Royal International Global Journal of Advance and Applied Research
Peer Reviewed International, Open Access Journal.
ISSN: 2998-4459 | Website: https://rlgjaar.com Volume-2, Issue-12 | December - 2025

Original Article

Green Synthesis of Cobalt Oxide Nanoparticles and their prospective applications

Amol Rajpurkar[1], Harshad Sonawane[2], Mehreen Dawre[3], Sanjay Sonawale[4], Sachin Bangale[5]
[1,2,5] Chemical Research Lab, UG and PG Department of Chemistry, G. M. Vedak College of Science, Tala-Raigad, Maharashtra, India
[3] D. G. Tatkare Arts and Commerce College, Mangaon, Tal Mangaon Dist. Raigad Maharashtra India,
[4]Department of Chemistry, Kirti M. Doongursee College of Arts, Science and Commerce, Dadar(W), Mumbai, Maharashtra

Manuscript ID:
RIGJAAR-2025-021251

ISSN: 2998-4459
Volume 2
Issue 12
Pp. 251-258
December 2025

Submitted: 16 Nov. 2025
Revised: 22 Nov. 2025
Accepted: 25 Dec. 2025
Published: 31 Dec. 2025

Correspondence Address:
Sachin Bangale
Chemical Research Lab, UG and PG Department of Chemistry, G. M. Vedak College of Science, Tala-Raigad, Maharashtra, India
Email:
sachinbangale98@gmail.com

Quick Response Code:

Web. https://rlgjaar.com

DOI: 10.5281/zenodo.18144691

DOI Link:
https://doi.org/10.5281/zenodo.18144691

Abstract

Nanoparticles have been studied and used in a variety of industrial applications during the past few decades. Cobalt oxide particles have garnered a lot of attention due to their many properties, including antifungal, photographic, high catalytic, and antimicrobial activities, as well as the high frequency of toxic substances and the harsh conditions used in the chemical and physical processes of synthesizing various nanoparticles. Plants, fungi, bacteria, and algae have been used in the development of green nanoparticle manufacturing techniques. Cobalt oxide nanoparticles with biological applications and non-hazardous effects have been confirmed by extensive research into several green production strategies in regulation. Consequently, we must compile relevant review articles from subpar sources.

For the ecological preparation of the nanoparticles, the green synthesis technique seems to be more ecologically friendly and safer than traditional physical and chemical preparation methods. Nonetheless, its biomedical uses in this sector occur on a regular basis in a number of processes, including gene transfer, medicine administration, bio-imaging, and biosensors. Furthermore, because of their poisonous look, cobalt oxide nanoparticles are an effective antibiotic substitute and can function as smart weapons against a variety of drug-resistant microorganisms.

Keywords: *Green synthesis. Cobalt oxide nanoparticles (CoO NPs), Eco-friendly nanotechnology, Antimicrobial,*

Introduction

One of the ideas in technological and scientific fields that is expanding the fastest is nanotechnology, which has advanced significantly in recent years. Nanomaterials with distinct physicochemical characteristics can create novel mechanisms, structures, nanoplatforms, and gadgets in a variety of industries [1-4]. Exceptional catalyst reactions, asymmetric optical performance, chemical durability, thermal efficiency, and a high surface area-to-volume ratio are all characteristics of nanomaterials [5–6]. Due of this trait, a number of scholars have searched for alternative methods of preparation. Environmental toxicity results from the need for various hazardous substances, such as defense agents, to preserve stability in traditional physical and chemical processes.

Green Synthesis induced nanoparticle biogenesis provides natural cap binders in the form of proteins and is economical. As a result, green technology is becoming more popular as a safe, non-toxic, and environmentally acceptable choice [7]. From side-to-side biological synthesis of different metal oxides and metal nanoparticles, extracting from plants is used to balance chemical toxicology in the environment. This is a marginal approach to regulate chemical manufacturing and permits different sizes and shapes of nanoparticles with controlled synthesis [8]. Research on environmentally friendly, customized and biocompatible nanomaterials is still quite active in the biomedical field. Nanoshells made of carbon nanotubes (CNTs), quantum dots (QDs), and paramagnetic nanoparticles [9–11] have all been researched extensively, among other biological applications [12-15]

How to cite this article:
Rajpurkar, A., Sonawane, H., Bangale, S., Dawre, M., & Sonawale, S. (2025). Green Synthesis of Cobalt Oxide Nanoparticles and their prospective applications. Royal International Global Journal of Advance and Applied Research, 2(12), 251–258. https://doi.org/10.5281/zenodo.18144691

