

Carica papaya latex-functionalized biogenic synthesis of cadmium oxide nanoparticles to improve antibacterial, anticancer and photocatalytic applications

Makarand K. Sakate

Department of Chemistry, Smt. Meenalben Mehta college, Panchgani .

Sandeep B. Wategaonkar

Department of Chemistry, Kisan Veer Mahavidyalaya, Wai

Neeraj R. Prasad

Department of HUMANITIES and Science Walchand College of Engineering, Sangli .

Shital S. Shendage

Department of Biomedical Sciences, College of Medicine, Chang Gung University, Taoyuan

Aviraj R. Kuldeep

Department of Chemistry, Shivaji University, Kolhapur

Balasaheb M. Sargar

Department of Chemistry, DST-FIST Sponsored Material Research Laboratory, Jaysingpur College, Jaysingpur.

Balasaheb N. Kokare

bnkokare@gmail.com

Department of Chemistry, Smt. Meenalben Mehta college, Panchgani .

Research Article

Keywords: Carica papaya Latex, Cadmium oxide nanoparticles, Anticancer, Antibacterial and Photocatalytic activity

Posted Date: April 15th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9169705/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

The present study reports the green synthesis of cadmium oxide nanoparticles (CdO-NPs) from *Carica papaya* latex in aqueous medium and their application for antifungal, antibacterial, anticancer and photocatalytic activities. The XRD, UV-visible, SEM-EDS, Raman, XPS, and zeta potential spectroscopy results revealed the formation of stable CdO-NPs with an average size of 35.67 nm. Further, the spherical shape of the CdO-NPs was confirmed by X-ray photoelectron spectroscopy (XPS) and scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS). The anticancer activity of the CdO-NPs was tested against KB 3 – 1 oral cancer cell line and results showed good anticancer activity with an IC_{50} value of 2.69%. Thus, the present study revealed CdO-NPs synthesized from *Carica papaya* latex acts as an antibacterial, antifungal, anticancer, and photocatalytic agents.

1. Introduction

The increase of toxic organic pollutants in the environment, increasing global rate of cancer, and the rapid emergence of multidrug-resistant microorganisms have collectively strengthened the demand for multifunctional materials with enhanced therapeutic and catalytic performance [1–2]. In this context, nanotechnology has provided new opportunities for designing advanced materials with improved efficiency through precise control over size, surface characteristics, and physicochemical properties [3]. In particular, metal oxide nanoparticles, have gained more attention owing to their high surface area, tunable electronic structure, and versatile biological and catalytic functionalities [4].

Among various metal oxides, cadmium oxide (CdO) is a promising n-type semiconductor with a narrow band gap, high electrical conductivity, and strong optical absorption in the visible region. These characteristics of CdO enable efficient charge transfer and reactive oxygen species (ROS) generation, which are essential for both photocatalytic degradation of organic pollutants and biological activity. Previous studies have reported that CdO nanoparticles exhibit significant antibacterial effects through membrane disruption and oxidative stress, as well as anticancer activity by inducing mitochondrial dysfunction and apoptosis in cancer cells. Additionally, CdO nanoparticles have shown excellent photocatalytic efficiency in the degradation of dye pollutants, highlighting their multifunctional potential [5–6]. Despite these advantages, conventional chemical and physical synthesis methods for CdO nanoparticles often involve toxic reducing agents, reaction conditions. To address these limitations, green and biogenic synthesis approaches have emerged as sustainable alternatives [7–8]. Plant-mediated synthesis is particularly attractive, as plant extracts contain diverse phytochemicals such as phenolics, proteins, enzymes, and alkaloids which acts as reducing, stabilizing, and capping agents, leading to environmentally friendly synthesis.

Over the past twenty years, researchers from a wide range of fields have been actively involved in designing and developing materials at the nanoscale. There is a growing need for this broad, multidisciplinary field of study in the industrial and medical sectors [9]. In every level of research and technology, including the veterinary and medical domains, scientists and engineers work together to use

metal nanoparticles. Scientists continue to work hard to uncover new facets of their value [10]. Applications for nanomaterials are numerous and include biomedical, pharmaceutical, food, animal nutrition, environmental sciences, mechanics, optics, chemical industries, electronics, and health care [11–14]. There are several uses for materials, primarily in veterinary medicine and health, and they show interesting features in the nanoscale regime that set them apart from their bulk counterparts [15]. Because of their unique properties, which include chemical stability, excellent conductivity, catalytic efficacy, and, most importantly, antibacterial, antiviral, antifungal, and anti-inflammatory activities, silver and gold nanoparticles have garnered the most interest of all the noble metal nanoparticles [16–18]

Carica papaya is a medicinally important plant known for its antibacterial, antioxidant, and anticancer properties. The latex of *Carica papaya* is especially rich in proteolytic enzymes, including papain and chymopapain, along with various bioactive secondary metabolites. These components make papaya latex an effective biogenic resource for nanoparticle synthesis and surface functionalization. In particular, the thixotropic fluid found in the latex of unripened fruit includes various secondary metabolites and proteins, including linamarase, chitinases, protease inhibitors, and cysteine endopeptidases.

In particular, the thixotropic fluid found in the latex of unripened fruit includes various secondary metabolites and proteins, including linamarase, chitinases, protease inhibitors, and cysteine endopeptidases [19–20]. In addition to its remarkable antibacterial, antioxidant, and chelating properties, it was successfully employed in desloughing necrotic tissue [21–22]. The papaya pulp comprises vitamins A, C, and E and antioxidants. Studies have indicated the existence of dietary fibres, Mg, K, Cu, Zn and B complex vitamins like folate and pantothenic acid [23]. Papain is another enzyme found in papaya that helps heal wounds, allergies, and skin lesions, while chymopapain enzyme shows antibacterial, antiviral and antifungal activity [24]. *C. papaya* pulp increases the platelet count in the dengue and dengue hemorrhagic fever patient [25]. The adsorption of such biomolecules on nanoparticle surfaces can enhance colloidal stability and promote synergistic biological and catalytic effects. For example, T. Gayathri et al. synthesized copper oxide nanoparticles (CuO NPs) using *C. papaya*, which shows better antimicrobial properties [26]. T. Jayamani et al. synthesized palladium NPs using papaya leaf extract, which showed significant antibacterial activity against bacteria and fungi strains [27]. Vasantaraj et al. synthesized iron oxide NPs are typically employed in a variety of fields, including biomedicine, where they are utilized to deliver drugs to specific sites and destroy tumour cells, as well as remove heavy metals, dyes, and antibiotics from water sources [28]. Anadozie et al. found that antioxidant and anticancer activities shown by *C. papaya* fruit gold nanoparticles (CPf-AuNPs) help to design new therapeutic molecules to treat different solid tumours [29]. Whereas, Muthukumar et al. stated that iron-based nanoparticles can generate highly reactive oxygen species (ROS), which is efficient against various pathogenic bacterial strains and fungi [30]. According to the literature, *C. Papaya* with metal oxide nanoparticles exhibits superior biomedical activity.

In the present study, we report a *Carica papaya* latex-functionalized biogenic synthesis of CdO nanoparticles. The synthesized CdO nanoparticles were comprehensively characterized to elucidate their

structural, morphological, and optical properties. Furthermore, their antibacterial activity against pathogenic microorganisms, anticancer potential against cancer cell lines, and photocatalytic efficiency in the degradation of organic pollutants were systematically investigated [31–35]. This work demonstrates that papaya latex-functionalized CdO nanoparticles represent a sustainable and multifunctional nanomaterial with promising applications in biomedical and environmental fields.

2. Experimental

2.1 Materials

The unripe fruit of the *C. papaya* was collected from cultivated near Raje Ramrao College, Campus, Jath (17°03' N latitude and 75°15' E longitude), Maharashtra. The plant material used in the present study, Carica papaya(papaya) latex, was collected from a local region in India, where the species is widely cultivated and naturally distributed across the Indian subcontinent. The collection of plant material was conducted in accordance with applicable national and institutional guidelines governing the use of biological resources for research purposes. The samples were collected from publicly accessible areas, ensuring that no protected habitats or endangered species were affected during the sampling process. Consequently, no specific permits or formal permissions were required for the collection of plant material.

All procedures related to plant collection and utilization were carried out responsibly and ethically, with due consideration to minimizing environmental impact. The study adheres to established guidelines for plant-based research and complies with relevant regulations concerning biodiversity conservation and sustainable bio-resource utilization.

Cadmium nitrate $\text{Cd}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$, absolute ethanol, and other AR-grade chemicals were purchased from Molychem.

2.2 Synthesis of latex functionalized CdO-NPs

The milky white carica papaya latex was collected in a sterile bottle; an equal volume of de-ionized water was added and further, the latex suspension was put on magnetic stirrer at 500 rpm at 37°C for 10 min for homogenization. The resulting supernatant was used as a source of latex extract and kept at 20°C for further use. To synthesize CdO-NPs, the reaction mixture was prepared by blending 20 ml of 50% aqueous latex extract and 50 ml of 0.2 M $\text{Cd}(\text{NO}_3)_2$ and further kept at 37°C in dark conditions. The mixture was then stirred for 48 hours; and obtained white-coloured precipitate was centrifuged followed by ethanol and water washing. The obtained precipitate was dried at 110°C for 3 hours followed by annealed at 600°C in a muffle furnace for 2 hours. The obtained black-coloured nanoparticles CdO-NPs were characterized by using different analytical tools.

