A review on synthesis of Cadmium and Manganese oxide nanoparticles with its vitro applications

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Abstract: *Nanoparticles have a greater surface area and thus precise characteristics in the implementation and development of nano-specifically dimensioned materials. The Photocatalytic degradation properties of cadmium oxide (CdO) and manganese oxide (MnO) nanoparticles (NPs) vary significantly than those of standard products due to their large bandwidth and energy binding. These nanoparticles have potential applications in antibacterial, antioxidant, antimicrobial etc. these nanoparticles were produced using a number of ways such as sol-gel, co-precipitation, green synthesis, microwave etc.*

Keywords: *CdO NPs, MnO NPs, Methods, Activities, Sizes*

1. Introduction:

Nanomaterials possessing a length scale smaller than 100 nm, have gained increasing interest because not just to their important research significance but also to the possible applications that result from their interesting magnetic, electrical and catalytic capabilities [1]. Many of the most appealing inorganic minerals is manganese dioxide (MnO_2). Manganese dioxide is a transition metal oxide of P-type semiconductors with a band gap of 3.3 eV and 3.8 eV [2]. Manganese dioxide nanoparticles could be employed in a variety of applications, including electrodes, catalysis, sensors and optoelectronics [3]. Because of its high theoretical capacity, low cost, and unique features, MnO and MnO_2 nanoparticles have piqued attention as anode materials in lithium ion batteries [4]. The hydrothermal approach [5], sol-gel synthesis [6], wet chemical approach [7], pulsed laser deposition method [8], and precursor approach [9] have all been used to create manganese oxide nanomaterials with diverse forms and outstanding characteristics. Manganese oxides, such as MnO, Mn_5O_8, Mn_2O_3, and Mn_3O_4, have diverse structures and can be employed in a range of applications. Mn-oxide NPs may hold a lot of promise for long-term nanotechnology. The green production use and future prospects of Mn NPs are also the focus of this review, different techniques of green synthesis of Mn NPs have been researched and pretended, including synthesis using plant extract, synthesis using microorganism and low-temperature synthesis of Mn NPs. Each methods structure and size of green produced Mn NPs was compared. Different approaches of green generated Mn NPs were also discussed. In addition, the prospects of green synthesis and characterization of green generated Mn NPs are discussed. Additionally, many applications for green produced Mn NPs, as well as potential uses for green synthesized Mn NPs are discussed [10]. Similarly, due to its n-type metallic oxide feature, cadmium oxide (CdO) has been discovered to be useful in Photocatalytic application such as solar cells, photovoltaics, flat displays, and sensors with explicit and implicit band gaps of 2.3 eV and 1.36 eV respectively [11]. Cadmium oxide nanostructures are a low-cost [12], chemically stable, and comparatively nontoxic metal oxide semiconductor nanomaterials with applications in photo catalysis [13], gas sensors [14], transistors [15], transparent electrode [16], and solar cells [17], drug delivery [18], antibacterial medicines [19], optics [20], and environmental cleanup [21] are only a few of the applications. Because of their physiochemical affinity with the human body, CdO-NPs have remarkable biological, chemical and physical features [22]. Furthermore, the various properties of CdO-NPs make them extremely powerful for commercial applications [23]. Aside from the numerous benefits and applications of metallic NPs, the anti-microbial application represents a significant advancement in the fight against antibiotic-resistant bacterial infection [24].