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Peer Reviewed International, Open Access Journal.
ISSN: 2998-4459 | Website: https://rlgjaar.com Volume-2, Issue-12 | December - 2025

Cobalt oxide nanoparticles are present in various nanostructures and possess unique properties such as semi-conductivity, piezoelectricity, and opticality [16, 17]. As a result, have all been thoroughly studied, among other biological uses [12–15]. Cobalt oxide nanoparticles come in a variety of nanostructures and have special qualities like opticality, piezoelectricity, and semi-conductivity [16, 17]. Cobalt oxide nanoparticle-derived nanomaterials are therefore being tested for a range of uses, such as nanosensors, storing energy, cosmetics, semiconductor devices, and nano- optical devices [18–25]. Two of the most important features of cobalt oxide particles are their low toxicity and biodegradability. Co2+ is an essential trace element for numerous processes in adulthood. Cobalt oxide particles dissolved slowly in strong basic and acidic environments. It has been demonstrated that the discharge of CO2+ ions from aqueous cobalt oxide nanoparticles stresses cells and harms a range of species [26]. The characteristics of cobalt oxide particles are becoming more important in biological applications [27]. The negative consequences of cobalt oxide nanocrystals are related to their solubility. Intracellular [Co2+] levels steadily rise as exterior cobalt oxide nanoparticles disintegrate. It is unclear how cobalt oxide nanoparticles and increased intracellular [Co2+] dissolve in the medium [28]. This study will cover the present-day status of cobalt oxide particles for medical purposes, their environmentally friendly production nature, and their detrimental effects. Based on their composition, nanoparticles can be classified as either organic or inorganic. One type of organic nanoparticle is fullerenes. On the other hand, noble metal nanoparticles (such as gold and silver), transistor nanoparticles, nanoparticles that are magnetic, and (like titanium dioxide and cobalt oxide nanoparticles) [29]. source, size, and structural makeup of nanoparticles can all be used to classify them. Based on where they come from, synthetic as well as natural nanomaterials are divided into two categories [30]. 3-dimensional (3D), zero-degree (0D), one-dimensional (1D), and two-dimensional (2D) nanomaterials are categorized according to their dimensions. One-dimensional nanomaterials have only one small measurement outside the nanoscale range, two-dimensional nanomaterials have a couple nano dimensions outside the nanometer range, and three-dimensional nanomaterials have all nano characteristics outside the nanometer range. Discrete nanometer-scale chunks (1–100 nm) contain various materials [31]. According to their structural configuration and form, nanomaterials are combined materials or nano dispersions. Dendrimers are highly branched macromolecules at the nanoscale.

The primary ingredient of these tiny particles in metallic-based materials is metal, which includes metal oxides like nanosilver, nanogold like dioxide of titanium, and densely packed electronic components like quantum dots. The shapes of carbon-based nanomaterials include ellipsoids, hollow spheres, and tubes. Fullerenes are circular and ellipsoidal carbon nanomaterials, while nanotubes are cylindrical [32]. Determining various techniques for the creation of cobalt nanoparticles of oxide depends heavily on this synthesis study. Additionally, it provides information on the toxicity of cobalt oxide nanoparticles as well as biomedical uses.

Greem Synthesis Experimental methods preparations of NPs

Nanoparticles synthesis methods

For the biogenesis of nanoparticles, two methods are recommended: top-down and bottom-up [30]. In a bottom-up strategy, oxidation/reduction is the most crucial process. These days, the synthesis of nanoparticles is a major scientific concern, and scientists are working to develop green materials and an environmentally acceptable method [31]. The three crucial processes in creating nanomaterials that should be assessed from the perspective of environmentally friendly approach chemistry are the synthesized solvent precursor, the environmentally friendly reducing catalyst, and the non-toxic substance for nanoparticle stability. Therefore, organic solvents are used in most of the physical and chemical interactions that have been reported thus far. The main reason is the ability of different capping agents to repel water [32].

Green chemistry concepts, such as (i) an environmentally benign approach, (ii) a reduction of the employed compound, and (iii) the reaction's rounding agent, are compatible with the synthesis of bio-organisms. Because of its special qualities (optical, electrical, chemical, etc.), the creation of metal oxide inorganic nanoparticles utilizing biological resources has sparked interest [33, 34]. The uses for metal oxides include sensors, passivation of surfaces coatings, fuel cells, semiconductor circuits, corrosion catalysts, and piezoelectric devices. In the environment, metallic oxides are also employed as pollutant absorbers. Because of their small mass and high limit density, cobalt

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Peer Reviewed International, Open Access Journal.
ISSN: 2998-4459 | Website: https://rlgjaar.com Volume-2, Issue-12 | December - 2025

oxide nanoparticles—a semiconducting metal oxide type—can exhibit unique chemical characteristics in nanotechnology, particularly in biological systems, optical components, and electronic devices [35–42].

