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Green synthesis of magnesium oxide nanoparticles and their antibacterial activity

R. Prasanth[1], S. Dinesh Kumar[1], A. Jayalakshmi[1], G. Singaravelu[1*], K.Govindaraju[2] & V.Ganesh Kumar[2]
[1]Department of Zoology, Thiruvalluvar University, Vellore, Tamil Nadu, India
[2]Centre for Ocean Research, Sathyabama Institute of Science and Technology, Chennai, Tamil Nadu, India
[*][E-mail: gsvelu@gmail.com]

Nanotechnology has prospects of opening new avenues to fight and prevent diseases using atomic-scale tailoring of materials. As the nano revolution emerges, it is imperative to develop “nano-naturo” links between nanotechnology and green domains of the nature. The present investigation describes the mangrove *Rhizophora lamarckii’s* property of synthesizing magnesium oxide nanoparticles . The newly synthesized magnesium oxide nanoparticle morphology is nanohexagonal and spherical. The particles range in dimensions between 20 and 50 nm and are crystalline in nature. The functional groups of the mangrove, amine, and alkane are found to act as reductants and stabilizers. The newly synthesized MgO nanoparticles are found to have potent antibacterial activity.

[**Keywords**: *Rhizophora lamarckii*; Magnesium oxide nanoparticles; Green synthesis; Nanohexagons]

Introduction

Nanostructured magnesium oxide has found numerous applications owing to its unique properties, such as large band gap, thermodynamic stability, low dielectric constant, and low refractive index[1,2]. MgO is an important inorganic oxide and is regarded as safe material for human beings[3]. In the medical field, MgO is used to treat various ailments, for example, it is used as an antacid for heartburn and sore stomach. Hence from the medical viewpoint, it would be rewarding to synthesize biocompatible magnesium oxide nanoparticles(MgONPs) using a green chemistry approach. Biological synthesis of MgONPs has not been widely exploited[4]. The distinctive properties of nanomaterials have given rise to tremendous research activity directed towards nanoparticle fabrication, characterization, and application[5].

Nanoparticle production through different physical and chemical routes has its own demerits as enormous environmental contaminations and hazardous by-products are produced during their synthesis. Thus, there is a need for “green chemistry” that ensures clean, nontoxic and environment-friendly methods to produce nanoparticles[6]. Biological synthesis of nanomaterials has received special attention as a tool to explore the little known avenues of medical sciences in several ways, such as imaging[7], sensing[8], drug delivery systems[9], cancer therapy, and diagnosis[10,11], and gene delivery[12].

Increasing awareness of biological processes has led to the desire to develop an environment-friendly approach for the synthesis of nontoxic nanoparticles. Unlike other processes in physical and chemical methods, which involve hazardous chemicals, biosynthesis of nanoparticles is a cost-effective and eco-friendly approach[13,14]. Owing to their rich diversity, plants have the innate potential for the synthesis of nanoparticles and they could be regarded as potential biofactories for nanoparticles synthesis[15,16].

It is in this context the idea of synthesizing MgONPs using mangrove plants has been conceived. Mangrove plants have been in use in folk medicine for treatment of several diseases. The present investigation proposes a one-step, simple, and efficient protocol for the preparation of MgONPs.

Materials and Methods

Chemicals and plant material

Mangrove plant samples were collected from Pichavaram mangrove forest (Lat.11º27´N; Long. 79º47´E), Tamil Nadu, India. *Rhizophora lamarckii* leaves were washed with deionized water, shade-dried, and powdered using an electronic blender. The dried coarse powder of *R. lamarckii* was extracted using deionized water (Fig. 1). Magnesium nitrate ($Mg(NO_3)_2$) was obtained from Loba Chem.

Synthesis and characterization of magnesium oxide nanoparticles

The *R. lamarckii* leaf extract (5g) was mixed with 100 ml of distilled water and boiled for 30 min at 100 °C. The extract was filtered using Whatman filter

Fig. 1 — Mangrove plant *Rhizophora lamarckii* selected for biological synthesis of magnesium oxide nanoparticles

paper. Five ml of filtrate was taken from the stock solution and 20 ml of distilled water was added along with 5 g of magnesium nitrate. The prepared solution was kept under stirring condition for 24 h. The formation of MgONPs was observed with the change of color of the solution from yellow to yellowish brown.

