Green Initiatives: Green Methods of Synthesizing Nanoparticles and their Role in Environment Sustainability

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***Abstract*—**Nanoscaled particles or nanoparticles have revolutionized surface adsorption in a great way. Nanoparticles prepared by greener methods have been recognized as the safest way of protecting the environment. Nanotechnology itself has invited humongous attention towards its role in maintaining environmental sustainability. Trapping the most significant characteristic of nanoparticles, which is their large surface area and high adsorption efficacies, the role of nanoparticles in adsorbing the contaminants of waste water has been largely explored and employed. Therefore designing a greener route in synthesizing the nanoparticles and then using them for the removal of heavy metals, organic dyes and pesticides generally present in industrial and agricultural waste water, comprises of an eco friendly approach for cleaning the environment and maintaining environmental sustainability.

***Keywords*—** Environmental remediation, Green Chemistry, Nanoparticles, Plant extracts.

I. INTRODUCTION

Nano word is originated from Latin word, which means dwarf. Ideal size range offered by nanotechnology refers to one thousand millionth of a particular unit thus nanometer is one thousand millionth of a meter (i.e. 1 nm = 10^{-9} m). The branch nanotechnology is the science that particularly deals with the processes that occur at nano molecular level. The unique and tunable properties of nanoparticles have created an enormous interest in its synthesis and utility in a wide range of applications including electronics [1], photonics, sensing, catalysis [2] and biotechnology [3]. Recent exploration of nanotechnology in biomedical and pharmaceutical science have resulted in successful improvement of conventional means of drug delivery system [4]. Nanoparticles have an array of advantage over bulk materials due to their surface plasmon resonance (SPR), enhanced Rayleigh scattering and surface enhanced Raman scattering (SERS) in metal nanoparticles, quantum size effect in semiconductors and supermagnetism in magnetic nanomaterials.

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The ratio between the surface areas to the volume is known as 'aspect ratio'. The smaller the particle size the greater will be the aspect ratio (i.e., greater surface area compared to their volume). Nanoparticles possess high 'aspect ratio' which enhances its reactivity, compared to non-nano forms of the same materials. This unique properties also allow them to remove pollutants from the environment [5]. The high surface area to mass ratios of nanoparticles can greatly enhance the adsorption capacities of sorbent materials. Silver, iron, gold, titanium oxides and iron oxides are some of the commonly used nanoscale metals and metal oxides that can be used in environmental remediation [6].

A large number of physical, chemical and biological methods are available to synthesize different types of nanoparticles [7]. Recently, a great amount of interest has been mounting in green synthesis of metal and metal oxide nanoparticles as it offers a holistic strategy in addressing environmental concerns. The techniques for obtaining nanomaterials using naturally occurring reagents such as plant extracts, vitamins, polymers, or microorganisms as reducing and stabilizing agents are garnering attention in nanotechnology. Among these, the synthesis of nanoparticles (NPs) using various parts of the plants is quite feasible and economical, leading to truly green chemistry as there is no necessity of high pressure, energy, temperature and toxic chemicals. According to the researchers, the polyphenols present in the plant extract are responsible for the reduction of metal ions, whereas the other heterocyclic components stabilize the formed nanoparticles. Furthermore, extra cellular synthesis of nanoparticles by using plant extracts whose role as a template, reducing agent and capping agent emphasizes atom economy and leads the green chemistry pathway. This review focuses on the phytosynthesis of metal nanoparticles using plant extracts and their role in environmental sustainability.

The general protocol for the nanoparticle syntheses involves, the collection of the part of plant of interest and then washing it thoroughly with water to remove associated debris. It is then dried and then further powdered using domestic blender. For the plant broth preparation, around 10 g of the dried powder is boiled with 100 mL of deionized distilled water. The resulting infusion is then filtered thoroughly until no insoluble material appears in the broth. To the metal salt

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solution, plant extract is added generating metal nanoparticles which can be monitored by measuring the UV–visible spectra of the solution at regular intervals.