Among the metal oxides, cobalt oxide nanoparticles are unique because to their rejuvenating qualities [43] (e.g., 3.3 vertical bandwidth at ambient temperature and stimulation power of 60 meV) [44], strong catalytic activity, anti-inflammatory properties, wound repair, and UV filters [45–49]. Cobalt oxide nanoparticles have been described by a number of authors as biosensors for enzyme biochemistry, cholesterol, and other biosensing applications [50–52]. Organic synthesis, sensors, visible conducting elements, and surface seismic wave devices have all shown interest in cobalt oxide nanoparticles (NP), which are non-hygroscopic, non-toxic, and frequently found in naturally occurring, polar, crystalline materials [53–57]. Cobalt oxide nanoparticles are found in clear electronics, UV light generators, chemical sensors, spin devices such as personal hygiene products, biological adhesives, and paint. Cobalt oxides NP is utilized in light-emitting coatings because of its special qualities. Transparent electrodes as an antibacterial substance [62], a photonic material [63], and a chevalier gas sensor in sunlight, UV light emitting diode lasers, varistors, electromechanical devices, spin electronic devices, electronics [58–60], and acoustic waves propagators [61]. Chevalier The extract plant's biomolecules function as active covers that aid in the creation of nanoparticles. Through a variety of mechanisms, including as electrostatic, steric, hydration, and Vander Wails force stabilization, capping agents stabilize NPs. For it to function and be implemented, NP stability is crucial [64]. When used in conjunction with biodegradable polymeric polymers, cobalt oxide nanoparticles (NPs) in the food storage and transportation sector have enhanced food quality and packaging mainly by releasing antimicrobial ions, destroying virus cells and the production of ROS as a result of light [65]. By spraying synthetic cobalt oxide nanoparticles on tomatoes and eggplant plants, Elmer and White examined the pesticide potential of these particles and discovered that they reduced disease by 28% when compared to the control [66].

Green synthesis methods are more beneficial than traditional physical and chemical methods because they are simple, cost-effective, free of toxic and environmentally unfriendly chemicals, and as a result they have gained considerable importance in recent years [67, 68]. Because green approaches are becoming more and more popular, cobalt oxide nanoparticles (NPs) have been made using a variety of sources, including microbes, fungi, algae, and plants, etc. Algae induced cobalt nanoparticles of oxide NP biosynthesis, which involves biological nanoparticle synthesis, is an efficient technique for both the chemical and physical methods of nanoparticle formation. A table summarizing the searches conducted in this topic has been prepared. The manufacture of raw iron and oxide nanoparticles has been the subject of numerous studies. For people, Algae-based nanoparticle production offers a quick, affordable, safe, and eco-friendly method. NPs against S. aureus and E. coli bacteria [69], and This is the first report in which a marine alga has been used to synthesize highly stable extracellular gold nanoparticles in a relatively short time period compared with that of other biological procedures. Indeed, 95% of the bio reduction of chloroauric ions occurred within 12 hours at stirring condition [70]. Cobalt oxide nanoparticles with a wavelength of 60–80 nm were produced in a hexagonal shape. Additionally, the author evaluated the efficacy of manufactured cobalt oxide nanoparticles with antidandruff, antibacterial, and antiarthritic properties [71–80].

Using A-extraction and betulina as an efficient oxidizing/reducing agent, they showed for the first time a composite of one-phase crystallized cobalt oxide particles with an outer diameter of 15.8 nanometer in a green and suitable font in the region. Several characteristics of cobalt oxide particles were investigated using a spectrophotometer for ultraviolet-visible analysis, FTIR, illumination, XRD, SEM, as well as TEM [81].

Characterization of cobalt oxide nanoparticles (CoO NPs)

Several aspects of cobalt oxide nanoparticles were investigated using the techniques of EDAX (energy dispersion evaluation of X-ray), AFM (an atomic force microscopy), XPS (X-ray photoelectric microscopy), ATR (attenuated ordinary mirrored photograph), UV-DRS (UV seen through diffuse reflection spectroscopy), XRD (Xray dispersion meter), TEM (transmitting electron microscopy), and TG-DTA thermogravimetric differential thermal evaluation). Vitex Segundo [82–86]. A range of techniques, such as TEM, XRD, and FESEM, are used to view and compare the size diversity [87-90].

