220.

He, H., Yang, S., Yu, K., Ju, Y., Sun, C., & Wang, L. (2010). Microwave induced catalytic degradation of crystal violet in nano-nickel dioxide suspensions. Journal of Hazardous Materials, 173(1-3), 393-400.

Surendra, T. V., & Roopan, S. M. (2016). Photocatalytic and antibacterial properties of phytosynthesized CeO2 NPs using Moringa oleifera peel extract. Journal of Photochemistry and Photobiology B: Biology, 161, 122-128.

Kurt, B. Z., Durmus, Z., & Durmus, A. (2016). Preparation and characterization of platinum (Pt) and palladium (Pd) nanoparticle decorated graphene sheets and their utilization for the elimination of basic fuchsin and indigo carmine dyes. Solid State Sciences, 51, 51-58.

Khan, M. A., Alam, M. M., Naushad, M., Alothman, Z. A., Kumar, M., & Ahamad, T. (2015). Sol–gel assisted synthesis of porous nano-crystalline CoFe2O4 composite and its application in the removal of brilliant blue-R from aqueous phase: An ecofriendly and economical approach. Chemical Engineering Journal, 279, 416-424.

Kashinath, L., Namratha, K., & Byrappa, K. (2016). Microwave assisted synthesis and characterization of nanostructure zinc oxide-graphene oxide and photo degradation of brilliant blue. Materials Today: Proceedings, 3(1), 74-83.

Saha, S., & Pal, A. (2014). Microporous assembly of MnO2 nanosheets for malachite green degradation. Separation and Purification Technology, 134, 26-36.

Huang, L., Weng, X., Chen, Z., Megharaj, M., & Naidu, R. (2014). Synthesis of iron-based nanoparticles using oolong tea extract for the degradation of malachite green. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 117, 801-804.

Kumar, P., Govindaraju, M., Senthamilselvi, S., & Premkumar, K. (2013). Photocatalytic degradation of methyl orange dye using silver (Ag) nanoparticles synthesized from Ulva lactuca. Colloids and surfaces B: biointerfaces, 103, 658-661.

Ghaedi, M., Ghaedi, A. M., Mirtamizdoust, B., Agarwal, S., & Gupta, V. K. (2016). Simple and facile sonochemical synthesis of lead oxide nanoparticles loaded activated carbon and its application for methyl orange removal from aqueous phase. Journal of Molecular Liquids, 213, 48-57.

Thapa, R., Maiti, S., Rana, T. H., Maiti, U. N., & Chattopadhyay, K. K. (2012). Anatase TiO2 nanoparticles synthesis via simple hydrothermal route: Degradation of Orange II, Methyl Orange and Rhodamine B. Journal of Molecular Catalysis A: Chemical, 363, 223-229.

Hamadanian, M., Sarabi, A. S., Mehra, A. M., & Jabbari, V. (2014). Photocatalyst Cr-doped titanium oxide nanoparticles: Fabrication, characterization, and investigation of the effect of doping on methyl orange dye degradation. Materials science in semiconductor processing, 21, 161-166.

Li, C., Dong, Y., Yang, J., Li, Y., & Huang, C. (2014). Modified nano-graphite/Fe3O4 composite as efficient adsorbent for the removal of methyl violet from aqueous solution. Journal of Molecular Liquids, 196, 348-356.

Zhang, F., Yin, X., & Zhang, W. (2016). Development of magnetic Sr5 (PO4) 3 (OH)/Fe3O4 nanorod for adsorption of Congo red from solution. Journal of Alloys and Compounds, 657, 809-817.

Guo, H. X., Lin, K. L., Zheng, Z. S., Xiao, F. B., & Li, S. X. (2012). Sulfanilic acid-modified P25 TiO2 nanoparticles with improved photocatalytic degradation on Congo red under visible light. Dyes and Pigments, 92(3), 1278-1284.

Gautam, R. K., Rawat, V., Banerjee, S., Sanroman, M. A., Soni, S., Singh, S. K., & Chattopadhyaya, M. C. (2015). Synthesis of bimetallic Fe–Zn nanoparticles and its application towards adsorptive removal of carcinogenic dye malachite green and Congo red in water. Journal of Molecular Liquids, 212, 227-236.

