RESEARCH PAPER

Preparation of Co_3O_4 Nanoparticles and Studying the Antibacterial Activity on Bacteria Isolated from the Aquatic Environment of the Diyala River

Salih Saood Yagoub

Department of Biology. College of Education for Pure Science, University of Diyala , Ba'agubah, Diyala, Iraq

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ABSTRACT

The sol-gel method, which involved dissolving cobalt nitrate in distilled water to create a solution, adding urea, heating the solution for an hour at 110 °C to create a gel, and drying the gel for an additional hour at 280 °C to create cobalt oxide powder, was used in this study to create cobalt oxide nanoparticles. The finished product was compared to the (ICCD) card number 96-900-5889 and analyzed using the X-ray diffraction method. It was found that the material has a cubic crystal structure. The crystal size (29.2 nm) was calculated using the Debye-Scherer equation. The antibacterial activity of cobalt oxide nanoparticles was then examined on a culture of Escherichia coli bacteria cultured in Molar Hinton agar by producing cobalt oxide as a circular disc and placing it inside the bacteria. It was discovered that a zone had developed around the disc, suggesting that no bacteria had grown there. It suggests that certain microbes are susceptible to the antibacterial effects of cobalt oxide nanoparticles.

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INTRODUCTION

One of the main pillars of the current scientific-industrial revolution, nanotechnology will support the advancement of science and technology during the coming decades [1,2]. Future technological improvement may arise from the combination of nanotechnology and other fields [2,3]. The production of intelligent materials that may help with the creation of bio-smart devices is one of the consequences of nanotechnology [4,5]. It makes it abundantly evident that developing and manufacturing nano-based systems ought to be a national priority [6]. Nanotechnology has made very basic applications in pharmacy possible, and patient-centered design and disease-driven, intelligent, and targeted medications are the major objectives in this discipline [7-10]. The pharmacodynamic and pharmacokinetic properties of nanodrugs can be controlled by these nano-based systems, which exhibit particular potency and the capacity to detect the damaged environment in the tissue [11–13]. If these medications do not fulfill the standards for their implementation, they will not be activated [14]. These medications are designed to precisely forecast their function, a feature that is absent from existing methods. International research efforts are concentrated on the use of nanotechnology in medicine in connection with the prompt detection and potential treatment

* Corresponding Author Email: Salih.saood@uodiyala.edu.iq

of cancer [15,16]. Fundamental shifts in how to approach the possible treatment of cancer may be brought about by nanotechnology [17,18].

Conversely, the abuse of antibiotics to eradicate the germs has resulted in antibiotic resistance and the rise of infectious diseases [19]. Therefore, in order to stop the growth of germs, it is imperative to search for new antibacterial compounds (new generation of antibacterial medications). Nanoparticles (NPs) of silver, gold, silver, and platinum have strong antibacterial properties. These particles' incredibly small size and surface-to-volume ratio are the causes of this property [20-26]. Therefore, because of the NPs' strong antibacterial action, they can be employed to improve food packaging safety [27,28] and to create a new class of antibacterial medications [29,30]. Cobalt oxide (Co3O4) nanoparticles (NPs) have displayed remarkable characteristics in this field due to their promising physicochemical properties, including the anisotropy constant, coercivity and Curie temperature, saturation magnetization, and ease of fabrication [31]. Co_3O_4 NPs have been reported to be used in various medical applications, including targeted drug delivery, magnetic resonance imaging (MRI), cancer therapy [32-35] and MRI [36,37]. However, before introducing NPs as antibacterial or anticancer agents, their effects on biological systems, such as protein structure, should be taken into consideration [38,39]. Human serum albumin (HSA) is the most extensively researched protein and has numerous uses in pharmacology, biochemistry, and biophysics [40]. The most prevalent protein in plasma, HSA transports a variety of medications and NPs to meet different therapeutic needs. In addition, HSA maintains osmotic pressure, controls blood pH, and transports hormones, fatty acids, and other substances [41,42]. Albumin is utilized as a circulating reservoir for several metabolites due to its ability to bind to ligands [43]. In biological processes, the way proteins interact with various ligands is crucial [44,45].