S. NO	METAL	SIZE	SHAPE	METHODS	CHARCATERIZATION	APPLICATION	REFERENCE
1	Cd	29 nm	Rod-shaped	Chemical precipitation method	XRD, FESEM, UV-vis, and FTIR analysis	Photocatalytic activity	*M. Vidhya et al* (2017)[25]
2	Cd	25 nm	Spherical shape	Microwave method		Photocatalytic and antimicrobial activity	*Kannan k et al* (2020)[26]
3	Cd	58 nm	Spherical shape	Co-precipitation method	UV-vis, spectroscopy, FTIR, SEM, XRD, EDX	Antibacterial activity	*Azam Z et al* (2020)[27]
4	Cd	41 nm	Rod-shaped	Green synthesis	DSC, DTA, and TGA, XRD, EDX, FTIR		*H. KohilaSubathra Christy et al* (2020)[28]
5	Cd	Approximately 5 nm	Spherical shape	Green synthesis	XRD, TEM, SEM, FTIR and EDX	antimicrobial activity	*Mohammed S. Alsaggaf et al* (2020)[29]
6	Cd	24 nm	Spherical shape	Laser ablation	FESEM, HRTEM, EDX, UV-vis, and FTIR		*Ayman M. Mostafa et al* (2017)[30]
7	Cd	28 nm	Spherical shape	Hydrothermal method	XRD, FESEM, UV-vis, and FTIR analysis	Photocatalytic activity	*Naveed Akhtar Shad et al* (2019)[31]
8	Cd	73-94 nm	Regular shape	Green synthesis	FTIR, UV-vis, SEM	Antibacterial activity	*Irfan Ijaz et al* (2020)[32]
9	Cd	22 nm	Spherical shape	Green synthesis	XRD, FESEM, HRTEM and FTIR	Antibacterial activity	*k. Karthik et al* (2017)[33]
10	Cd	approximately 14 nm	Spherical shape	Hydrothermal method	XRD, FESEM, UV-vis, FTIR	Photocatalytic activity	*Sumeet Kumar et al* (2016)[34]
11	Cd	Approximately 22 nm	Spherical shape	Laser ablation	IR, UV-vis, XRD, TEM, SEM, and EDX		*Eman A. Mwafy et al* (2019)[35]
12	Cd	28.92 and 44.95 nm	Stick-like morphology	Sol-gel method	XRD, FESEM, HRTEM and FTIR		*Y N Permana et al* (2017)[36]
13	Cd	4-8 nm	Spherical shape	Co-precipitation method and hydrothermal method	UV, FTIR, HRTEM, XRD, XPS, AFM, and BET	Antibacterial activity	*Sourav Sadhukhanet et al* (2019)[37]
14	Cd	39.73 nm	Spherical shape	Co-precipitation method	FTIR, XRD, SEM, with EDAX and UV-vis	antimicrobial activity	*D. Durga Vijay Karthik et al* (2014)[38]
15	Cd	10-32 nm	Spherical shape	Green synthesis	XRD, FESEM, HRTEM and FTIR	Cytotoxic and genotoxic activity	*E. Demir et al* (2020)[39]