Gupta, V. K., Agarwal, S., Pathania, D., Kothiyal, N. C., & Sharma, G. (2013). Use of pectin–thorium (IV) tungstomolybdate nanocomposite for photocatalytic degradation of methylene blue. Carbohydrate polymers, 96(1), 277-283.

Zhao, X., Wang, W., Zhang, Y., Wu, S., Li, F., & Liu, J. P. (2014). Synthesis and characterization of gadolinium doped cobalt ferrite nanoparticles with enhanced adsorption capability for Congo Red. Chemical Engineering Journal, 250, 164-174.

Kolya, H., Maiti, P., Pandey, A., & Tripathy, T. (2015). Green synthesis of silver nanoparticles with antimicrobial and azo dye (Congo red) degradation properties using Amaranthus gangeticus Linn leaf extract. Journal of Analytical Science and Technology, 6(1), 1-7.

Liu, Y., Pei, F., Lu, R., Xu, S., & Cao, S. (2014). TiO2/N-graphene nanocomposite via a facile in-situ hydrothermal sol–gel strategy for visible light photodegradation of eosin Y. Materials Research Bulletin, 60, 188-194.

Kansal, S. K., Lamba, R., Mehta, S. K., & Umar, A. (2013). Photocatalytic degradation of Alizarin Red S using simply synthesized ZnO nanoparticles. Materials letters, 106, 385-389.

Gholivand, M. B., Yamini, Y., Dayeni, M., Seidi, S., & Tahmasebi, E. (2015). Adsorptive removal of alizarin red-S and alizarin yellow GG from aqueous solutions using polypyrrole-coated magnetic nanoparticles. Journal of Environmental Chemical Engineering, 3(1), 529-540.

Abraham, S. D., David, S. T., Bennie, R. B., Joel, C., & Kumar, D. S. (2016). Eco-friendly and green synthesis of BiVO4 nanoparticle using microwave irradiation as photocatalayst for the degradation of Alizarin Red S. Journal of Molecular Structure, 1113, 174-181.

Roosta, M., Ghaedi, M., & Mohammadi, M. (2014). Removal of Alizarin Red S by gold nanoparticles loaded on activated carbon combined with ultrasound device: Optimization by experimental design methodology. Powder technology, 267, 134-144

Herna´ndez-Gordillo A, Rodrı´guez-Gonza´lez V, Oros-Ruiz S, Go´mez R (2015). Photodegradation of Indigo Carmine dye by CdS nanostructures under blue-light irradiation emitted by LEDs. Catal Today 266, 27-35.

Agorku, E. S., Mamo, M. A., Mamba, B. B., Pandey, A. C., & Mishra, A. K. (2015). Palladium-decorated zinc sulfide/reduced graphene oxide nanocomposites for enhanced visible light-driven photodegradation of indigo carmine. Materials Science in Semiconductor Processing, 33, 119-126.

Coelho, M. G., De Lima, G. M., Augusti, R., Maria, D. A., & Ardisson, J. D. (2010). New materials for photocatalytic degradation of Indigo Carmine—Synthesis, characterization and catalytic experiments of nanometric tin dioxide-based composites. Applied Catalysis B: Environmental, 96(1-2), 67-71.

Kazeminezhad, I., & Sadollahkhani, A. (2014). Photocatalytic degradation of Eriochrome black-T dye using ZnO nanoparticles. Materials Letters, 120, 267-270.

Kansal, S. K., Lamba, R., Mehta, S. K., & Umar, A. (2013). Photocatalytic degradation of Alizarin Red S using simply synthesized ZnO nanoparticles. Materials letters, 106, 385-389.

Kumar, R., Rashid, J., & Barakat, M. A. (2014). Synthesis and characterization of a starch–AlOOH–FeS 2 nanocomposite for the adsorption of congo red dye from aqueous solution. RSC advances, 4(72), 38334-38340.

Soni, H., Kumar, J. N., Patel, K., & Kumar, R. N. (2017) Comparative investigations on synthesis characterization of metallic nanoparticles and their applications in dye decolouration biocidal activity and abatement of pollutants from industrial effluents agriculture Thesis, Sardar Patel university

Casellas, M., Fernandez, P., Bayona, J. M., & Solanast, A. M. (1995). Bioassay-directed chemical analysis of genotoxic components in urban airborne particulate matter from Barcelona (Spain). Chemosphere, 30(4), 725-740.