2.3 Characterization of CdO NPs

The structure of *C. papaya* latex-functionalized CdO-NPs was confirmed by an X-ray diffractometer equipped with an irradiation line K α of copper (Equipment Name: XRD- X-Ray Diffractometer Model: D8). The crystallite size of CuBG was calculated using Scherrer Eq. (1);

$$D = \frac{0.9\lambda}{\Delta \cos\theta} \quad (1)$$

Where in, λ (monochromatic X-ray wavelength), Δ (full-width half maxima-FWHM), and θ is the diffraction angle. Further, the ALPHA Bruker FT-IR spectrometer was used to investigate the functional group present in the sample using a KBr pellet. The Raman spectra were captured using Renishaw INVIA 0120 – 20 Equipment Code: 2734619 Raman System (excitation at 532 nm, 2.33 eV). The surface morphologies of the CdO-NPs were investigated using a scanning electron microscope with Energy Dispersive Spectroscopy (JEOL Japan), and compositional data was obtained using the attached energy dispersive spectrophotometer (SEM-EDS). Further, the particle size and charge were analyzed using Model Nano ZS 90 ZEN 3696 and Nano ZS 90 ZEN 3696. The elemental composition of the CdO-NPs was determined by X-ray photoelectron spectroscopy (XPS) (Model: JPS-9030 Equipment Code: CFC SAIF DST Shivaji University, Kolhapur) using an Al K α μ -focused monochromator (1486.6eV) with an adjustable spot size (30–400 μ m in 5 μ m steps) at 3 mA and 12 kV.

2.4 Antibacterial and antifungal activity

Using a modified agar well diffusion method, the antibacterial activity of DMSO-suspended nanoparticles was tested against bacterial strains that were Gram-negative (*E. coli* NCIM 2832 and *P. aeruginosa* NCIM 5032) and Gram-positive (*Staphylococcus aureus* NCIM 2654 and *B. cereus* NCIM 2703) as well as fungal pathogens such as *Aspergillus niger* NCIM 503 and *Candida albicans* NCIM 3466 [36]. For additional research, a sterile saline suspension of the corresponding test pathogens was made. To assess the antimicrobial activity, microorganisms were dispersed on plates using a sterile spreader after being inoculated on the surface of sterile Muller and Hinton agar. After that, a sterile cork borer with a 0.7 cm diameter was used to prepare agar wells aseptically. The wells made on the agar plates were then filled with 100 μ l of the CdO nanoparticle solution. After 20 minutes of sample diffusion in a culture medium at 4°C, the plates were moved to an incubator set at 37°C for 24 hours. Additionally, the outcomes were contrasted with the well that contained DMSO as a negative control and 1000 μ g/ml streptomycin as a positive control. The results were documented and the inhibitory zone's diameter was determined in millimetres. For antifungal activity, a similar process was followed; MGYD agar plates were made by submerged inoculation with the corresponding fungal strain previously indicated, and they were then incubated for 48 to 72 hours at 27°C. Plates were checked for a zone of clearing surrounding the corresponding wells after incubation. The acquired antifungal findings were contrasted with DMSO as a negative control and a typical fluconazole pill (100 μ g/ml) as a positive control.

2.5 Anticancer activity

A 96-well flat-bottom microplate was used to seed the cells, and they were kept at 37°C for the entire night with 95% humidity and 5% CO₂. Samples of CdO-NPs at several doses (100, 50, 25, 12.5, 6.25, and

3.125 µg/ml) were treated. Another forty-eight hours were spent incubating the cells. The plate was incubated at 37°C after the wells were twice cleaned with PBS and 20 µL of the MTT staining solution was applied to each well. To dissolve the formazan crystals, 100 µL of DMSO was given to each well after 4 hours. The absorbance was then measured using a microplate reader set at 570 nm [37].

2.6 Photocatalytic activity of CdO-NPs

Using a 250 W mercury lamp equipped with an ultraviolet cut off filter, degradation experiments of methylene blue (MB) dye as model pollutants under visible light irradiation were conducted to examine the photocatalytic activity of the CdO [38].

To evaluate the photocatalytic activity at room temperature, 25 mg of CdO nanoparticles were mixed with 50 mL of MB dye aqueous solution, starting at a concentration of 25 mg/L. The initial stage of the photocatalytic degradation process is the creation of the adsorption–desorption equilibrium. Therefore, in order to guarantee the establishment of the adsorption–desorption equilibrium between MB and the photocatalyst, the suspensions were magnetically agitated in the dark for 30 minutes prior to light irradiation. This has been confirmed by the consistent percentage of MB dye adsorption in the dark. After that, the suspension was constantly stirred while exposed to visible light radiation. To get rid of the remaining photocatalyst, 4 mL of the suspension was taken after 60 minutes and centrifuged for 2 minutes at 10,000 rpm. Next, using a UV-Vis spectrophotometer to record changes in the absorption peak maxima in the organic dye, the concentration of MB in the supernatant was determined.

The photocatalytic degradation of MO was carried out in order to evaluate the photocatalytic activity of TiO₂-carbon nanocomposite (TC60). The dye solutions were subjected to Visible analysis to determine the precise concentration for MB at λ max = 665nm. The dye's photodegradation (D) was computed using Eq. (2):

$$D (\%) = \frac{C_0 - C_t}{C_0} \times 100 - (2)$$

Where, C₀ is initial concentration, C_t is final concentration, and D is degradation rate.

2.7 Statistical analysis

The experiments were repeated three times and presented in mean ± standard deviation. The comparison between the groups was studied by one-way ANOVA and the significance was considered p < 0.05.

3. Result and discussion

The CdO-NPs was synthesized by *C. papaya* considering multifunctional application in biomedical and photocatalysis. The detailed synthesis of CdO-NPs using *C. papaya* latex is presented in the Scheme 1. Papain is the protein which is main component of papaya crude latex. A single polypeptide chain of amino acids makes up the protein papain [39]. Cadmium ions and amino acid residues in the chain

attach to papain's active site. When vigorously stirred at room temperature, Cadmium ions and papain combine to create the Cd-papain complex. CdO-NPs are formed when the two closest active surfaces of papain react with cadmium ions to generate a complex structure. When the Cd-papain complex is heated, it loses its thermal stability and produces papain ions and CdO-NPs. Both of produced papain ions and CdO-NPs are calcined at 600°C temperature gives *C. papaya* latex-functionalized CdO-NPs [40]. Further, the synthesis of CdO-NPs was characterized by the structural and physicochemical properties such as, XRD, FTIR, SEM-EDS measurement.

Figure 1a shows the XRD patterns for synthesized CdO-NPs with cubical crystal structure and polycrystalline nature. The XRD peaks at $2\theta = 33.15^\circ$, 38.43° , 55.66° , 66.22° , and 69.58° correspond to (1 1 1), (2 0 0), (2 2 0), (3 1 1), and (2 2 2) of the cubic structure of metallic CdO-NPs (JCPDS 00-001-1049) respectively. The CdO-NP showed average crystallite size of 35.67 nm. Thus, the synthesized CdO-NP has a slightly hexagonal crystalline structure with a face-centered cubic (FCC) structure, which is consistent with earlier findings [41–42].

Further, the Raman spectroscopy of the CdO-NPs was analyzed 100–1500 cm^{-1} spectral region. The peak at ~ 257 , ~ 400 and a wide weak band at $\sim 960 \text{ cm}^{-1}$ is observed in the Raman spectra as shown in Fig. 1b. According to literature, CdO-NPs expected to exhibit second-order Raman scattering. The peaks at ~ 257 and $\sim 400 \text{ cm}^{-1}$ correspond to 2TA (L) and 2LA (L) Raman scattering peaks [43]. Cusco et al. [44] stated that, Raman peak that obtained at $\sim 400 \text{ cm}^{-1}$ may be due to high density of two phonons in the spectral range of 350–450 cm^{-1} and that it would most likely originate from 2LA overtones at various high symmetry points of the Brillouin zone. Whereas, at peak at $\sim 960 \text{ cm}^{-1}$ attributed due to indicate Cd–O stretching vibrations [45].

Further, the Raman study was supported with the FTIR results. FTIR measurement was used to detect functional groups present in the CdO-NPs synthesized from the *C. papaya* latex, which acts as a reducing agent and stabilizer. The spectral data recorded for the synthesized sample reveals the presence of different functional groups and stretching and bending vibrations. Figure 1c represents the FTIR spectrum of CdO-NPs in the 400–3700 cm^{-1} range. The peak at $\sim 1112 \text{ cm}^{-1}$ was attributed due to C–O stretching vibrations of the carbonyl group and it confirms the deformation that may occur of C–H of the alkane group [46]. Whereas, the peak at $\sim 1633 \text{ cm}^{-1}$ were attributed to O–H–O bending vibration [47]. The peaks ranging between $\sim 488 \text{ cm}^{-1}$ is due to Cd–O vibration, which confirms the presence of CdO NPs [48]. Further, it was observed that, the peaks at 3400 to 3550 cm^{-1} is due to O–H from the hydrogen bonds [49]. Thus, the FTIR results revealed that the formation of the CdO NPs.

The DLS and zeta potential analysis was used to determine the size and surface charge present on the synthesized CdO-NPs. It was observed that, the CdO-NPs has 28.9 mV zeta potential. The agglomeration of the particles is inhibited by the strong repelling force which leads to obtain high zeta potential value [47]. Rayleigh scattering is the process by which light scatters small particles in a colloidal solution by bombarding them with light. There is a variation in light intensity even in cases where the incident light is

monochromatic or laser. Brownian motion in solution, which happens continuously, is the reason for this variation in light intensity. As observed in Fig. 1d, the green, synthetic cadmium oxide nanoparticles had an average particle size distribution of 324.9 d.nm. The mono-dispersed character of biogenic CdO-NPs is shown by a prominent peak that spans from 300 to 900 d.nm. Ball milling reduces the poly-dispersed CdO-NPs particle size [50].

