International Journal of Scientific Research in Science and Technology
Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)
doi : https://doi.org/10.32628/IJSRST229530

Ultrasound-Assisted Green Synthesis of Nanoparticles and their Applications

Pankaj Sarkar
Nabadwip Vidyasagar College, Nabadwip Nadia, West Bengal, India

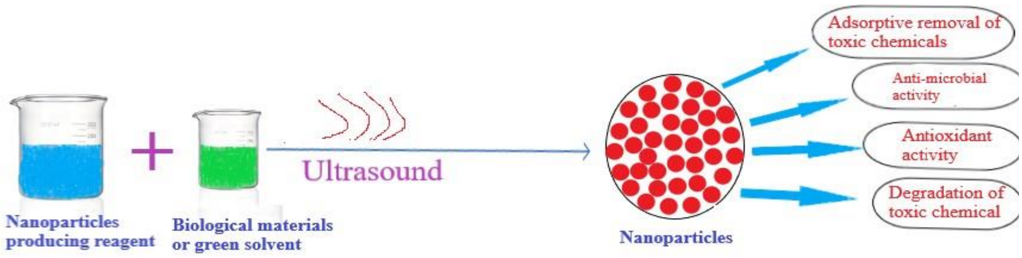
Article Info
Volume 9, Issue 5
Page Number : 197-202

Publication Issue
September-October-2022

Article History
Accepted : 08 Sep 2022
Published : 20 Sep 2022

ABSTRACT

Since the 1990s, the popularity of green synthesis has been steadily increasing because the process is environment-friendly, cost-effective and requires biological materials or green solvent. In the present case, the ultrasound-assisted green synthesis of nanoparticles has been studied. Nanoparticles provide more surface area and active sites compared to their bulk materials and hence they are more effective in applied fields. The potential use of nanoparticles in adsorptive removal of toxic chemicals, catalytic use in degradation of dyes, pesticides, pharmaceutical drugs etc., antioxidant activity and antimicrobial activity has been highlighted. Antioxidant activity of nanoparticles was performed by scavenging DPPH free radicals. Antimicrobial activity of synthesized nanoparticles was tested on some bacteria such as Escherichia Coli, Enterococcus faecalis, Salmonella typhimurium, Staphylococcus aureus, Bacillus subtilis, Streptococcus faecalis, Klebsiella pneumoniae, Streptococcus pyogenes etc. The catalytic activity toward degradation of methylene blue, methyl orange, 4-nitrophenol, Rhodamine B and parasoaniline were tested by the researchers. The use of nanoparticles as adsorbents for the removal of malachite green, Rhodamine B, Cu2+ metal ion and BR18 synthetic dye has been demonstrated by the researchers.



Keywords : Ultrasound, Sonication, Green synthesis, Nanoparticles, Antimicrobial activity, antioxidant activity, Degradation of toxic chemicals, Adsorptive removal

I. INTRODUCTION

The concept of green chemistry and green synthesis was initially developed after the U.S. pollution prevention act (1990) which declared to reduce pollution by improving the design. Green synthesis involves the use of cost-effective biological materials, use of green solvents such as water, ethanol etc., use of raw materials and recycling of the process. Green chemistry and green synthesis became more popular among researchers as they could reduce environmental pollution. A large number of chemical compounds such as toothpaste, soap, detergents, medicines, toilet cleaner, vinegar, Epsom salt, hand sanitizer, shampoo, insect repellent etc. have been used by us in our daily life. In most cases, the synthesis of these chemical compounds involves several steps releasing chemical waste which comes out with the industrial effluents. With the increasing global population, the environment becomes more polluted by chemical compounds. Green synthesis may help us to reduce such types of chemical pollution as it produces less toxic or non-toxic side products.

Particles with diameters 1-100 nm are known as nanoparticles. Nanoparticles generally show different physical and chemical properties compared to their bulk materials. Nanoparticles are widely used in medicines, tissue engineering and regenerative medicine [1], diagnosis and treatment of breast cancer [2], as an electrode in electroanalysis [3], as an agent to control pests [4] and as activity against bacterial growth [5]. The use of nanoparticles is also found in sustainable agriculture. Uses of nanofertilizers, nanopesticides, nano-plant growth promoters and nanoherbicides have been developed for potential use in agriculture [6,7]. Nanoparticles are frequently used as an adsorbent for the decontamination of water and wastewater from synthetic dyes, drugs, pesticides and many other contaminants. They provide more surface area as well as more active sites which facilitate the adsorption process. Nanoparticles have great importance for their catalytic activity in the degradation of toxic chemicals. The antioxidant activity of nanoparticles by scavenging DPPH radicals was also reported by researchers [5,8].