Applications of CoO NPs

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Biomedical applications of cobalt oxide nanoparticles

Cobalt nanoparticles of oxide are utilized in biomedicine to provide drugs. There are two primary reasons why they are used in drug delivery. First, because of their small size, nanoparticles can enter tiny capillaries and be absorbed by cells, enabling the accumulation of potent medications in the intended regions. Second, long-term medication release in a specific location is made possible by using biological material for nanoparticle synthesis [91]. The impact of the cobalt oxide nanoparticles on medication release was investigated using an antibiotic called metronidazole benzoate and the ointment. The results indicate that the use of cobalt nanoparticles with oxides in medicine significantly affects biological membranes.

Bio-imaging of cobalt oxide nanoparticles particles

Fluorescence imaging is widely employed in preclinical research due to its affordability and simplicity [92–94]. Cobalt nanoparticles made of oxide have been utilized for cell imaging in earlier research due to their notable blue emission and close proximity to UV, with greenish illumination correlating to O2 spaces [95]. For cancer cell imaging, tiny cytotoxic bound to transferrin green fluorescence cobalt oxide particles were employed [96]. Cobalt oxide nanoparticles' physical characteristics can be altered by adding pertinent components [97]. Before being utilized in different cells to assess cell pictures, cobalt oxide nanoparticles had been mixed with cations like Co, Cu, or Ni and reduced in aqueous colloidal medium [98]. It is possible for these microscopic cobalt oxide nanoparticles to enter the cell. Co/Au heterostructural the biocompatibility and optical qualities of nanocomposites were investigated [99]. Au NCs flourish at the bottom of the cobalt oxides nanoparticle nanorods or close to their surface. In vitro cancer cells have recently been aged using cobalt oxide nanoparticles and nanorods connected to anti-epidermic growth factor antibodies [100]. Due to their numerous appealing characteristics, QDs are typically regarded as nanoparticles for optical visualization [101]. When employed for in vitro cell examination, cobalt oxide nanoparticles (QDs) were found in the cytoplasm, exhibiting continuous illumination under UV light without appreciable damage. Similar QDs were examined in a prior work that used mice with intravascular and intradermal injections [102]. Every approach has benefits and drawbacks [103]. Several imaging techniques can be used to make nanomatadium visible, resulting in synergistic reactions. Nanomaterials are more adept at multimodality thinking when combined with smaller molecules because their greater volume permits more functional sites as well as facilitates the design of multimodal acquisitions. Gd-doped cobalt nanoparticles made of oxide (QDs) with a dimension of under six nanometers were shown to be useful in optical and magnetic resonance imaging [104]. Singh has published core-shell magnetic QDs and Fe_3O_4-cobalt oxide nanoparticles for cancer treatment and imaging. However, single-photon emission computed ultrasound (SPECT) [105] and radionuclide-based techniques like PET [106] are more clinically meaningful than optical imaging. There are no limitations on tissue penetration in the intricate and diverse PET and SPECT routes.

Drug delivery of cobalt oxide nanoparticles

Cobalt oxide nanoparticles are adaptable nanoplatforms that are useful not only in bio-imaging but also in drug delivering packages because of their varied surface chemistry, wide surface location, and picture-poisonous effect, among other things. Cobalt oxide nanoparticles, however, were detrimental to bacteria and leukemic T cells [107] as well as cancer cells [108, 109]. Through electrostatic interaction, folate-conjugated chitosan diffused the intrinsic blue fluorescence of the cobalt oxide nanoparticles (QDs). When used with doxorubicin, a frequently utilized chemotherapy drug, it may perform 75% [110]. It was suggested that DOX be captured using hydrogen bonding and collaboration with the QD surface of the cobalt oxide nanoparticles.

The outer chitosan layer was enhanced by the water durability of the cobalt nanoparticles of oxide (QDs) because of their hydrophilicity and fees. Studies conducted in vitro and in laboratory should take into account the expected quick elicitation of DOX at an appropriate pH of 7.4. Creating a system that can accurately deliver the right antigen to DCs is one of the major challenges of dendrite migration (DC)-based therapeutics for the majority of cancer types [111]. Because of their huge surface area, nanomaterials are challenging to use in this application. Fe_3O_4 nanoparticles of cobalt oxide. Carcinoembryonic antigens have been delivered to DCs using core-shell nanostructures with a typical diameter of 16 nm [112].