Figure 1d displays the zeta potential of CdO-NPs, which is -17.3 mV. Because of negative-negative repulsion, the high negative zeta potential (ξ) value contributes to the long-term stability, good colloidal nature, and excellent dispersion of CdO-NPs. The produced nanomaterials exhibit exceptional stability and have zeta potential values ranging from -35 to 0 mV. However, the zeta potential values are also influenced by the dispersion stability [51–52].

The sample's microstructure is studied using a SEM-EDS analysis. The as-synthesized SEM shows the uneven or irregular morphology. Figure 2 shows that 40–100 nm average particle size for CdO-NPs. The present results are found to be similar with the literature with irregular morphology. [53–54] Further, the elemental composition of synthesized nanomaterials and their composites has been investigated using EDS analysis. The EDS analysis shows the peak for cadmium and oxygen as shown in Fig. 2 inset, which support the formation of CdO-NPs [55–57].

The XPS measurements were performed to investigate the chemical state in the CdO NPs. Figure 3a exhibits an signal from the C 1s, O 1s, and Cd 3d. Further, the comprehensive XPS spectra for the O 1s and Cd 3d are shown in Fig. 3b and 3c respectively. The Cd 3d spectrum is formed of a spin-orbit doublet, which seems to be pretty well duplicated by a unique Gaussian-shape doublet. Cadmium primary $3d_{5/2}$ and $3d_{3/2}$ spin-orbit components comprise the Cd 3d features, with binding energies of 407.12 and 413.99 eV, respectively [58]. Further, the C 1s peak can be attributed at 285.0 eV, while the O 1s peak is depicted at 532.4 eV and 529.1 eV binding energies for Cd-O & Cd-OH [59] is shown in Fig. 3c. Based on these peaks, the spin-orbit splitting of 6.875 eV has been determined by spectrum fitting, confirming the synthesis of CdO-NPs via green synthesis. These results suggest that the NPs comprise a single CdO-related phase because no peak for secondary phases, like CdO_2 or $\text{Cd}(\text{OH})_2$ is observed [59–60]. It is important to point out that the binding energy of the Cd 3d core level observed in these NPs appears to be moved to higher energies in comparison to bulk CdO [61] by around 1.7 eV, which could result from nanosize effects of CdO NPs. Thus, the XRD, FTIR, SEM-EDS analysis revealed the formation of CdO NPs. Further, the in vitro antibacterial and antifungal activity of the CdO NPs were studied.

Well diffusion method is used to study the antimicrobial and antifungal activity of the CdO NPs against the *B. cereus*, *S. aureus*, *E. coli*, *A. niger*, and *C. albicans*. The methanol used as the negative control, whereas ascorbic acid is the used as positive control [62–64]. In Fig. 4(a–e) the CdO NPs showed 19, 18, 08, 18, and 18 mm, zone of inhibition against *B. cereus*, *S. aureus*, *E. coli*, *A. niger*, and *C. albicans* [65]. The *Carica papaya* latex-functionalized CdO NPs shows good antibacterial activities for *B. cereus*, *S. aureus*, and poor for *E. coli*. But the CdO-NPs show good antifungal activities for *C. albicans* than, *A. niger* Fig. 4f.

The anticancer activity of the CdO NPs is investigated using the KB-3-1 cancer cells. The anticancer activity of the CdO NPs is studied at concentration from 100-3.125 $\mu\text{g/ml}$ for 48 hrs [66] [67]. The latex-functionalized CdO-NPs showed the anticancer activity with 2.69 $\mu\text{g/mL}$ IC_{50} value against the KB-3-1 cells. Similar findings were obtained in Kathiraven et al. [68] study. The *Melia dubia* leaf-mediated AgNPs had an IC_{50} of 31.2 $\mu\text{g/mL}$ and demonstrated in vitro carcinogenic activity against the MCF-7 cells. Further, phase contrast microscopy at a 100 $\times$ magnification was used to investigate morphological changes observed after treatment of CdO-NPs, as shown in Fig. 5. Cell burst, growth retardation, clumping, and loss of membrane stability were among the cytomorphological changes observed. A similar reaction was seen in cancer cell lines treated with green generated AgNPs [69–70]. However, the molecular mechanism of *Carica papaya* latex-functionalized CdO-NPs in cancer and normal cell lines, as well as on the human immune system, need more thorough research.

The prepared CdO-NPs showed the antibacterial and anticancer activity. Further, considering the multifunctional properties of the prepared material the photocatalytic degradation study was also performed. The initial stage of the photocatalytic degradation process is the formation of the adsorption-desorption equilibrium. Thus, in order to guarantee the establishment of the adsorption-desorption equilibrium between methylene blue (MB) and the photocatalyst, the suspensions were magnetically agitated in the dark for 30 minutes prior to light irradiation. This has been confirmed by the consistent percentage of MB dye adsorption in the dark. After that, the suspension was constantly stirred while exposed to visible light radiation. To get rid of the remaining photocatalyst, 4 mL of the suspension was taken after 60 minutes and centrifuged for 2 minutes at 10,000 rpm. Next, using UV-Vis spectrophotometeric record changes in the absorption peak maxima in the organic dye, the concentration of MB in the supernatant was determined. After that, the dye's photocatalytic activity at a concentration of 25 ppm was tested using 25 mg of *Carica papaya* latex-functionalized CdO-NPs photocatalyst. As observed in Fig. 6, the quantity of MB produced by visible light gradually decreases. After 60 minutes of exposure, the degradation efficiency was found to be 21.02%. By doping it with some active species, this may be raised.

4. Conclusion

CdO-NPs were effectively synthesised in this study for biomedical applications employing an easy, environmentally friendly method. *Carica papaya* latex is aged using a method lever to aid in the in-situ reduction of cadmium ions. This produces well-defined CdO-NPs with irregular shape and a regulated crystallite size of 35.67 nm. The cost-effectiveness and environmental friendliness of this green synthesis approach are just two of its benefits, which are consistent with current research trends that support the creation of bio-mediated NPs. In this case, CdO-NPs showed strong antifungal and antibacterial qualities. Additionally, CdO-NPs showed unique toxicity to KB-3-1 cancer cells, indicating that they could be effective anticancer drugs with an IC_{50} value of 2.69%. These results demonstrate the possibility for creating superior nanoparticles with exciting biomedical uses through *Carica papaya* latex-functionalized synthesis. The amount of MB generated by visible light steadily declines. The

deterioration efficiency after 60 minutes of exposure was 21.02%. This could be increased by doping it with some active species.

Declarations

CRediT authorship contribution statements

Makarand K. Sakate: Conceptualization, methodology, design experiment, investigation, data collection, and curation, writing the original draft. **Sandeep B. Wategaonkar:** data curation, writing, and review. **Neeraj R. Prasad:** data curation, writing, and review. **Shital S. Shendage:** data curation, writing, and review. **Aviraj R. Kuldeep:** data curation, writing, and review. **Balasaheb M. Sargar** and **Balasaheb N. Kokare:** Conceptualization, guidelines for execution of the project, following the investigation, methodology, data curation, interpretation, supervision, validation, drafting of the manuscript, review, editing, and finalizing the draft.

Conflict of interest - The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics declaration - Not applicable.

Funding - This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests

Data Availability Statement:

All data generated or analysed during this study are included in this published article [and its supplementary information files].

Clinical trial number: not applicable.