Aliquots of the reaction solutions were measured using a UV-2300 TECHCOMP spectrophotometer containing a double beam in the identified compartment. For Fourier Transform Infrared (FTIR) measurements, the newly synthesized MgONPs were centrifuged at 8000 rpm for 10 min. The deposited residue was dried and ground with KBr to obtain pellets that were analyzed using a Thermo Nicolet Quator instrument in the diffuse reflectance mode operating at 4 cm^{-1} in the solution. The X-ray diffractometer was operated at a voltage of 40 kV and tube current of 30 mA using Cukα radiation. For transmission electron microscopy (TEM) studies, newly synthesized MgONPs were prepared by placing a drop of the nanoparticle solution on carbon-coated copper grids and allowing the water to evaporate. The TEM studies were performed using a JEOL 3010 microscope operated with an accelerating voltage of 120 kV.

Antibacterial activity of magnesium oxide nanoparticles

The antibacterial activity of MgONPs against the Gram positive (*Staphylococcus aureus, Streptococcus pneumoniae*) and Gram negative bacteria (*Escherichia coli, Salmonella typhi*) were evaluated by the disc diffusion method. Bacterial cultures having a load of 1 × 10^8 CFU/ml were used to evaluate the antimicrobial activity.

Fig. 2 — (a) Magnesium nitrate solution, (b) aqueous extract of *Rhizophora lamarckii*, and (c) magnesium oxide nanoparticles synthesized using *R. lamarckii*

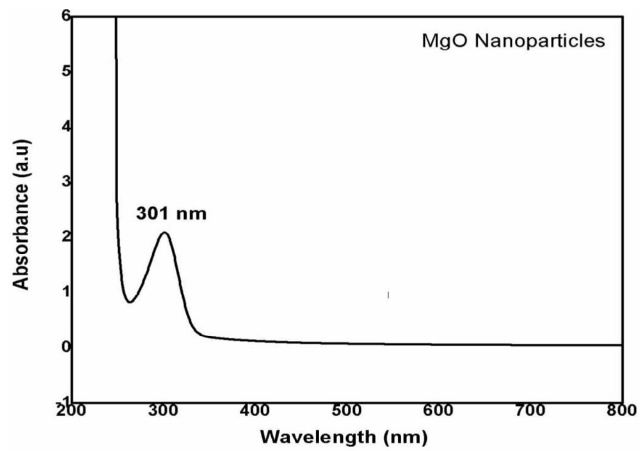

Fig. 3 — UV–Vis spectrum showing the formation of magnesium oxide nanoparticles

Results and Discussion

The phytosynthesis of metal oxide nanoparticles is intriguing and major efforts have been invested in this direction in recent times[17]. The main reasons for the wide research interest in phytosynthesis are that this approach is simple, highly reproducible with higher stability, and cheap, and it leads to multipurpose effective nanomaterials with low environmental risks (Fig. 2).

The formation of MgONPs was confirmed by UV–Vis spectrophotometry (Fig. 3). The morphology of the *R. lamarckii*-fabricated MgONPs was characterized by TEM. Figure 4 shows polydisperse and heterogenously structured (hexagonal and spherical shapes) nanoparticles with sizes ranging between 20 and 50 nm.

FTIR was used to identify the possible biomolecules which are responsible for the reduction and capping of MgONPs . Figure 5 represents the FTIR spectra of MgONPs synthesized using the *R. lamarckii* leaf extract. The spectra show bands at 3405, 2925, 1626, 1402, 1260, 1035 cm^{-1} and peaks were shifted to 3395, 2921, 1644, 1450, 1232, 1077 cm^{-1}, respectively.

The spectrum absorption peak at 3405 cm^{-1} and shift to 3395 cm^{-1} and that at 1626 cm^{-1} and shift to 1644 cm^{-1}, denote stretching of the N-H amine group. The spectrum absorption peaks at 2925 cm^{-1} shifted