Ultrasound is a sound wave with a frequency greater than the upper audible limit of human hearing. The frequency of ultrasound may vary from 20 kHz to several gigahertzes. Although humans can't hear this sound, its use is immense in various fields including medical science and chemical synthesis. Ultrasound-assisted synthesis is found quite effective in organic synthesis. Mostly, the reactions under influence of ultrasound have taken place via cavitation. Ultrasound has also been noticed important use for the initiation or enhancement of homogeneous and heterogeneous catalytic reactions [9]. Ultrasound is also widely used to disperse material in a suitable solvent. Ultrasound-assisted green synthesis of nanoparticles and their applications towards antimicrobial activity, antioxidant activity, catalytic activity and adsorptive removal of contaminants have been studied in this review paper.

II. DISCUSSION

Green synthesis of CuO nanoparticles was performed by Gu et al. (2017) [5] using extract of a brown alga, Cystoseira trinodis. They synthesized colloidal CuO nanoparticles from copper sulphate and extract of Cystoseira trinodis in presence of ultrasonic conditions (500 Hz, 20 kH). The antimicrobial activity of synthesized nanoparticles was examined against a few bacterial strains such as Escherichia

Coli, Enterococcus faecalis, Salmonella typhimurium, Staphylococcus aureus, Bacillus subtilis, and Streptococcus faecalis. They reported that the synthesized nanoparticles exhibited excellent activity against bacterial growth. Gu et al. (2017) [5] also reported the antioxidant property of synthesized nanoparticles by performing the DPPH free radical scavenging activity. They also studied the degradation of synthetic using synthesized nanoparticles as a catalyst. The degradation of methylene blue was performed by varying dye concentration, pH, and amount of catalyst in presence of sunlight and UV light. Mahmoodi et al., (2019) [10] synthesized a novel bio-based metal organic framework nanocomposite, ZIF-67@Fe_3O_4@ESM, and the synthesized adsorbent was utilized to remove Cu^{2+} metal ion and BR18 synthetic dye from water. The green ultrasound method was selected for the synthesis of the eggshell membrane-zeolitic imidazolate framework. The adsorbent was employed to remove pollutants by the adsorptive method. It was found that the pseudo-second-order kinetic model and Langmuir isotherm model fitted well with the experimental data showing the maximum adsorption capacity of 344.82 and 250.81 mg g^{-1} corresponding to Cu^{2+} and BR18 concentration respectively. P´erez-Beltr´an et al. (2021) [11] studied the ultrafast green synthesis of magnetic nanoparticles from a solution of $FeCl_2·4H_2O$ and $FeCl_3·6H_2O$ by a sonochemical approach. They employed different methods for the functionalization of bare magnetic nanoparticles by several coating agents such as chitosan, polydopamine etc. The enzymatic inhibition study was carried out with functionalized magnetic nanoparticles. Anchoring of antibody and immunoprecipitation studies were also carried out with the functionalized magnetic nanoparticles. A green synthetic method of gold and silver nanoparticle synthesis was reported by Fatimah et al. (2019) [8]. Clitoria ternatea flower extract was used to synthesize nanoparticles of Ag and Au with particle size ranging from 18 to 50 nm. The antioxidant activity of Au and Ag nanoparticles was evaluated by scavenging DPPH radicals. The antibacterial activity of synthesized nanoparticles was investigated against Escherichia coli, Klebsiella pneumoniae, Streptococcus pyogenes, and Staphylococcus aureus. Ruíz-Baltazar et al. (2021) [12] reported the sonochemical activation-assisted biosynthesis of Au/Fe_3O_4 nanoparticles. Ruíz-Baltazar et al. used the extract of Piper auritum, an endemic plant, as a reducing agent during the biosynthesis of Au/Fe_3O_4 nanoparticles. The synthesized nanoparticles were employed to the ultrasound-assisted catalytic degradation of methyl orange in a dark room to nullify the photocatalytic effect. Dheyab et al. (2021) [13] reported the synthesis of highly stable gold nanoparticles by the sonochemical method by using an ultrasonic probe in an aqueous solution of sodium citrate and $HAuCl_4$. The synthesized nanoparticles were employed as a catalyst for the degradation of methylene blue by sodium borohydride. Akilandaeaswari and Muthu (2021) [14] reported the one-pot synthesis of bimetallic nanoparticles in an ultrasonic bath. In order to synthesize Au/Ag bimetallic nanoparticles, an aqueous solution of $HAuCl_4$ and $AgNO_3$ was taken with the extract of Lawsonia inermis seed in an ultrasonic bath operating at 40 kHz. The synthesized bimetallic nanoparticles were applied for the catalytic degradation of methyl orange and 4-nitrophenol.