Permissions and/or licences for collection of plant specimens - Not applicable

References

1. Jadhav SR, Gupta A, Colaco V, Saha M, Sreedevi A, Datta D, Moorkoth S, Ligade VS. Namdev Dhas, Multifunctional nanosponges in cancer therapy: Integrating targeted drug delivery and theranostic potential. *Int J Pharmaceutics: X*, 10, 2025, 100421, ISSN 2590 – 1567, <https://doi.org/10.1016/j.ijpx.2025.100421>
2. Elaheh Amirinezhad AN, Tabar L-J, Xia W-C, Yang. Plant-derived nanomaterials in cancer therapy: Advances from green synthesis to application of PANoptosis-mediated tumor suppression, *Industrial Crops and Products*, 236, 2025, 121850, ISSN 0926–6690, <https://doi.org/10.1016/j.indcrop.2025.121850>
3. Aamir, Sohail. Progress in nanomaterials: Synthesis, characterization, and applications, *Next Nanotechnology*, Volume 8, 2025, 100263, ISSN 2949–8295. <https://doi.org/10.1016/j.nxnano.2025.100263>
4. Aigbe UO, Osibote OA. Green synthesis of metal oxide nanoparticles, and their various applications. *J Hazard Mater Adv*. 2024;13:2772–4166. <https://doi.org/10.1016/j.hazadv.2024>.
5. Ganesh Singh MS, Chauhan. Synthesis and characterization of nanostructured La³⁺ doped CdO for photocatalytic application. *Chem Phys Lett*. 2023;830:0009–2614. <https://doi.org/10.1016/j.cplett.2023.140810>.
6. Yathisha RO, Arthoba Nayaka Y, Manjunatha P, Vinay MM, Purushothama HT. Doping, structural, optical and electrical properties of Ni²⁺ doped CdO nanoparticles prepared by microwave combustion route. *Microchem J*. 2019;145. <https://doi.org/10.1016/j.microc.2018.10.060>. Pages 630–641, ISSN 0026-265X.
7. Beatriz Cardoso G, Nobrega InêsS, Afonso JoãoE, Ribeiro RA, Lima. Sustainable green synthesis of metallic nanoparticle using plants and microorganisms: A review of biosynthesis methods, mechanisms, toxicity, and applications. *J Environ Chem Eng*. 2025;13(3):2213–3437. <https://doi.org/10.1016/j.jece.2025.116921>.
8. Anjuman Ayub AK, Wani SM, Malik M, Ayub R, Singh C, Chopra T, Malik. Green nanoscience for healthcare: Advancing biomedical innovation through eco-synthesized nanoparticle, *Biotechnology Reports*, Volume 47, 2025, e00913, ISSN 2215-017X, <https://doi.org/10.1016/j.btre.2025.e00913>
9. Jinhui Wu N, Gu. New Orientation of Interdisciplinarity in Medicine: Engineering Medicine, *Engineering*, Volume 45, 2025, Pages 252–261, ISSN 2095–8099. <https://doi.org/10.1016/j.eng.2024.09.009>
10. Abayomi Bamisaye MA, Adekola SM, Abati NO, Etafo. Okewole Samson Ademola, Philips Tosin Joseph, Oreniyi Samuel, Olumuyiwa Olufisayo Ogunlaja, Henrietta Langmi, Mopelola Abidemi Idowu, Recent advances in metal/metal-oxide nanoparticle-polymer nanohybrid for biomedical applications. *Mater Today Chem*. 2025;49(103086):2468–5194. <https://doi.org/10.1016/j.mtchem.2025.103086>.
11. Ahmed S, Ahmad M, Swami BL, Ikram SA. A review on plant extract mediated synthesis of silver nanoparticles for antimicrobial applications: a green expertise. *J Adv Res*. 2016;7(1):17–28. <https://doi.org/10.1016/j.jare.2015.02.007>.

12. Rajeshkumar S, Jayakodi S, Tharani M, Alharbi NS, Thiruvengadam M. Antimicrobial activity of probiotic bacteria-mediated cadmium oxide nanoparticles against fish pathogens. *Microb Pathog.* 2024;189:106602. <https://10.1016/j.micpath.2024.106602>.
13. Ahmed N, Abd, Mohammed F, Al-Marjani ZA, Kadham. Antibacterial Activity Of Cadmium Oxide Nanoparticles Synthesized By Chemical Method. *J Multidisciplinary Eng Sci Technol.* 2016;3:5007–11.
14. Ejidike IP, Direm A, Parlak C et al. Cadmium oxide nanoparticles from new organometallic Cd(II)-Schiff base complex and in vitro biological potentials: dual *S. aureus* and *E. coli* DNA gyrase inhibition by the precursors via in silico binding modes' study. *Res Chem Intermed* 50, 2763–2791 (2024). <https://doi.org/10.1007/s11164-024-05291-9>
15. Mahdiah M, Zolanvari A, Azimee AS, Mahdiah M. Green biosynthesis of silver nanoparticles by *Spirulina platensis*. *Sci Iran.* 2012;19(3):926–9. <https://doi.org/10.1016/j.scient.2012.01.010>.
16. Jaiswal RL, Pandey BK. Modeling for the study of thermophysical properties of metallic nanoparticles. *SN Appl Sci.* 2021;3:466. <https://doi.org/10.1007/s42452-021-04478-8>.
17. Ahmad A, Mukherjee P, Senapati S, Mandal D, Khan MI, Kumar R, Sastry M. Extracellular biosynthesis of silver nanoparticles using the fungus *Fusarium oxysporum*, *Colloids Surf. B Biointerfaces.* 2003;28(4):313–8. [https://doi.org/10.1016/S0927-7765\(02\)00174-1](https://doi.org/10.1016/S0927-7765(02)00174-1).
18. Klaus-Joerger T, Joerger R, Olsson E, Granqvist C. Bacteria as workers in the living factory: metal-accumulating bacteria and their potential for materials science. *Trends Biotechnol.* 2001;19(1):15–20. <https://doi.org/10.1016/s0167-7799>.
19. Urfa Anisa DB, Darmadi SS, NgafwanNgafwan M, Effendy ING, Wardana. The role of *Carica papaya* latex bio-catalyst in recycling of used fibre pulp. *Arab J Chem Volume.* 2022;15:1878–5352. <https://doi.org/10.1016/j.arabjc.2022.103952>.
20. Ngafwan M, Effendy GS, Samidjo I, Gusti Ketut Puja ING, Wardana. The role of *Carica papaya* latex bio-catalyst and thermal shock in water on synthesizing rice husk. *Arab J Chem.* 2023;16(4):104568, ISSN1878–5352. <https://doi.org/10.1016/j.arabjc.2023.104568>.
21. Babalola BA, Akinwande AI, Otunba AA, Adebami GE, Babalola O. ChekwubeNwufo, Therapeutic benefits of *Carica papaya*: A review on its pharmacological activities and characterization of papain. *Arab J Chem.* 2024;17(1):1878–5352. <https://doi.org/10.1016/j.arabjc.2023.105369>.
22. Eziuche A, Ugbogu ED, Dike ME, Uche LR, Etumnu BC, Okoro OC, Ugbogu OE, Adurosakin. Chiemela EnyinnaChinma, Esther Ohaeri, Emeka J. Iweala, Ethnomedicinal uses, nutritional composition, phytochemistry and potential health benefits of *Carica papaya*, *Pharmacological Research - Modern Chinese Medicine*, Volume 7,2023,100266, ISSN 2667 – 1425,<https://doi.org/10.1016/j.prmcm.2023.100266>
23. Amin AH, Bughdadi FA, Abo-Zaid MA, Ismail AH, El-Agamy SA, Alqahtani A, El-Sayyad HIH, Rezk BM, Ramadan MF. Immunomodulatory effect of papaya (*Carica papaya*) pulp and seed extracts as a potential natural treatment for bacterial stress, *J. Food Biochem.* 43 (12) (2019) e13050 2019 Dec. <https://doi.org/10.1111/jfbc.13050>

24. Santana LF, Inada AC, Espirito Santo BLSD, Filiú WFO, Pott A, Alves FM, Guimarães RCA, Freitas KC, Hiane PA. Nutraceutical potential of *Carica papaya* in metabolic syndrome. *Nutrients*. 2019;11(7):1608. <https://doi.org/10.3390/nu11071608>.
25. Dharmarathna SL, Wickramasinghe S, Waduge RN, Rajapakse RP, Kularatne SA. Does *Carica papaya* leaf extract increase the platelet count? An experimental study in a murine model, *Asian Pac. J Trop Biomed*. 2013;3(9):720–4. [https://doi.org/10.1016/S2221-1691\(13\)60145-8](https://doi.org/10.1016/S2221-1691(13)60145-8).
26. Gayathri T, Logesh Kumar S, Sangavi S, Yudhika M, Swathy M. Green synthesis of copper oxide nanoparticles using *Carica papaya* and their antimicrobial activity, *Materials Today: Proceedings*, 2023, ISSN 2214–7853. <https://doi.org/10.1016/j.matpr.2023.11.136>
27. Jayamani T, Augustine Arul Prasad T, Edal Queen J, Scholastica Mary Vithiya B, Tamizhdurai P, Kumar NS, Al-Fatesh AS. Janardhan Reddy Koduru, Catalytic reduction of anionic and cationic toxic dyes and evaluation of antimicrobial activity using green synthesized palladium nanoparticles employing *Carica papaya* aqueous leaf extract. *J Saudi Chem Soc* Volume 27, Issue 6,2023,101759, ISSN 1319–6103, <https://doi.org/10.1016/j.jscs.2023.101759>
28. SeerangarajVasantharaj S, Sathiyavimal P, Senthilkumar F, LewisOscar A, Pugazhendhi. Biosynthesis of iron oxide nanoparticles using leaf extract of *Ruellia tuberosa*: Antimicrobial properties and their applications in photocatalytic degradation. *J Photochem Photobiol B*. 2019;192:74–82. <https://doi.org/10.1016/j.jphotobiol.2018.12.025>.
29. Scholastica O, Anadozie OB, Adewale AO, Fadaka OB, Afolabi S, Roux. Synthesis of gold nanoparticles using extract of *Carica papaya* fruit: Evaluation of its antioxidant properties and effect on colorectal and breast cancer cells, *Biocatalysis and Agricultural Biotechnology*, 42, 2022, 102348, ISSN 1878–8181<https://doi.org/10.1016/j.bcab.2022.102348>
30. Harshiny Muthukumar SN, Mohammed NI, Chandrasekaran AD, Sekar A, Pugazhendhi M, Matheswaran. Effect of iron-doped Zinc oxide nanoparticles coating in the anode on current generation in microbial electrochemical cells, *International Journal of Hydrogen Energy*, Volume 44, Issue 4,2019, Pages 2407–2416, ISSN 0360–3199,<https://doi.org/10.1016/j.ijhydene.2018.06.046>
31. Haq BU, Ahmed R, Goumri-Said S. DFT characterization of cadmium doped zinc oxide for photovoltaic and solar cell applications, *Solar Energy Materials and Solar Cells*, 130, 2014, Pages 6–14, ISSN 0927 – 0248, <https://doi.org/10.1016/j.solmat.2014.06.014>
32. Elżbieta R-L, Pyszka I, Włodzimierz, Urbaniak. Cadmium(II) and lead(II) extraction and transport through polymer inclusion membranes with 1-alkyl imidazole, *Desalination and Water Treatment*, Volume 214, 2021, Pages 56–63, ISSN 1944–3986,<https://doi.org/10.5004/dwt.2021.26646>
33. Deepak Singhal PS, Rana. Cadmium oxide nanoparticles doped with nickel and silver: Photocatalytic activity for environmental remediation. *Mater Chem Phys*. 2024;314:0254–584. <https://doi.org/10.1016/j.matchemphys.2024.128895>.
34. Sivalingam S, Kavirajwar J, Seethalakshmi K, Gayathri J, Roniboss A. Green synthesis of cadmium oxide nanoparticles (CdO-NPS) using *syzygiumcumini*: exploring industrial applications of CdO NPs