16	Cd	35 nm	Spherical shape and irregular	Green synthesis	UV-vis, FESEM, TEM, XRD		*JavadkarimiAndeani et al* (2013)[40]
17	Cd	25 nm		Sol-gel method	SAED, EDX, XRD, TEM, SEM		*B. Goswami et al* (2015)[41]
18	Cd	8 nm	Quasi-spherical shape	Green synthesis	HRTEM, EDS, XRF, XRD, ATR, FTIR Raman, XPS		*F.T. Thema et al* (2015)[42]
19	Mn	25-30 nm		Co-precipitation method	UV-vis, XRD, FTIR		*Harish Kumar et al* (2013)[43]
20	Mn	40.5-70 nm	Spherical shape	Co-precipitation method	XRD, FESEM, HRTEM and FTIR	antimicrobial activity	*Elsa Cherian et al* (2016)[44]
21	Mn	23.7 nm	Tetragonal shape	Green synthesis	UV-vis, XRD, FTIR, SEM	Antibiofilm and antioxidant activity	*KeerthanaSivanesan et al* (2017)[45]
22	Mn	33 nm	Regular shape	Co-precipitation method	FTIR, UV-vis, TGA/DSC, XRD, SEM-EDX, TEM and BET		*Taimur Athar et al* (2012)[46]
23	Mn	31.7 nm	Hexagonal shape	Solid state reaction route	UV-vis, XRD, FTIR		*VikaskumarVerma et al* (2018)[47]
24	Mn	13.50 nm	Irregular shaped	Green synthesis	XRD, FESEM, HRTEM, FTIR		*Nur Oktri Mulya Dewi et al* (2020)[48]
25	Mn	22 nm, 18 nm and 16 nm	Sphere shaped	Green synthesis	FTIR, XRD and FESEM	Antibacterial activity	*Naveen Chandra Josh et al* (2020)[49]
26	Mn	20 nm and 22 nm	Ball shaped	Green synthesis	UV-vis, XRD, FTIR, DSC		*Yikal Dessie et al* (2020)[50]
27	Mn	32 nm	Spherical shape	Green Synthesis	UV-vis, XRD, FTIR, SEM		*Mahsa Souri et al* (2018)[51]
28	Mn	17-32 nm	Spherical shape	Green Synthesis	UV-vis, XRD, FTIR, PSA, SEM, EDAX and HRTEM	antimicrobial activity	*R. Manjula et al* (2019)[52]
29	Mn	4-18 nm	Spherical shape	Green Synthesis	UV-vis, XRD, FTIR, SEM		*A K M Atique Ullah et al* (2018)[53]
30	Mn	29 and 6 nm	Nanorod shape	Simple microwave method	HRTEM, XRD, FTIR, FESEM		*Veeman Sannasi et al* (2020)[54]
31	Mn	8-15 nm	Spherical shape	Green synthesis	TEM, XRD, BET, XPS, VSM		*Adina Stegarescu et al* (2019)[55]
32	Mn	20-50 nm	Needle like shape	Co-precipitation method	TEM, UV-vis, Raman, XRD	Supercapacitor capacitance	*Sheng Chen et al* (2010)[56]
33	Mn	40-70 nm	Rectangular shape	Electrophoretic deposition method	UV-vis, FTIR, XRD, SEM, EDAX, HRTEM		*Shahram Ghasemi et al* (2015)[57]