Doong, R. A., & Lin, Y. T. (2004). Characterization and distribution of polycyclic aromatic hydrocarbon contaminations in surface sediment and water from Gao-ping River, Taiwan. Water research, 38(7), 1733-1744.

Siebielska, I. (2014). Comparison of changes in selected polycyclic aromatic hydrocarbons concentrations during the composting and anaerobic digestion processes of municipal waste and sewage sludge mixtures. Water Science and Technology, 70(10), 1617-1624.

Manzetti, S. (2013). Polycyclic aromatic hydrocarbons in the environment: environmental fate and transformation. Polycyclic Aromatic Compounds, 33(4), 311-330.Marsalek, R. (2014). Particle size and zeta potential of ZnO. APCBEE procedia, 9, 13-17.

Fouda, A., Hassan, S. E. D., Abdel-Rahman, M. A., Farag, M. M., Shehal-Deen, A., Mohamed, A. A., ... & Azab, M. S. (2021). Catalytic degradation of wastewater from the textile and tannery industries by green synthesized hematite (α-Fe2O3) and magnesium oxide (MgO) nanoparticles. Current Research in Biotechnology, 3, 29-41.

. **Table 1 Advantages and disadvantages of available wastewater treatment technologies**

Technology	Advantage	Disadvantage	Reference
Filtration	Low solid waste generation, Low chemical consumption	High initial capital cost High maintenance and causes Membrane fouling	(Madaeni and Mansourpanah, 2003)
Chemical Precipitation	Process simplicity, Inexpensive capital cost	Production of large amounts of sludge, Cost for Sludge disposal,	(Aderhold *et al*., 1996)
Ion exchange	Limited pH tolerance, High initial capital cost	High maintenance cost	(Aderhold *et al*., 1996)
Coagulation	Bacterial inactivation Capability, Good sludge settling	Chemical consumption, Increased sludge volume Generation	(Aderhold *et al*., 1996)
Electrochemical treatment	No use of chemicals, Can be engineered to tolerate suspended solids	High initial capital cost	(Kongsricharoern and Polpraser, 1995)

.

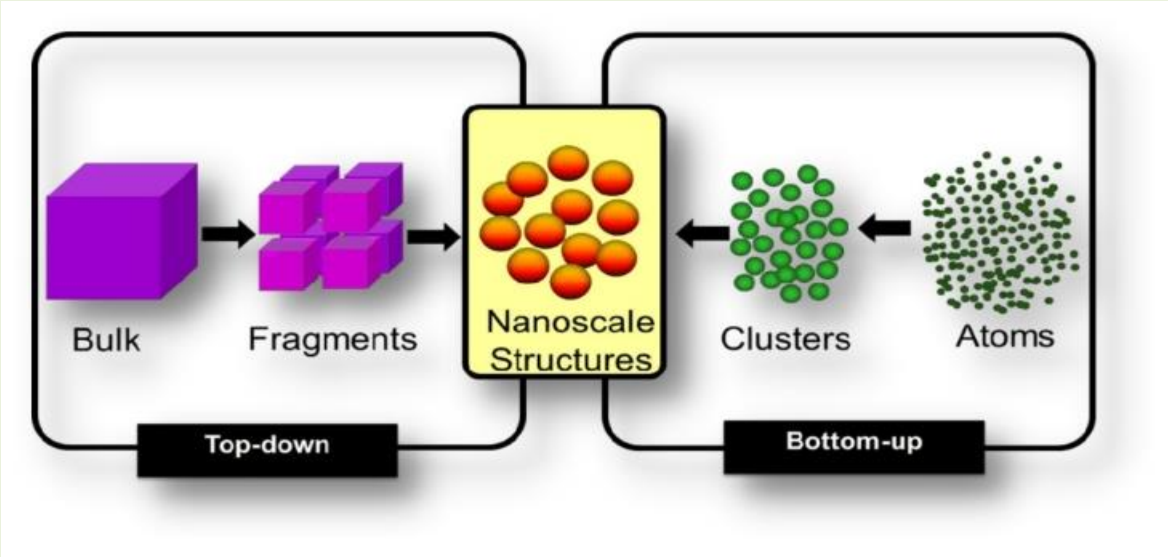

Figure 1.Picture courtesy: Rawat et al., 2015