- as a corrosion inhibitor of mild steel in the acidic environment. RSC Adv. 2024;14(12):7932–9. <https://doi.org/10.1039/d4ra00560k>. ISSN 2046–2069.
35. Muhammad Tariq AK, Qureshi S, Karim M, Sirajuddin N, Abbas M, Imran. Jaffir Hussain Shirazi, Synthesis, characterization and fuel parameters analysis of linseed oil biodiesel using cadmium oxide nanoparticles, Energy, 222, 2021, 120014, ISSN 0360–5442, <https://doi.org/10.1016/j.energy.2021.120014>
 36. Panchsheela Ubale S, Mokale S, More S, Waghmare V, More N, Munirathinam S, Dilipkumar RK, Das S, Reja VB, Helavi. Shiva Prasad Kollur, Evaluation of in vitro anticancer, antimicrobial and antioxidant activities of new Cu(II) complexes derived from 4(3H)-quinazolinone: Synthesis, crystal structure and molecular docking studies. J Mol Struct Volume. 2022;1251:0022–2860. <https://doi.org/10.1016/j.molstruc.2021.131984>.
 37. Bulbule AM, Mandroli PS, Bhat KG, Bogar CM. In vitro evaluation of cytotoxicity of Emblica officinalis (amla) on cultured human primary dental pulp fibroblasts. J Indian Soc Pedod Prev Dent. 2019 Jul-Sep;37(3):251–257. doi: 10.4103/JISPPD.JISPPD_85_18. PMID: 31584024. 10.4103/JISPPD.JISPPD_85_18
 38. Tammina DS, Kumar. Mandal, Badal, Kadiyala, Photocatalytic Degradation of Methylene Blue Dye by Nonconventional synthesized SnO₂ Nanoparticles Environmental Nanotechnology, Monitoring & Management 2018/07/01,VL-10 DO- 10.1016/j. enmm.2018.07.006
 39. Garima Mishra P, Singh M, Molla YS, Yimer A, Ewunetie. Tesfaye Yimer Tadesse, Teklie Mengie Ayele, Belayneh Kefale, Nutraceuticals: A source of benefaction for neuropathic pain and fibromyalgia. J Funct Foods Volume. 2022;97:1756–4646. <https://doi.org/10.1016/j.jff.2022.105260>.
 40. Makarand K, Sakate SB, Wategaonkar DN, Zambare UV, Shembade AV, Moholkar, Neeraj R, Prasad AP, Patil AR, Patil BM, Sargar, Balasaheb N, Kokare. Dual extracellular activities of cobalt and zinc oxides nanoparticles mediated by Carica Papaya Latex: Assessment of antibacterial, antifungal, and anticancer activities. Inorg Chem Commun. 2025;114538:1387–7003. <https://doi.org/10.1016/j.inoche.2025.114538>.
 41. Monu Gupta P, Chaudhary A, Singh A, Verma D, Yadav BC, Yadav. Development of MoO₃-CdO nanoparticles based sensing device for the detection of harmful acetone levels in our skin and body via nail paint remover. Sens Actuators B: Chem 368. 2022;132102:0925–4005. <https://doi.org/10.1016/j.snb.2022.132102>.
 42. Aysha Bukhari I, Ijaz H, Zain U, Mehmood MM, Iqbal E, Gilani A, Nazir. Introduction of CdO nanoparticles into graphene and graphene oxide nanosheets for increasing adsorption capacity of Cr from wastewater collected from a petroleum refinery, Arabian Journal of Chemistry, Volume 16, Issue 2,2023, 104445, ISSN 1878–5352. <https://doi.org/10.1016/j.arabjc.2022.104445>
 43. Ganesh Singh MS, Chauhan. Characterization of nanocrystalline CdO prepared by solution combustion method for photocatalytic and fluorescence sensing applications. Mater Chem Phys. 2023;308:0254–584. <https://doi.org/10.1016/j.matchemphys.2023.128302>.

44. Sumeet Kumar, Animesh K. Ojha; Synthesis, characterizations and antimicrobial activities of well dispersed ultra-long CdO nanowires. AIP Adv. May 2013;1(5):052109.
<https://doi.org/10.1063/1.4804930>.
45. Kumar S, Kumar. Sumeet, Synthesis, characterizations and antimicrobial activities of well dispersed ultra-long CdO nanowires 2013/05/08 VL – 3 DO – 10.1063/1.4804930.
46. Cuscó R, Ibáñez J, Domenech-Amador N, Artús L, Zúñiga-Pérez J. Muñoz-Sanjosé; Raman scattering of cadmium oxide epilayers grown by metal-organic vapour phase epitaxy. J Appl Phys. March 2010;15(6):063519. <https://doi.org/10.1063/1.3357377>.
47. Saha B, Das S, Chattopadhyay KK. Electrical and optical properties of Al-doped cadmium oxide thin films deposited by radio frequency magnetron sputtering, Solar Energy Materials and Solar Cells, 91, Issue 18,2007, Pages 1692–1697, ISSN 0927 – 0248, <https://doi.org/10.1016/j.solmat.2007.05.025>
48. Sivalingam S, Kavirajwar J, Seethalakshmi K, Gayathri J, Roniboss A. Green synthesis of cadmium oxide nanoparticles (CdO-NPS) using Syzygium cumini: exploring industrial applications of CdO NPs as a corrosion inhibitor of mild steel in the acidic environment. RSC Adv. 2024;14(12):7932–9. <https://doi.org/10.1039/d4ra00560k>. ISSN 2046–2069.
49. Aliaa Mazhar NS, Elkholy NM, Yousif MS, Shalaby. Investigations of Structural, Optical, Thermal, and spectroscopic characteristics of CdO-Ni nanoparticles employed in anticancer activities for cancer cells, Results in Chemistry, 6, 2023, 101204, ISSN 2211–7156, <https://doi.org/10.1016/j.rechem.2023.101204>
50. Khanderao Pagar K, Chavan S, Kasav P, Basnet A, Rahdar N, Kataria R, Oza Y, Abhale B, Ravindran O, Pardeshi S, Pawar B, Pagar S, Ghotekar. Bio-inspired synthesis of CdO nanoparticles using Citrus limetta peel extract and their diverse biomedical applications. J Drug Deliv Sci Technol. 2023;82(104373):1773–2247. <https://doi.org/10.1016/j.jddst.2023.104373>.
51. Srivastava N, Mukhopadhyay M. Green synthesis and structural characterization of CdO nanoparticles. Adv Sci Lett. 2016;22(4):929–34. <https://doi.org/10.1166/asl.2016.6964>.
52. Roman, Marsalek, Particle Size and Zeta Potential of ZnO, Procedia APCBEE. Volume 9, 2014, Pages 13–17, ISSN 2212–6708. <https://doi.org/10.1016/j.apcbee.2014.01.003>
53. Janani B, Gayathri G, Syed A, et al. The Effect of Various Capping Agents on Surface Modifications of CdO NPs and the Investigation of Photocatalytic Performance, Antibacterial and Anti-biofilm Activities. J Inorg Organomet Polym. 2020;30:1865–76. <https://doi.org/10.1007/s10904-020-01440-w>.
54. Aldwayyan A, Jekhedab F, Noaimi M, Hammouti BB, Hadda T, Suleiman. Mohammed. Synthesis and Characterization of CdO Nanoparticles Starting from Organometallic Dmphen-CdI₂ complex. Int J Electrochem Sci. 2013;8:10506–14. [https://doi.org/10.1016/S1452-3981\(23\)13126-9](https://doi.org/10.1016/S1452-3981(23)13126-9).
55. Thema FT, Beukes P, Gurib-Fakim A, Maaza M. Green synthesis of Montepelite CdO nanoparticles by Agathosma betulina natural extract. J Alloys Compd. 2015;646. <https://doi.org/10.1016/j.jallcom.2015.05.279>. Pages 1043–1048, ISSN 0925–8388.