Table 1. **shows different methods, characterization and applications of CdO and MnO NPs.**

M. Vidhya et al (2017) successfully synthesized CdO NPs using a simple chemical precipitation approach. XRD, FESEM, UV-vis, and FTIR analysis validated the as-produced NPs. According to the FESEM investigation, SnO_2 has a spherical morphology with no agglomeration, whereas CdO NPs have rod-shaped grains with highly agglomerated structures. The average crystallite size of CdO NPs was determined to be 23 nm. **Kannan k et al (2020)** have successfully manufactured CdO nanocomposites utilizing a simple and effective microwave-assisted process. CdO nanocomposite crystal lattice structure was discovered to be cubic. The particle of the nanocomposites has a spherical form, and their size is 25 nm. The Photocatalytic activity of the microwave-assisted CdO nanocomposites against RB dye was remarkable as was its antibacterial efficacy against human infections. **Azam Z et al (2020)** aimed to develop a simple, efficient, and cost-effective method for producing microbially mediated CdO-NPs. The research will be useful in explaining NPs creation in medication synthesis against resistant infection. The CdO NPs that have been created were spherical in shape, with an average crystalline size of 58 nm. **H. KohilaSubathra Christy et al (2020)** synthesized CdO NPs utilizing cassia auriculata extract, which provides cost-effective, simple, and efficient techniques. The SEM image depicts a rod-like structure of produced CdO NPs with a particle size of 41 n. the temperature behaviour of CdO NPs is depicted by DSC, DTA, and TGA curves. The electro catalytic of produced CdO NPs is demonstrated by cyclic voltammeter measurements. **Mohammed S. Alsaggaf et al (2020)** synthesized CdO NPs by green approach from *Aspergillus niger* extract. The presence of spherical particles around 5 nm was discovered using scanning electron microscopy. Antimicrobial activity was found in the CdO NPs against E. coli, pseudomonas vulgaris. Staphylococcus aureus, and Bacillus subtilis. The biosynthesized CdO NPs show cytotoxic action against MCF7, PC3, and A549 cell lines, with 50% inhibitory doses of 190g/ml, 246g/ml, and 149g/ml respectively. **Ayman M. Mostafa et al (2017)** successfully produce CdO NPs used laser ablation in a liquid environment with an average particle size of 24 nm. A UV-vis spectrophotometer and an FTIR spectrophotometer were used to investigate the optical characterization. XRD was used to investigate the material structure, whereas FESEM, HRTEM, and EDX were used to investigate its morphological qualities. The creation of the CdO phase was confirmed by the experimental results of XRD and FTIR investigation. **Naveed Akhtar Shad et al (2019)** was employed to make CdO nanosheets by hydrothermal approach. The particle sizes are 28 nm in diameter and have a spherical form. The photodegradation effectiveness of the hazardous organic dye CBB has been successfully evaluated using CdO nanosheets. **Irfan Ijaz et al (2020)** synthesized CdO NPs from Calendula Officinalis. Several techniques, including UV-vis spectroscopy, FTIR, and SEM were used to analyze the nanoparticles. Similarly, UV absorbance at 300 nm was obtained, indicating that CdO NPs had been synthesized. In nanosynthesis, the photochemical serves as a capping agent. SEM is an abbreviation for scientific and engineering method SEM images revealed that the size of CdO NPs varied between 73-94 nm. **K. Karthik et al (2017)** make CdO NPs by chelating agent A. paniculata via a biological approach. The cubic structure of the XRD pattern is seen and the nanoparticles are 164 nm on average, according to the FESEM image and HRTEM. EDS examination indicated the existence of Cd and O. **Sumeet Kumar et al (2016)** synthesized CdO NPs by hydrothermal method. Pure CdO and GO-CdO nanocomposites were studied for their structural, optical and magnetic properties, as well as Photocatalytic activity. The hydrothermal process is a good way to develop mono-disperse, stable, and dense CdO NPs on the GO sheets, according to the result of HRTEM and Raman studies. **Eman A. Mwafy et al (2019)** synthesized CdO NPs by pulsed laser ablation of Cd sheets immersed in functionlized MWCNTs solution, followed by cauterization employing various spectroscopic techniques such as IR, UV-vis, XRD, TEM, SEM and EDX. Under the influence of CdO NPs, mixing of MWCNTs and nano CdO vibration modes, bundles and spherical shape particles are attached with nanotubes of MWCNTs structure, crystallized rombohedral and face-centered cubic structures. **Y N Permana et al (2017)** synthesized CdO NPs using Parkiaspeciosa Hassk seed extract as the basic source and stabilizing agent. The direct band gap at 2.0 eV was confirmed by UV-vis DRS measurements. The CdO bond was discovered in the range of 400-705 cm^{-1} in the FTIR spectrum. The XRD measurement revealed that the CdO structure is well formed in cubic phase, with typical nanocrystals sizes ranging between 28.92 and 44.95 nm. **Sourav Sadhukhan et al (2019)** synthesized CdO NPs using dextrose as a reducing agent by green approach hydrothermal method, which is effective for removing oxygen functionalities from GO after reduction and makes a significant contribution to the accumulation of CdO NPs on the RGO sheets. HRTEM, XRD, XPS, AFM and BET analysis were used to explore the structural morphology and surface chemistry of RGO/CdO nanocomposites, revealing a dense and homogeneous distribution of CdO NPs on RGO sheets. Synthesized CdO nanoparticles have a particle size of 3-4 nm and are spherical in shape. **D. Durga Vijay karthik et al (2014)** synthesized CdO NPs by using precipitation method. CdO NPs have an average crystallographic size of 39.73 nm and a spherical shape. FTIR, XRD, SEM with EDAX, and UV-vis measurement were used to characterize the produced nanoparticles, which demonstrated good antibacterial efficacy by preventing their growth. **Demir E et al (2020)** synthesized CdO NPs were both cytotoxic and genotoxic. In both TK6 and HepG2 cells, treatment with NPs reduced cell viability, decreased ATP content, and increased LDH leakage. In TK6 cells, the NPs caused DNA breaks and chromosomal damage, as well as