Cobalt oxide nanoparticle delivery of genes the most challenging aspect is creating secure gene vectors that might prevent DNA deterioration while taking into account high-performance cell digestion of DNA. Among the many nanomaterials used to study gene therapy protocols and gene transport are cobalt oxide nanoparticles, which have shown promise in multiple investigations. The experimental fluorescent protein gene is carried by pEGFPN1 DNA, which was delivered to A375 human cancerous cells using cobalt oxide nanoparticle nanostructures that mimic a three-dimensional tetrapod [113]. Three needle-shaped legs encouraged internalization of the clues for gene delivery into cells, while electrostatic interactions linked the plasmid DNA to the cobalt oxide nanoparticle nanostructures. The three-dimensional geometry was found to be responsible for the lack of cytotoxicity.

For effective gene transport, the nanoparticle floor coating is crucial. Cobalt oxide nanoparticles (QDs) have been stacked using obviously charged poly (2-dimethylamino) ethyl methacrylate) (PDMAEMA) polymeric for condensing DNA for gene switch, in accordance with a study [114]. The polymer-covered cobalt oxide nanoparticles (QDs) condensed large amounts of pDNA, which includes the luciferase sensor gene, and fluoresced at 570 nm with a huge proportion of considerably less than 20%. According to the scientists, COS-7 cells may be effectively transfected with pDNA that transmit cobalt oxide nanoparticles (QDs) with significantly less cytotoxicity, while PDMAEMA is ultimately utilized as the gene vector by adding negatively charged polymethacrylate to the QDs, cytotoxicity was reduced and costs were stabilized.

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Cobalt oxide nanoparticle-based biosensors

Biosensors are widely employed in the food business, chemical and biological analysis, environmental monitoring, and fitness care. Biosensors labelled with discovery principles include electrochemical, photometric, piezoelectric in and calorimetric biosensors [115]. Because of its potential to provide a great platform for creating especially effective biosensors, nanomatadium, either by itself or in combination with natural chemicals, attracts developing hobbies [116]. In addition to other proteins, enzymes, and antibodies. Additionally, they may permit direct quantum drift between conductors and biomolecules' active regions. Cobalt oxides nanoparticles, a component of semiconductor structures, also have strong promoting electricity, high charging point, extreme performance, and biosensing. They are suitable for combining the electrostatic adsorption of particular proteins with antibody and enzymes with low IEPs since they are catalytic (IEP; 9.5) [117].

Toxicity studies of cobalt oxide nanoparticles

TiO_2 NPs and cobalt oxide nanoparticles were employed. Cobalt oxides nanoparticles (NPs) are more dangerous than the extremely poisonous ionic form of cobalt. The toxicity of unprocessed cobalt oxide nanoparticles in the eggs of zebrafish [118, 119]. Furthermore, it was shown that cobalt oxide particles had strong antibacterial activity against Enterobacter aerogenes and Staphylococcus epidermidis. According to toxicity experiments, zebra fatality survival and disability were not significantly affected by cobalt oxide nanomaterials at a concentration of 10 mg/ml. Sprague Dawley mice administered 100 nm of cobalt oxide nanoparticles exhibited a higher charge in a 90-day toxicity test. [120] and were more accurately charged, identifying the target organs and assessing the degree of risk. Both sexes exhibit severe toxicity at dosages greater than 125 mg/kg.

Conclusions

Sustainable cobalt oxide nanoparticles research indicates that NP synthesis is far safer and more environmentally friendly than chemical and physical procedures. Cobalt nanoparticles made from oxide are among the most important and versatile materials due to their many qualities, capabilities, advantages, and human applications. Raw materials serve as stabilizing and decreasing agents when controlled length and shaped nanoparticles arrive. Cobalt nanoparticles of oxide support agricultural output and moderate plant growth. At the same time, the demand for meals keeps growing despite a crucial crop's insufficient output. As a result, metallic oxide nanoparticles ought to be promoted for long-term agricultural sustainability. Among the organic applications in this field are gene transfer, biosensors, medication management, and bioimaging.

Furthermore, due to their toxicity, cobalt oxide nanoparticles have the potential to be effective antibiotics and clever weapons against a variety of drug-resistant diseases. Researching innovative methodological and scientific links in this field should be made simple by this outline. Health-related issues will be addressed in the interim.

Acknowledgement

The author A. S. Rajpurkar are thankful to N. G. Vedak and N. S. Yadav for providing necessary facilities and encouragement during research work.

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Royal International Global Journal of Advance and Applied Research
Peer Reviewed International, Open Access Journal.
ISSN: 2998-4459 | Website: https://rlgjaar.com Volume-2, Issue-12 | December - 2025

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