56. Ayman M, Mostafa SA, Yousef, Wael H, Eisa, Mahmoud A, Ewaida, Emad A, Al-Ashkar. Synthesis of cadmium oxide nanoparticles by pulsed laser ablation in liquid environment, *Optik*, 144, 2017, Pages 679–684, ISSN 0030-4026, <https://doi.org/10.1016/j.ijleo.2017.06.065>
57. Alaa Munshi T, Prakash E, Ranjith Kumar A, Balamurugan TM, Habeebullah TM, Bawazeer, Shams H, Abdel-Hafez NM, El-Metwaly T, Indumathi. Comparative investigation of physicochemical properties of cadmium oxide nanoparticles, *Ceramics International*, 48, Issue 3, 2022, Pages 4134–40, ISSN 0272–8842, <https://doi.org/10.1016/j.ceramint.2021.10.204>
58. Rajappan Achary S, Agouram S, Sánchez Royo J Francisco, Martínez-Tomás MC. & Muñoz-Sanjosé, Vicente. One-step growth of isolated CdO nanoparticles on r-sapphire substrates using spray pyrolysis methodology. *RSC Advances* 2014, (44):23137 <https://doi.org/10.1039/c4ra01818d>
59. Trilok Singh DK, Pandya R, Singh. Annealing studies on the structural and optical properties of electrodeposited CdO thin films, *Materials Chemistry and Physics*, 130, Issue 3, 2011, Pages 1366–71, ISSN 0254–0584, <https://doi.org/10.1016/j.matchemphys.2011.09.035>
60. Hammond JS, Gaarenstroom SW, Winograd. Nicholas. X-ray photoelectron spectroscopic studies of cadmium- and silver-oxygen surfaces. *Anal Chem.* 1975;47:2193–9. <https://doi.org/10.1021/ac60363a019>.
61. Gowri S, Gopinath K, Arumugam A. Experimental and computational assessment of my synthesized CdO nanoparticles towards biomedical applications. *J Photochem Photobiol B.* 2018;180. <https://doi.org/10.1016/j.jphotobiol.2018.02.009>. Pages 166–174, ISSN 1011–1344.
62. Rajappan, Achary, Sreekumar and Agouram, Said and Sánchez Royo, Juan Francisco and, Martínez-Tomás MC, Muñoz-Sanjosé. Vicente, One-step growth of isolated CdO nanoparticles on r-sapphire substrates by using the spray pyrolysis methodology, *RSC Advances*, volume 4, 2014, Pages 23137. <https://10.1039/c4ra01818d>
63. Ubale P, Mokale S, More S, Waghamare S, More V, Munirathinam N, Kollur SP. Evaluation of in vitro anticancer, antimicrobial and antioxidant activities of new Cu (II) complexes derived from 4 (3H)-quinazolinone: Synthesis, crystal structure and molecular docking studies. *Journal of Molecular Structure*, (2022).1251, 131984.
64. Gurav R, Surve SK, Babar S, Choudhari P, Patil D, More V, Sankpal S, Hangirgekar S. Rust-derived Fe₂O₃ nanoparticles as a green catalyst for the one-pot synthesis of hydrazine thiazole derivatives. *Org Biomol Chem.* 2020;18(24):4575–82. <https://doi.org/10.1039/d0ob00109k>.
65. Skłodowski K, Chmielewska-Deptuła SJ, Piktel E, Wolak P, Wollny T, Bucki R. Metallic Nanosystems in the Development of Antimicrobial Strategies with High Antimicrobial Activity and High Biocompatibility. *Int J Mol Sci.* 2023;24(3):2104. Published 2023 Jan 20. 10.3390/ijms24032104
66. Maksoud MIAA, El-Sayyad GS, Ashour AH, El-Batal AI, Elsayed MA, Gobara M, El-Khawaga AM, Abdel-Khalek EK, El-Okr MM. Antibacterial, antibiofilm, and photocatalytic activities of metals-substituted spinel cobalt ferrite nanoparticles. *Microb Pathog.* 2019;127:144–58. <https://doi.org/10.1016/j.micpath.2018.11.045>.

67. Arshad A, Osman H, Bagley MC, Lam CK, Mohamad S, Zahariluddin ASM. Synthesis and antimicrobial properties of some new thiazolyl coumarin derivatives. *Eur J Med Chem.* 2011;46(9):3788–94.
68. AshaRani PV, Low Kah Mun G, Hande MP, Valiyaveetil S. Cytotoxicity and genotoxicity of silver nanoparticles in human cells. *ACS Nano.* 2009;3(2):279 – 90. 10.1021/nn800596w. PMID: 19236062.
69. Kathiravan V, Ravi S, Ashokkumar S. Synthesis of silver nanoparticles from *Melia dubia* leaf extract and their in vitro anticancer activity. *Spectrochim Acta Part A Mol Biomol Spectrosc.* 2014;130:116–21.
70. Kanipandian N. Kannan, Soundarapandian, Ramesh, Ramar, Subramanian, Periyasamy, Ramasamy, Thirumurugan Characterization, antioxidant and cytotoxicity evaluation of green synthesized silver nanoparticles using *Cleistanthus collinus* extract as surface modifier. *Mater Res Bull* 2014/01/31-494-502(49) <https://doi.org/10.1016/j.materresbull.2013.09.016>

Scheme 1

Scheme 1 is available in the Supplementary Files section.

Figures

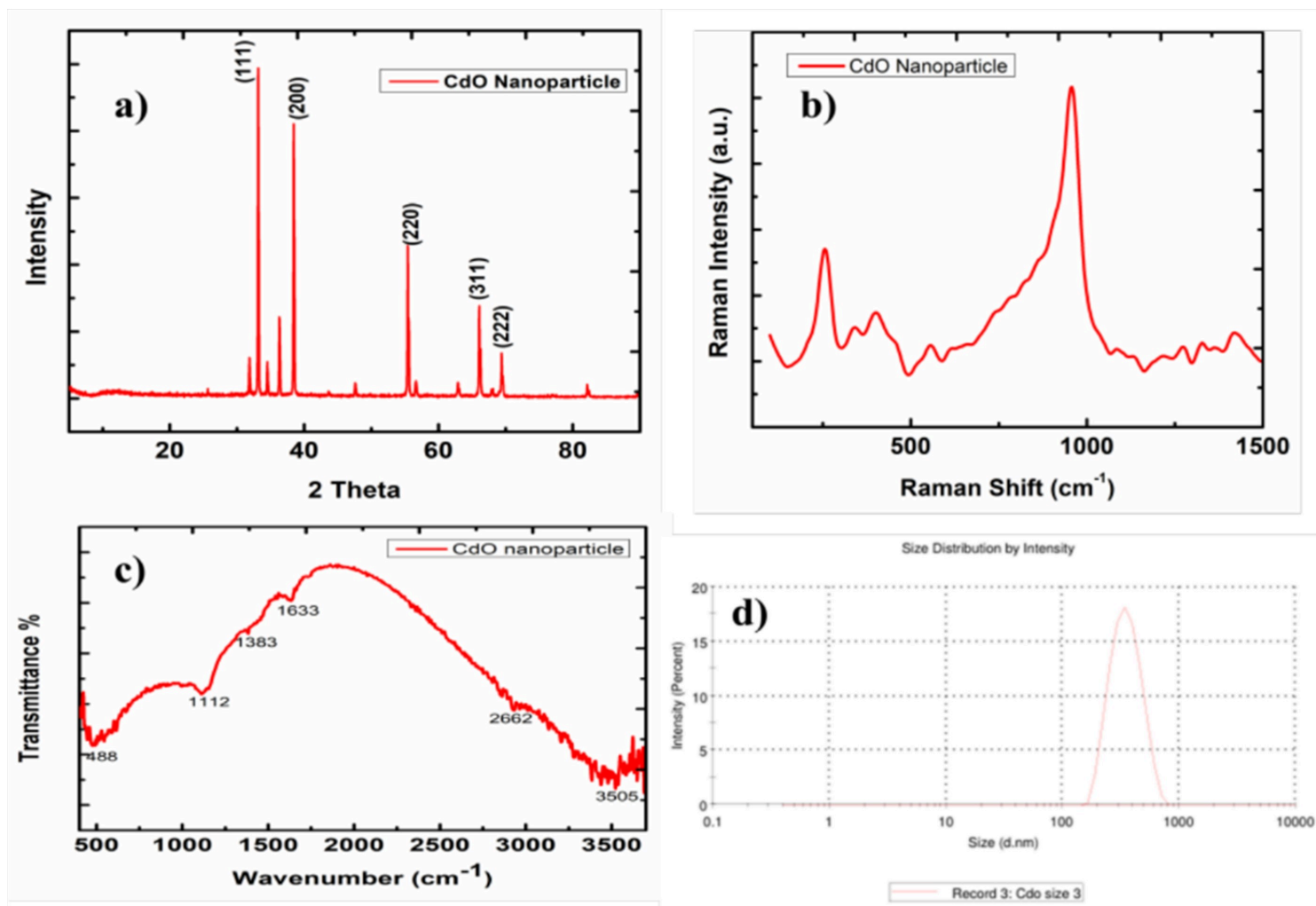


Figure 1

a) XRD, b) Raman Spectrum, c) FT-IR spectrum, and d) Zeta potential of CdO NPs.