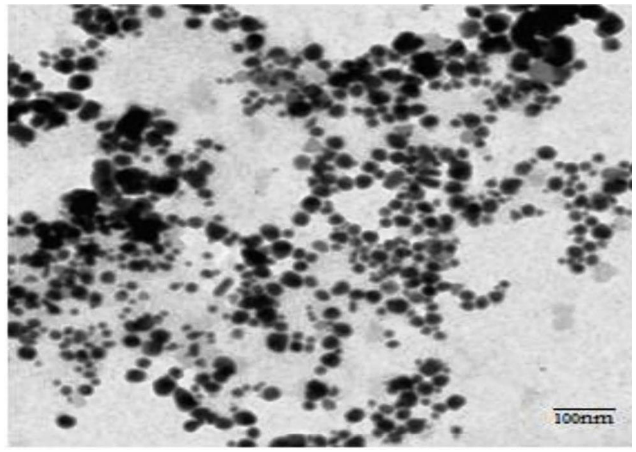

Fig. 4 — TEM image of magnesium oxide nanoparticles at the scale of 100 nm

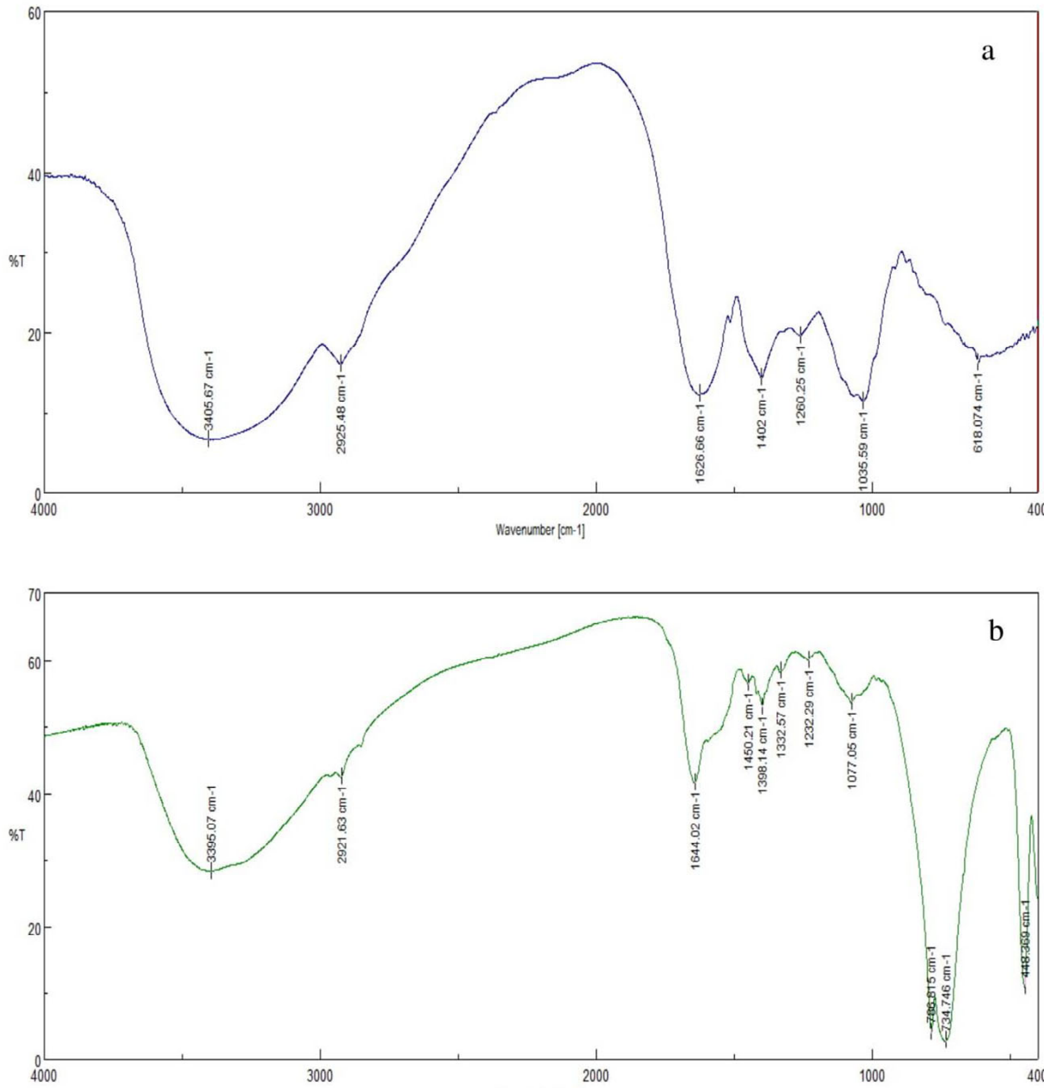

Fig. 5 — FTIR spectrum of (a) extract of *R. lamarckii* and (b) magnesium oxide nanoparticles synthesized using *R. lamarckii*

to 2921 cm^{-1} and 1402 cm^{-1} to 1450 cm^{-1} denote stretching of the C-H alkane group. Hence it is reasonable to infer that the amine and alkane functional groups present in *R. lamarkii* are involved in the reduction and capping of the newly formed MgONPs .