mutations in murine lymphoma cells. These findings reveal the cytotoxicity and genotoxicity of CdO NPs in human and rodent cell lines, which can be used to determine the danger of CdO NPs. **Javadkarimi Andeani et al (2013)** synthesized CdO NPs using flower broth of A. wilhelmsii. UV-vis, FTIR, and FESEM were used to characterize these nanoparticles. We believe that tannins, flavonoids alkaloids and carotenoids were primarily responsible for the decrease in cadmium ions and the stabilization of the nanoparticles. The biological generation of CdO NPs has shown to be a simple, quick and environmentally friendly way for manufacturing CdO NPs at room temperature and extracellular without the need for further physical and chemical procedures**. B. Goswami et al (2015)** synthesized CdO NPs using a simple sol-gel synthesis process demonstrated luminescent capabilities in the visible region of the electromagnetic spectrum. The luminescence characteristics of cadmium interstitial vacancies and oxygen vacancies were both relevant. X-ray diffraction corroborated the morphological alteration caused by annealing. All of the experimental outcomes were found to be highly correlated. Diffuse reflectance spectra and photoluminescence spectra were used to examine optical characteristics. High-resolution transmission electron microscopy was used to evaluate structural characteristics. **F.T. Thema et al (2015)** demonstrated the green, innovative, and environmentally friendly synthesis of single phase highly crystalline CdO nanoparticles employing the natural extract of Agathosmabetulina's as an effective oxidizing/reducing chemical agent. HRTEM, EDS, XRF, XRD, ATR-FTIR, and XPS tests all show that a thermal annealing of 500º C for 2 hours under normal air circumstances results in well crystalline single phase CdO NPs. **Harish Kumar et al (2013)** used a green chemistry co-precipitation approach to make MnO_2 nanoparticles with a simple cubic structure. The characteristics peaks of Mn-O stretching are revealed by FTIR spectral analysis. Metal nanoparticles cause a sharp absorption at 339.60 nm in the UV-visible spectrum. The average size predicted by XRD spectra is 25-30 nm. **Elsa Cherian et al (2016)** used the co-precipitation approach to make manganese dioxide nanoparticles. The existence of manganese dioxide nanoparticles was confirmed using UV-vis spectroscopy. The FTIR spectrum findings show the manganese dioxide nanoparticles peculiar peaks. SEM investigation revealed a spherical shape with a diameter ranging from 40.5-70 nm. Synthesized manganese dioxide nanoparticles can be employed as an antibacterial agent. **Keerthana Sivanesan et al (2017)** synthesized MnO NPs from the Aegle marmelos fruit extract in a more environmentally friendly method. The average crystallite size of the produced nanoparticles was 23.7 nm. The maximum activity against E.coli was 1.2170.43 at 80 g/ml, and the highest activity against B.subtilis was 1.7050 at 100 g/ml. The maximum activity of nanoparticles against reactive oxygen species was reported to be 27.310 at a dose of 5 mg/ml. **Taimurathar et al (2012)** synthesized MnO NPs were created using a soft chemical technique with regulated morphological and surface particle properties, with a size of roughly 33 nm. Synthetically and physically well defined particles allow for a better grasp of knowledge and structural qualities, which aids in the development of future applications. FTIR, UV-vis, TGA/DSC, XRD, SEM-EDX, TEM, and BET were used to characterize the nanoparticles as they were produced. **Vikas kumar Verma et al (2018)** synthesized MnO NPs from solid state process. X-ray diffraction, scanning electron microscopy, and UV-vis absorption spectroscopy were used to analyze the produced material. The addition of MnO_2 to Zn increased crystallization and reduced crystallite size. The hexagonal sized particles were uniformly distribution in zinc oxide, leaving a large number of pores. These pores served as adsorption sites for moisture, for 1.0 weight % MnO_2 doped zinc oxide, the minimum average crystallite size was 31.7 nm. **NurOktriMulyaDewi et al (2020)** synthesized MnO NPs by green synthesis approach employing Euphorbia heterophylla leaves extract. FTIR at 559 cm^{-1} wave number revealed chemical bonding of Mn-O. Particle size analyser measurement revealed that the particle size of MnO_2 NPs was around 56.68 nm. TheUV-vis DRS spectrophotometer confirmed that the band gap energy of MnO_2 NPs was 2.85 eV. SEM, XRD, and TEM were used to confirm the morphology of MnO_2 NPs. MnO_2 NPs was found to have an uneven form using an electron microscope. **Naveen Chandra Josh et al (2020)** synthesized MnO NPs by green synthetic technique utilizing A.vera extract was found to be very low cost, efficient, and nontoxic. The FTIR, XRD, and FESEM procedures were used to characterize the recently produced MnO_2 NPs. MnO_2 NPs discovered to have greater antibacterial action. **Yilkal Dessie et al (2020)** synthesized MnO NPs using a biosynthetic process under 25 distinct physiochemical conditions, including the ratio of V. Amygdalina leaf extract, beginning permanganate ion concentration. pH, and reaction duration. XRD research revealed that the average size was between 20-22 nm. According to SEM examination, MnO_2 NPs synthesized under ideal conditions with plant extract as a reducing agent created a better porous image with nanosphericl flower like topograph. **Mahsa Souri et al (2018)** synthesized MnO NPs as a reducing and stabilizing agent with Y. Gloriosa leaf extract and turmeric extract. XRD, FESEM, and TEM studies were used to characterize the MnO_2 NPs. The MnO_2 NPs were produced with a size of roughly 32 nm, according to XRD examination. Plant extract synthesis is possible with a simple reaction at room temperature and pressure, without the use of catalysts, casts or expensive materials. **R.Manjula et al (2019)** synthesized MnO NPs from G. Resinifera leaf extract and characterize them. UV-vis, PSA, SEM-EDAX, XRD, and HRTEM analysis were used to evaluate the produced MnO_2 NPs. According to the findings, the produced MnO_2 NPs are 17-35 nm in diameter and spherical in form. The findings of the FTIR analysis reveal the presence of numerous functional groups that could be involved in diverse biological functions. The antibacterial activity of the produced MnO_2 NPs is strong. **A K M Atique**