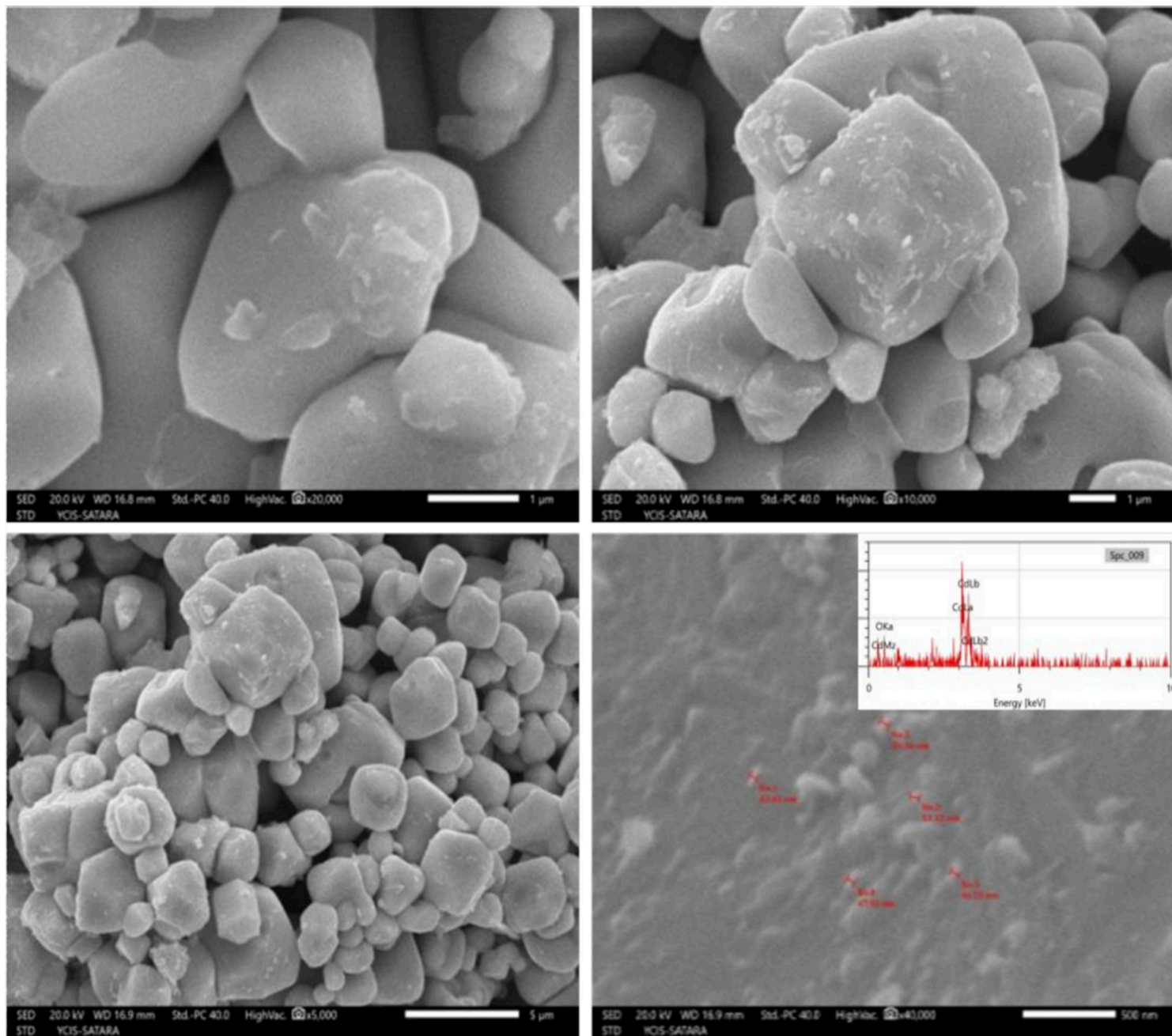


Figure 2

SEM images of CdO NPs (inset shows EDS spectrum of CdO NPs).

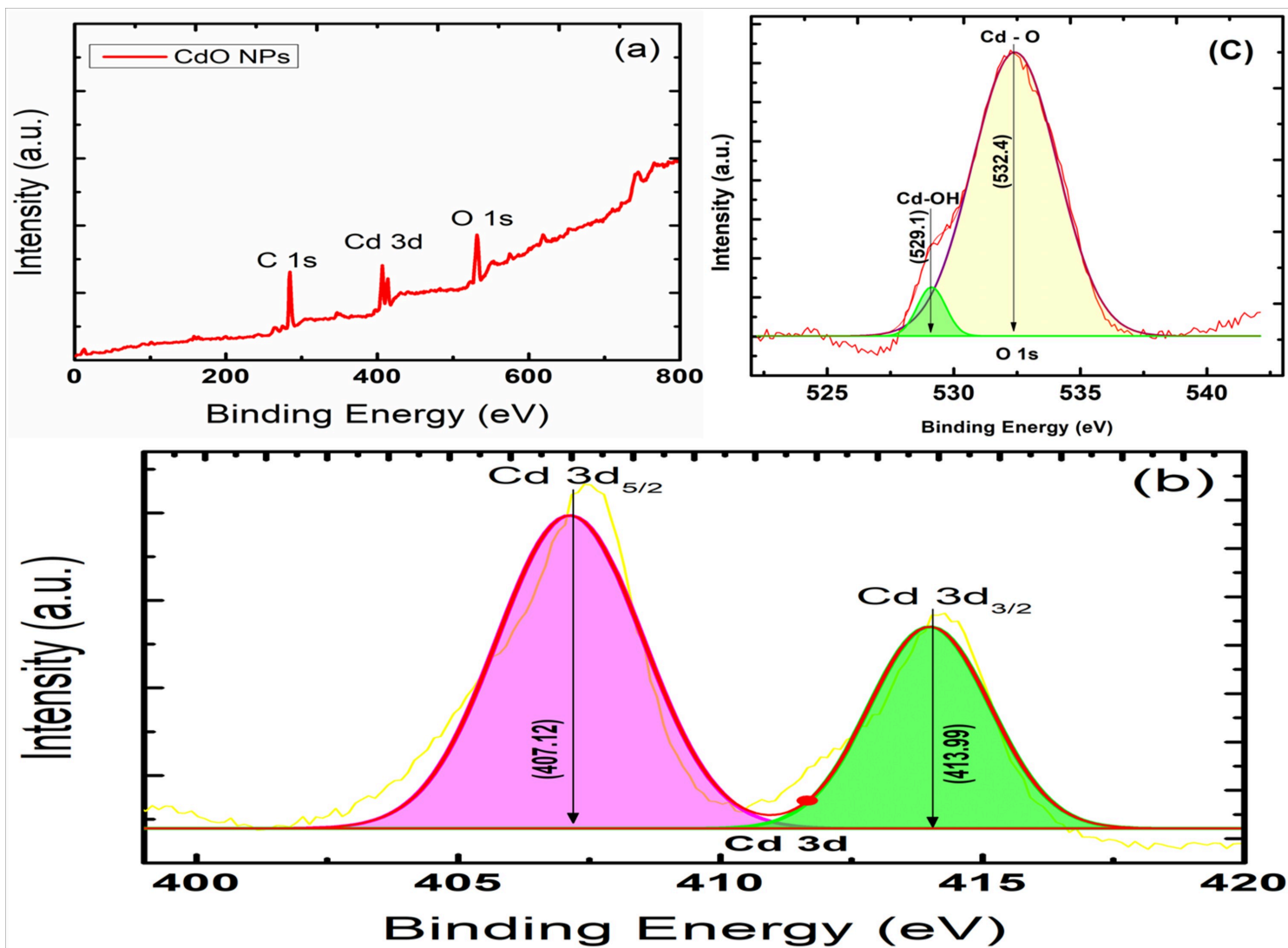


Figure 3

XPS spectrum of (a) CdO NPs, (b) O 1s, and (c) Cd 3d.