Synthesis of ultrasound-assisted SnO_2 nanoparticles was reported by Fathima et al. (2022) [15] via Tinospora cordifolia stem extract and reduction methods. The synthesized nanoparticles were tested for degradation of Rhodamine B dye in an aqueous solution. Ultrasound-assisted green synthesis of silver nanoparticles was reported by Nouri et al. (2020) [16] using Mentha aquatica leaf extract. The preparation of leaf extract was also carried out by an ultrasonic probe. They prepared silver nanoparticles from silver nitrate solution and Mentha aquatica leaf extract in presence of ultrasound by varying pH, ultrasonic power, temperature, and volume of silver nitrate solution to Mentha aquatica extract. Nouri et al. studied the antibacterial and catalytic activity of synthesized nanoparticles. Catalytic reduction of methylene blue was carried out using ultrasound-assisted synthesized silver nanoparticles by varying pH, $NaBH_4$/ methylene blue molar ratio, and amount of catalyst. They also studied the antibacterial activity of synthesized nanoparticles against two gram-positive bacteria namely, P. aeruginosa and E. coli.

Vatandost et al. (2020) [17] reported the synthesis of reduced graphene oxide from grapheme oxide precursor using the extract of green tea. In this method, the green tea extract was prepared by applying a sonicator. The reduced graphene oxide nanoparticles were employed to detect the electrochemical detection of sunset yellow in the food products. Green synthesis of iron oxide and silver nanoparticles was reported by Deshmukh et al. (2019) [18] using fenugreek seed extract. The ultrasound-assisted silver nanoparticles were synthesized from silver nitrate and fenugreek seed extract where the seed extract was found to behave as a reducing and capping agent. Ultrasound-assisted synthesis of iron oxide nanoparticles was performed from a mixture of $FeCl_3$ and $FeCl_2$. The antibacterial activity of synthesized nanoparticles was investigated against two bacteria namely S. aureus and E. coli. Deshmukh et al. (2019) [19] reported the synthesis of hexagonal boron nitride nanosheet using various plant extracts as a green solvent. They reported that the plant extract was used as a reducing, capping and stabilizing agent. The adsorption of plant extract was found on the surface of h-BN and thereafter the plant extract weakened the interlayer interaction exfoliating h-BN in the form of layer nanosheets. The synthesized h-BN nanosheets were applied to study the antioxidant activity by scavenging DPPH radical. Besides the antioxidant activity, they also studied the adsorptive removal of both cationic and anionic dyes. Sonochemical synthesis of platinum nanoparticles was reported by Jameel et al. (2021) [20] using Prosopis farcta fruit extracts. An aqueous solution of K_2PtCl_4 and Prosopis farcta fruit extracts were subjected to an ultrasonic solid horn of 20 kHz. Prosopis farcta fruit extracts behave as the reducing agent in the synthesis of black-coloured platinum nanoparticles. Jameel et al. (2021) [20] also reported the mechanism and the effect of solvent properties on the ultrasound irradiation power. They did not mention any application of their synthesized platinum nanoparticles in this research paper. CDS/multiwalled carbon nanotube quantum dots was synthesized by Kandasamy et al., (2020) [21] using an ultrasound-assisted microwave method. Opuntia ficus-indica fruit sap was used in the synthesis of the quantum dots. The photocatalytic activity of CDS/multiwalled carbon nanotube quantum dot was studied for the degradation of parasoaniline dye. Mahmoodi et al. (2019) [22] reported the green ultrasound-assisted magnetic amine functionalized carbon nanotube (NH_2-CNT/Fe_2O_3)-zeolitic imidazolate framework-8 nanocomposites. The synthesized nanocomposites were applied to the removal of two cationic dyes namely malachite green and Rhodamine B.The optimum condition of dye removal obtained from RSM study was found at pH=6.0, adsorbent dose = 0.004 g, contact time = 145 min and dye concentration = 25 mg/L. Adrover et al. (2017) [23] described the synthesis of hierarchical FAU zeolite with uniform nano-sized crystals. They prepared a precursor gel containing Na_2O, Al_2O_3, SiO_2 and water with the molar composition of 9.5:1.0:14.0:288. The precursor gel was sonicated for 1 h at 47 kHz followed by hydrothermal treatment at 60^0C for 48 h under the static condition to obtain nanocrystalline zeolite. They also performed the aging pretreatment by mechanical agitation instead of sonication.