II. SILVER NANOPARTICLES

Silver nanoparticles have proved to be effective antimicrobial agents and can treat wastewater containing bacteria, viruses and fungi. The reduction of silver ions to spherical shaped silver nanoparticles was performed using *Alternanthera dentate* aqueous extract within 10 min. These silver nanoparticles exhibited antibacterial activity against *Pseudomonas aeruginosa, Escherichia coli, Klebsiella pneumonia* and *Enterococcus faecal* [8]. Similarly, *Boerhaavia diffusa* plant extract synthesized silver nanoparticles were tested for antibacterial activity against *Pseudomonas fluorescens, Aeromonas hydrophila* and *Flavobacterium branchiophilum* [9]. *Acorus calamus* was also used for the synthesis of silver nanoparticles to evaluate its antioxidant, antibacterial as well as anticancer effects [10]. Silver nanoparticles using *Tribulus terrestris L.* were evaluated against multi-drug resistant bacteria such as *Streptococcus pyogens, Pseudomonas aeruginosa, Bacillus subtilis, Escherichia coli* and *Staphylococcus aureus* [11]. Silver nanoparticles by *Cocous nucifera* in ethyl acetate and methanol showed significant antimicrobial activity against human bacterial pathogens such as *Salmonella paratyphi, Klebsiella pneumoniae, Bacillus subtilis* and *Pseudomonas aeruginosa* [12]. Nanosilver has been proved as a fast-acting fungicide against a broad spectrum of common fungi including genera such as *Aspergillus, Candida* and *Saccharomyces* [13]. The aqueous *P. longum* extract was used for green synthesis of silver nanoparticles and it showed powerful antioxidant properties [14]. Stable and spherical shaped silver nanoparticle has been synthesized using a variety of plant extracts such as callus extract of the salt marsh plant, *Sesuvium portulacastrum* L. [15], *Ziziphoratenuior* leaves [16], *Ficuscarica* leaf extract [17], and *Acalypha indica* [18]. By using tea extract, and changing reaction conditions such as temperature and the dosage of the tea, rate of formation of silver nanoparticles changes [19]. Formation of stable silver nanoparticles using orange peel (*Citrussinensis*) has been reported to prepare polymer bio-mimetic template ‘‘green’’ silver nanoparticles [20]. Silver nanoparticles were also synthesized on reduction of silver nitrate solution by aqueous extract of *Azadirachta indica* leaves [21].

Silver has been known to have antibacterial properties because of which it has been widely employed in drinking-water treatment systems, ceramic filters and can be used as a water disinfectant. Numerous studies have been conducted on the disinfection efficacy of silver nanoparticles against a range of microorganisms found in water. A number of different types of silver-coated or silver-impregnated ceramic filters have been used as point-of-use (POU) devices for household treatment of drinking-water [22].

III. GOLD NANOPARTICLES

Biosynthesis of gold nanoparticles using plant extracts is getting more popular due to the strong antibacterial action of nanoparticles and easy reduction of their salts. The properties of gold nanoparticles are very different from that of bulk. Gold nanoparticles are wine red solution while the bulk gold is yellow solid. The gold nanoparticles can be manufactured into a variety of shapes including nanorods, nanospheres, nanocages, nanostars, nanobelts and nanoprisms [23]. The size and shape of gold nanoparticles strongly influence their chemical and other properties [24]. Due to their extremely small size, high surface area, stability, non-cytotoxicity and tunable properties, they are used in targeted drug delivery, imaging, and diagnosis [25]. Gold nanoparticles may potentially be another useful material for removing contaminants, such as toxic chlorinated organic compounds, pesticides and inorganic mercury, from water and also be used to remediate air.