The crystal structure and phase composition of MgONPs were determined using an X-ray diffraction (XRD) technique (Figure 6). The XRD pattern suggests that the sample is probably nanocrystalline in nature, which matches very well with that of the standard.

Antibacterial activity of the newly synthesized MgNOPs was assessed against Gram positive bacteria (*S. aureus*, *S. pneumoniae*) and Gram negative bacteria (*E. coli*, *S. typhi*) (Figure 7). The antibacterial activity was determined by the zone of inhibition. The MgNOPs synthesized from *R. lamarckii* showed potential antibacterial activity against *S. aureus* (9.1 mm, 18.6 mm, 20.1 mm, and 26.5 mm for concentrations 10 µl, 20 µl, 50 µl, and 100 µl, respectively), *S. pneumonia* (9.4 mm, 18.7 mm, 19.8 mm, and 26.3 mm for concentrations 10 µl, 20 µl, 50 µl, and 100 µl, respectively) as compared to *E. coli* (9.6 mm, 18.1 mm, 20.0 mm, and 26.1 mm for

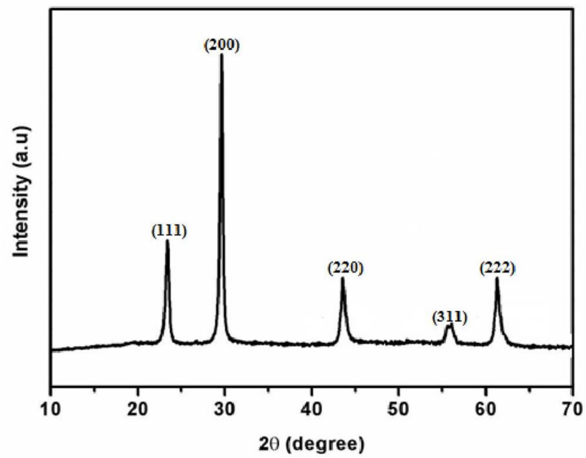

Fig. 6 — XRD pattern of magnesium oxide nanoparticles synthesized using *R. Lamarckii*