Conclusion

A large number of research papers have been published in different journals every year on the green synthesis of nanoparticles. Among these, few papers have reported the ultrasound-assisted synthesis of nanoparticles. This review paper briefly describes the ultrasound-assisted synthesis of nanoparticles along with the required materials. The applications of synthesized nanoparticles toward the degradation of toxic chemicals including synthetic dyes, adsorptive removal of toxicants, antibacterial activity and antioxidant activity by scavenging DPPH free radicals have been studied in this paper. This paper may be helpful for those researchers, who are engaged in the synthesis of ultrasound-assisted nanoparticles.

III. Acknowledgment

The author sincerely acknowledges Nabadwip Vidyasagar College and University of Kalyani for providing infrastructural facilities.

IV. REFERENCES

1. Fathi-Achachelouei, M., Knopf-Marques, H., Ribeiro da Silva, C. E., Barthès, J., Bat, E., Tezcaner, A., & Vrana, N. E. (2019). Use of nanoparticles in tissue engineering and regenerative medicine. Frontiers in Bioengineering and Biotechnology, 7, 113.
2. Yezhelyev, M. V., Gao, X., Xing, Y., Al-Hajj, A., Nie, S., & O'Regan, R. M. (2006). Emerging use of nanoparticles in diagnosis and treatment of breast cancer. The Lancet Oncology, 7(8), 657-667.
3. Welch, C. M., & Compton, R. G. (2006). The use of nanoparticles in electroanalysis: a review. Analytical and Bioanalytical Chemistry, 384(3), 601-619.
4. Athanassiou, C. G., Kavallieratos, N. G., Benelli, G., Losic, D., Usha Rani, P., & Desneux, N. (2018). Nanoparticles for pest control: current status and future perspectives. Journal of Pest Science, 91(1), 1-15.
5. Gu, H., Chen, X., Chen, F., Zhou, X., & Parsaee, Z. (2018). Ultrasound-assisted biosynthesis of CuO-NPs using brown alga Cystoseira trinodis: Characterization, photocatalytic AOP, DPPH scavenging and antibacterial investigations. Ultrasonics Sonochemistry, 41, 109-119.
6. Singh, H., Sharma, A., Bhardwaj, S. K., Arya, S. K., Bhardwaj, N., & Khatri, M. (2021). Recent advances in the applications of nano-agrochemicals for sustainable agricultural development. Environmental Science: Processes & Impacts, 23(2), 213-239.
7. Sarkar, N., Chaudhary, S., & Kaushik, M. (2021). Nano-fertilizers and Nano-pesticides as Promoters of Plant Growth in Agriculture. In Plant-Microbes-Engineered Nano-particles (PM-ENPs) Nexus in Agro-Ecosystems (pp. 153-163). Springer, Cham.
8. Fatimah, I., Hidayat, H., Nugroho, B. H., & Husein, S. (2020). Ultrasound-assisted biosynthesis of silver and gold nanoparticles using Clitoria ternatea flower. South African Journal of Chemical Engineering, 34, 97-106.
9. Suslick, K. S. (1990). Sonochemistry. Science. 247 (4949), 1439–45.
10. Mahmoodi, N. M., Taghizadeh, M., Taghizadeh, A., Abdi, J., Hayati, B., & Shekarchi, A. A. (2019). Bio-based magnetic metal-organic framework nanocomposite: Ultrasound-assisted synthesis and pollutant (heavy metal and dye) removal from aqueous media. Applied Surface Science, 480, 288-299.
11. Pérez-Beltrán, C. H., García-Guzmán, J. J., Ferreira, B., Estévez-Hernández, O., López-Iglesias, D., Cubillana-Aguilera, L., ... & Palacios-Santander, J. M. (2021). One-minute and green synthesis of magnetic iron oxide nanoparticles assisted by design of experiments and high energy ultrasound: Application to biosensing and immunoprecipitation. Materials Science and Engineering: C, 123, 112023.
12. de Jesús Ruíz-Baltazar, Á. (2021). Sonochemical activation-assisted biosynthesis of Au/Fe3O4 nanoparticles and sonocatalytic degradation of methyl orange. Ultrasonics sonochemistry, 73, 105521.
13. Dheyab, M. A., Aziz, A. A., Jameel, M. S., Khaniabadi, P. M., & Mehrdel, B. (2021). Sonochemical-assisted synthesis of highly stable gold nanoparticles catalyst for decoloration of methylene blue dye. Inorganic Chemistry Communications, 127, 108551.