Ullah et al (2018) synthesized MnO NPs from a simple green synthesis technique for the production of crystalline-MnO_2 NPs with diameters ranging from 4-18 nm. The method for making MnO_2 nanocrystals is easy, environmentally friendly, cost-effective, and efficient and it does not require any external reducing agents or stabilizers. The magnetic properties of MnO_2 NPs prepared by this method were investigated using a vibrating sample magnetometer at room temperature, and the VSM analysis revealed a small hysteresis loop, indicating that the bio-molecule capped MnO_2 NPs have a weak ferromagnetic property. **Veeman Sannasi et al (2020)** synthesized MnO NPs by two crystallographic phases of MnO_2, a-MnO_2 and b-MnO_2 respectively. The materials were analyzed using SEM and TEM and revealed nanocrystals morphology for a-MnO_2 and nanorod morphology for b-MnO_2. **Adina Stegarescu et al (2019)** synthesized MnO NPs from the surface area of biochemically generated was four times that of chemically generated nanoparticles. MnO_2 oregano had the biggest crystalline core (3.4 nm), the biggest pore volume (0.77 cm^3/g), the biggest surface area (398 m^2/g), and the most Mn ions in low oxidation states. For these reasons, biochemically produced MnO_2 NPs were evaluated for microwave-assisted Trans esterification of grape residue and seeds oil, as well as yeast to get a biofuel end product efficiently.**Sheng Chen et al (2010)** synthesized MnO NPs by a grapheme oxide composite supported by needle like in a water isopropyl alcohol solution using a simple soft chemical method. Intercalation and adsorption of manganese ions onto the GO sheets, followed by crystallization of the crystal species in a double solvent system via dissolution crystallization and oriented attachment mechanism, is proposed as the formation mechanism of these intriguing nanocomposites studied by TEM, Raman, and UV-vis spectroscopy. **Shahram Ghasemi et al (2015)** synthesized MnO NPs using the electrophoretic deposition approach. After that, an electrochemical reduction process is used to reduce the grapheme oxide coating. For the deposition of MnO_2 or ERGO, a two step potential approach and anodic electro deposition approach have been devised. Two potential steps have been used to nucleate and develop manganese oxide on graphene sheets, resulting in homogeneous dispersion of MnO_2 NPs decorated onto ERGO.

2. Conclusion:

CdO NPs and MnO NPs provide a wide range of possible uses due to their unique properties. In this paper we describe how we have been able to encourage progress in Cd and Mn with antibacterial, antimicrobial, Photocatalytic, antibiofilm and antioxidant activities. There have been a number of configurable systems built for large-scale application.

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