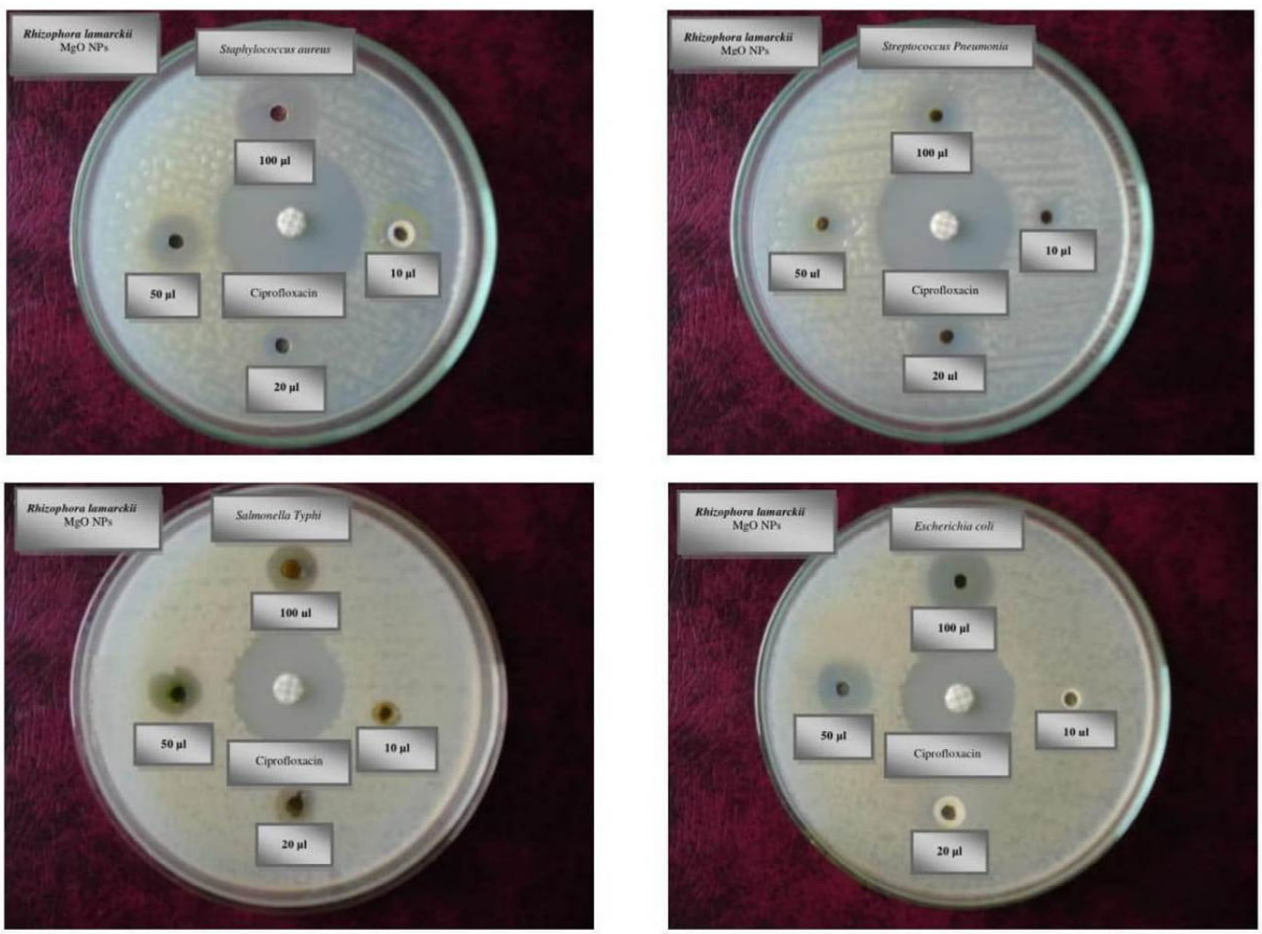

Fig. 7 — Antibacterial activity of magnesium oxide nanoparticles synthesized using *R. lamarckii*

Table 1 — Zone of inhibition (mm) of *R. lamarckii*-synthesized MgO nanoparticles (µl) against bacteria

S.No.	Test organisms	Zone of inhibition (mm)				
		10 µl	20 µl	50 µl	100 µl	Control
1.	*Staphylococcus aureus*	9.1	18.6	20.1	26.5	30
2.	*Streptococcus pneumonia*	9.4	18.7	19.8	26.3	30.1
3.	*Salmonella typhi*	9.7	18.0	19.9	25.7	30
4.	*Escherichia coli*	9.6	18.1	20.0	26.1	29.5

concentrations 10 µl, 20 µl, 50 µl, and 100 µl, respectively), *S. typhi* (9.7 mm, 18.0 mm, 19.9 mm, and 25.7 mm for concentrations 10 µl, 20 µl, 50 µl, and 100 µl, respectively). These results show that the MgNOPs have strong antibacterial activity against both Gram positive and Gram negative bacterial organisms (Table 1). As the antibacterial assay was fused with magnesium nitrate and with the aqueous extract of mangrove *R. lamarckii*, which were used to synthesize MgNOPs, the results clearly demonstrate the activity at higher concentration. It has been reported by earlier studies that owing to the increase in the surface area of nanomaterials, the surface oxide ion concentration would be increased, which may lead to destruction of the cytoplasmic membrane of the bacteria[18,20].

Nanotechnology provides a novel way to enhance the activity of inorganic materials. It has been demonstrated that MgONPs have promising anticancer activity[21] and antibacterial activity[22]. There are reports stating that MgONPs have more inhibitory activity on Gram positive bacteria than on Gram negative bacteria[23,24]. In the present investigation, no such difference of inhibition has been noticed. It is worth mentioning here that the properties and physico-chemical nature of nanomaterials differ according to the mode of their synthesis[25].

Conclusion

This article highlights the potential of mangrove *R. lamarckii* in the phytosynthesis of MgONPs. The aqueous mangrove extract acted as a capping and reducing agent in forming MgONPs, which are mostly spherical or hexagonal in nature and with a size range of 20–50 nm. The zone of inhibition values reveal that biologically synthesized MgONPs have strong antibacterial activity against both Gram positive and Gram negative bacterial organisms at low concentration.

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