14. Akilandaeaswari, B., & Muthu, K. (2021). One-pot green synthesis of Au-Ag bimetallic nanoparticles from Lawsonia inermis seed extract and its catalytic reduction of environmental polluted methyl orange and 4-nitrophenol. Journal of the Taiwan Institute of Chemical Engineers, 127, 292-301.
15. Fatimah, I., Purwiandono, G., Jauhari, M. H., Maharani, A. A. A. P., Sagadevan, S., Oh, W. C., & Doong, R. A. (2022). Synthesis and control of the morphology of SnO2 nanoparticles via various concentrations of Tinospora cordifolia stem extract and reduction methods. Arabian Journal of Chemistry, 15(4), 103738.
16. Nouri, A., Yaraki, M. T., Lajevardi, A., Rezaei, Z., Ghorbanpour, M., & Tanzifi, M. (2020). Ultrasonic-assisted green synthesis of silver nanoparticles using Mentha aquatica leaf extract for enhanced antibacterial properties and catalytic activity. Colloid and Interface Science Communications, 35, 100252.
17. Vatandost, E., Ghorbani-HasanSaraei, A., Chekin, F., Raeisi, S. N., & Shahidi, S. A. (2020). Green tea extract assisted green synthesis of reduced graphene oxide: Application for highly sensitive electrochemical detection of sunset yellow in food products. Food chemistry: X, 6, 100085.
18. Deshmukh, A. R., Gupta, A., & Kim, B. S. (2019). Ultrasound assisted green synthesis of silver and iron oxide nanoparticles using fenugreek seed extract and their enhanced antibacterial and antioxidant activities. BioMed research international, 2019.
19. Deshmukh, A. R., Jeong, J. W., Lee, S. J., Park, G. U., & Kim, B. S. (2019). Ultrasound-assisted facile green synthesis of hexagonal boron nitride nanosheets and their applications. ACS Sustainable Chemistry & Engineering, 7(20), 17114-17125.
20. Jameel, M. S., Aziz, A. A., & Dheyab, M. A. (2021). Impacts of various solvents in ultrasonic irradiation and green synthesis of platinum nanoparticle. Inorganic Chemistry Communications, 128, 108565.
21. Kandasamy, K., Surendhiran, S., Khadar, Y. S., & Rajasingh, P. (2021). Ultrasound-assisted microwave synthesis of CdS/MWCNTs QDs: a material for photocatalytic and corrosion inhibition activity. Materials Today: Proceedings, 47, 757-762.
22. Mahmoodi, N. M., Oveisi, M., Taghizadeh, A., & Taghizadeh, M. (2019). Novel magnetic amine functionalized carbon nanotube/metal-organic framework nanocomposites: From green ultrasound-assisted synthesis to detailed selective pollutant removal modelling from binary systems. Journal of hazardous materials, 368, 746-759.
23. Reinoso, D., Adrover, M., & Pedernera, M. (2018). Green synthesis of nanocrystalline faujasite zeolite. Ultrasonics sonochemistry, 42, 303-309.

Cite this article as :

Pankaj Sarkar, "Ultrasound-Assisted Green Synthesis of Nanoparticles and their Applications", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 9 Issue 5, pp. 197-202, September-October 2022. Available at doi : https://doi.org/10.32628/IJSRST229530
Journal URL : https://ijsrst.com/IJSRST229530