The triangular shaped Au core-Ag shell nanoparticles have been reported and were obtained by using electrostatic complexation of Ag^+ ions with negatively charged lemongrass reduced gold nanoparticles followed by reduction of the surface-bound Ag^+ ions by ascorbic acid [26]. Agricultural waste has also been utilized for the synthesis of nanoparticles, thus helping in the waste management, recycling, reuse and recovery. Gold nanoparticles of 20 to 25 nm particle size were synthesized from grape waste [27]. Also, waste banana peel extract was used to get gold nanoparticles with average particle size of 300 nm [28]. The fruit peel extract of *Punica granutum* was used to procure gold nanoparticles for cancer targeted drug delivery [29].

Gold nanoparticles were rapidly synthesized using aqueous leaves extract of *Acalypha indica* [30]. The leaf extract of *Cymbopogon citratus* was used as a novel source of bio-reductant and were tested against larvae and pupae of the malaria vector Anopheles stephensi and the dengue vector Aedes aegypti [31]. *Cucurbita pepo* and *Malva crispa* acted as a reducing and capping agent for the synthesis of potent antibacterial gold nanoparticles [32]. The aqueous seed extract of *Abelmoschus esculentus* for gold nanoparticles and its antifungal activities against *Puccinia graminis tritci, Aspergillus flavus, Aspergillus niger* and *Candida albicans* has been studied [33].

Biosynthesis of triangular and spherical shape gold nanoparticles using leaf extract of *Zingiber officinale* [34], *Nepenthes Khasiana* [35] and Syzygium cumini fruit extract was also reported [36]. The reduction of auric chloride takes using *Cassia auriculata* aqueous leaf extract took place within 10 min at room temperature [37]. Hibiscus leaf extract and coriander leaf extract [38] was used to synthesise gold nanoparticles of different size and shape [39]. Alfalfa plants were used for synthesis of gold particles with an icosahedron structure [40]. The treatment of tamarind leaf extract with aqueous chloroauric acid solution led to the rapid reduction of chloroaurate ions and formation of gold nanoparticles [41].

Nanoscale gold nanoparticle can kill bacteria and disinfect water. In addition they also help in breaking down halogenated compounds, and removing dyes and metal toxins from drinking water and wastewater. Thus, acting against a broad range of pollutants.

IV. TITANIUM DIOXIDE NANOPARTICLES

Titanium dioxide is the most frequently used photocatalyst for water and air purification. It is relatively cheap, non-toxic, insoluble in water and abundant. Photocatalytic degradation of pollutants by titanium dioxide nanoparticles is mainly triggered by ·OH radicals, along with the direct oxidation of adsorbed pollutants. The kinetics of photocatalytic degradation by titanium dioxide nanoparticles depends on catalyst loading, the extent of adsorption, and light intensity.[42] Presence of capping and stabilizing agent like phytochemicals in plants also prevent agglomerization of the nanoparticles.

TiO_2 nanoparticles by the reaction between titanium tetraisoproxide and ethanolic leaf extract of *nyctanthes arbor-tristis* have been obtained [43]. Reaction between latex of *Jatropha curcas* L and $TiO(OH)_2$ yielded 100-200 nm TiO2 NPs [44]. Similarly, aqueous extracts of *Eclipta prostrata* were used with precursor, $TiO(OH)_2$ [45]. By using Paddy (*Oriza sativam*) TiO_2 NPS of size 10-20 nm were made [46]. Ethanolic extract of neem [47] and aqueous extract of Aloe Vera gel has been used as a biotemplate for titanium dioxide nanoparticles synthesis [48]. Aqueous extract of *Albizia Saman* leaf [49], ethanolic extract of *Cassia Auriculata* leaf [50], aqueous extract of orange peel [51], *Calotropis Giganta* flower have been employed in the green synthesis of TiO2 NPS [52].

V. CONCLUSION

In this review, we summarized the progress in the green synthesis of silver, gold and titanium oxide nanoparticles and their role in water treatment and also cleaning up contaminants that enter land and air environments. They have shown expedient potential in environmental remediation and treating effluents from industries and other human activities. Further work is needed to improve the shape, sizes, structures, functionality of nanomaterials. A better understanding of the potential harm to the environment is also required. Further focus should be inclined towards the optimisation of reaction conditions for large scale preparation using green methods.

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