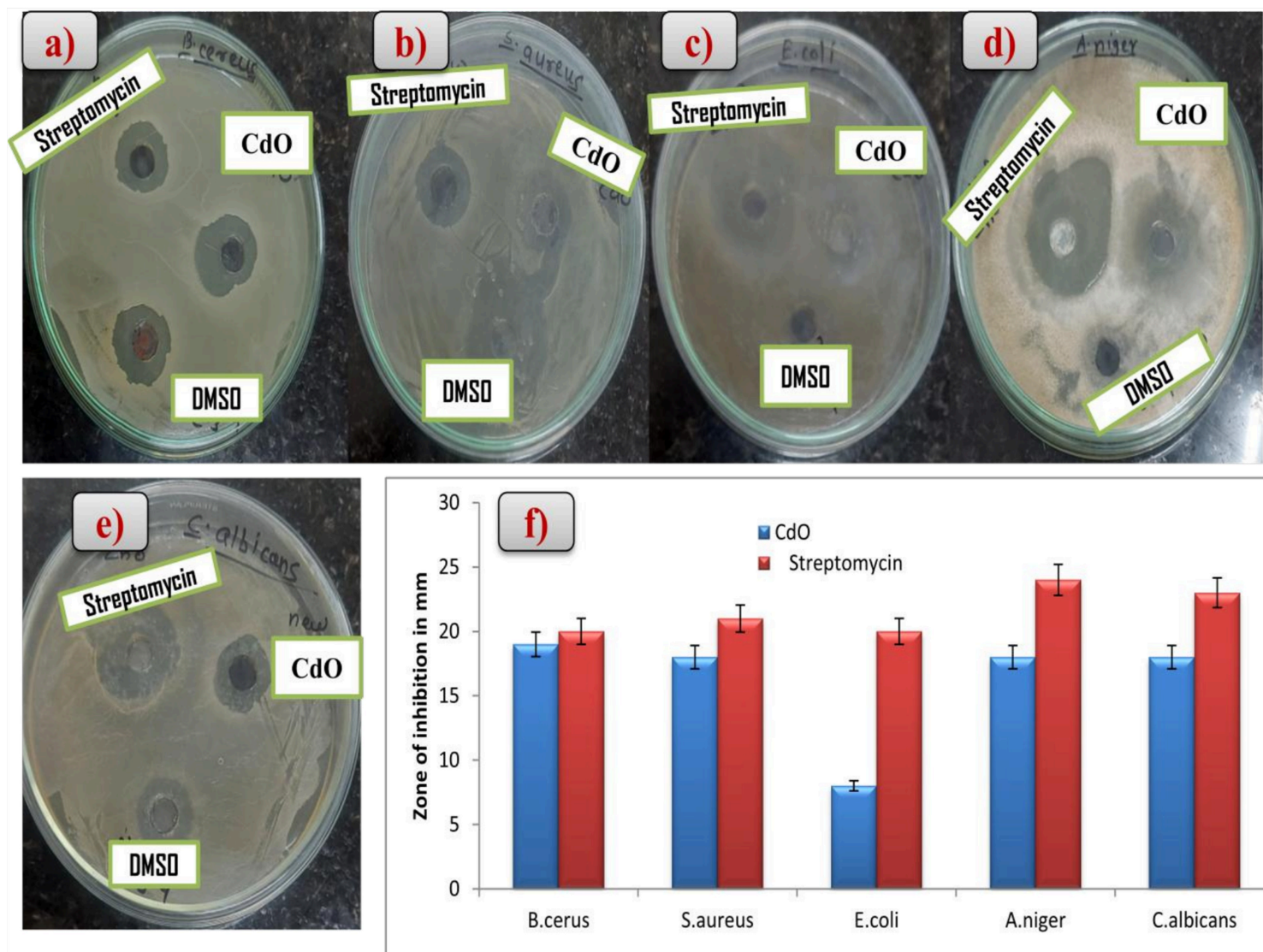


Figure 4

Antibacterial and antifungal activity of the CdO NPs against a) *B. cereus* b) *S. aureus* c) *E. coli* d) *A. niger* and e) *S. albicans*. f) Bar graph of the corresponding CdO NPs

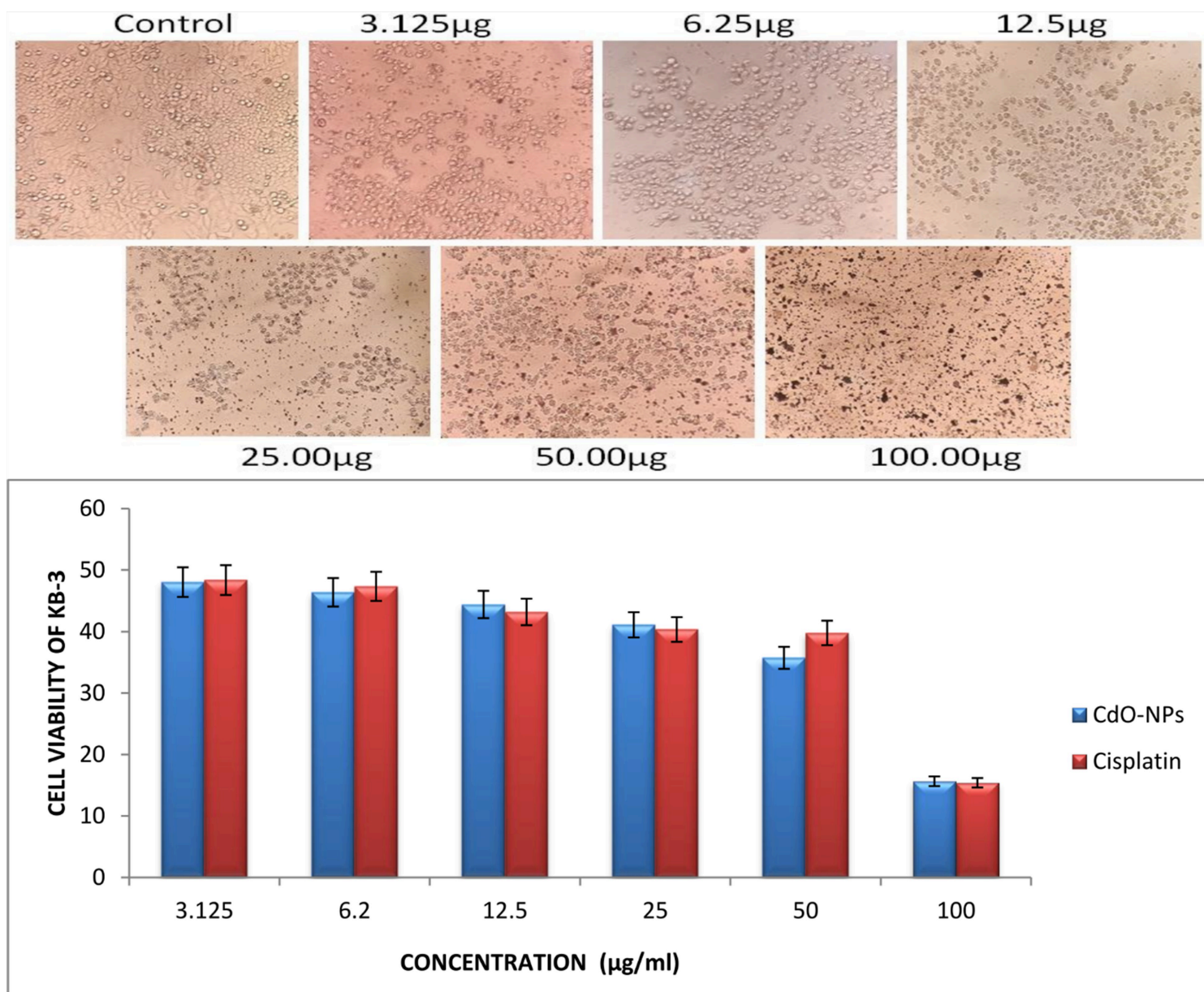


Figure 5

Anticancer activity of CdO nanoparticles at different concentrations.

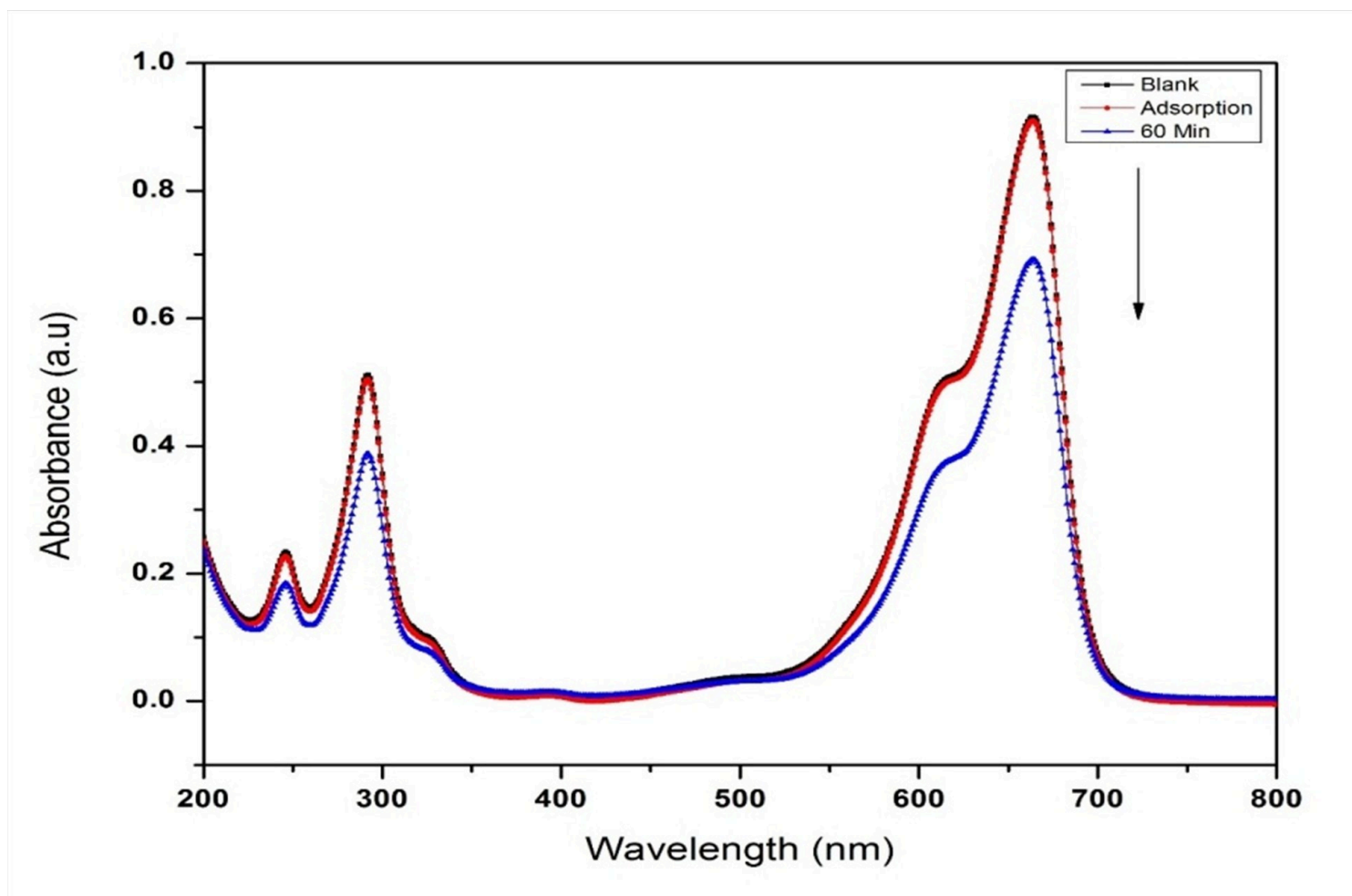


Figure 6

Photocatalytic degradation profiles of MB using pure CdO-NPs.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [GA.docx](#)
- [Highl..docx](#)
- [Scheme1.png](#)