MATERIALS AND METHODS

Preparation of nano (Co_3O_4)

Using the sol-gel method, cobalt oxide nanoparticles are made by dissolving 35 grams of cobalt nitrate in 35 milliliters of distilled water with a magnetic stirrer, adding urea, heating the mixture for an hour at 110 degrees Celsius to form

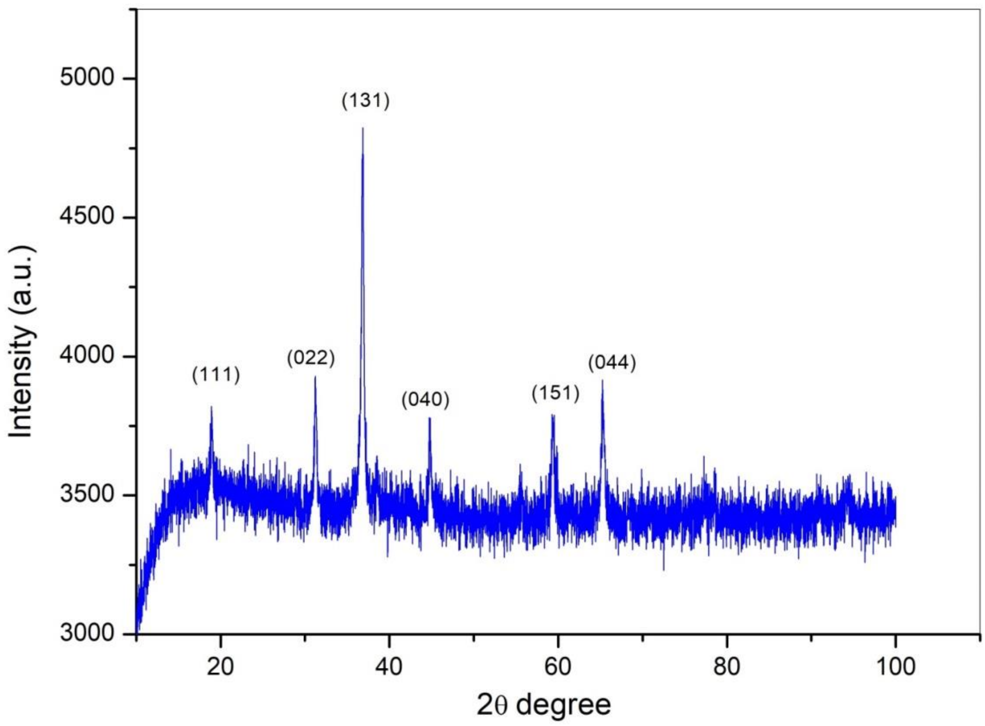

Fig. 1. XRD diffraction of nano Co_3O_4

a gel, and then drying the gel for another hour at 280 degrees Celsius to produce cobalt oxide powder. The finished product was analyzed using X-ray diffraction and FE-SEM techniques.

The isolating bacteria from Diyala river

A water sample was taken from Diyala River in Baqubah city, then it was grown on two agricultural media: Maconkey, and Molarhinton agar for 24 h at 37C . After that, the bacteria growth culture media, which was Molarhinton agar, and it was Escherichia coli.

Studying Antibacterial Activity of nano (Co_3O_4)

To observe the impact on bacterial growth, we choose a portion of dishes and introduce a nano-cobalt oxide capsule. After that, to observe how oxide affects bacteria, all of the plates are placed in an incubator set at 37 °C for a day.

RESULTS AND DISCUSSION

Fig. 1 showed that prepared material is cobalt oxide (Co_3O_4) after matching with ICCD Card no.(96-900-5889) and the crystal system is cubic, where the location of peaks at 2θ=(18.96, 31.21, 36.78, 44.73, 59.25, 65.11) and its Miller indices (111 , 022 , 131 , 040 ,151 , 044). the trend of growth is (131) and the crystal size is (29.2) nm measure by Debye sherrer equation:

$$D= K\lambda /\beta \cos \Theta$$

Where K=0.9 and λ = 0.154060 nm.

The surface form of Co_3O_4 made by the Sol-Gel technique was examined with a scanning electron microscope (FE-SEM). At magnifications of 120000 X, FE-SEM images were used to examine the surface morphology of Co_3O_4. The surface morphology of Co_3O_4 is usually densely packed with pinholes. The grains are also available in a range of sizes and semi-spherical shapes, such as nano cauliflower. This result aligns with the reference [46]. Additionally, Fig. 2 shows how the grains were evenly distributed across the entire surface and devoid of imperfections like fissures.

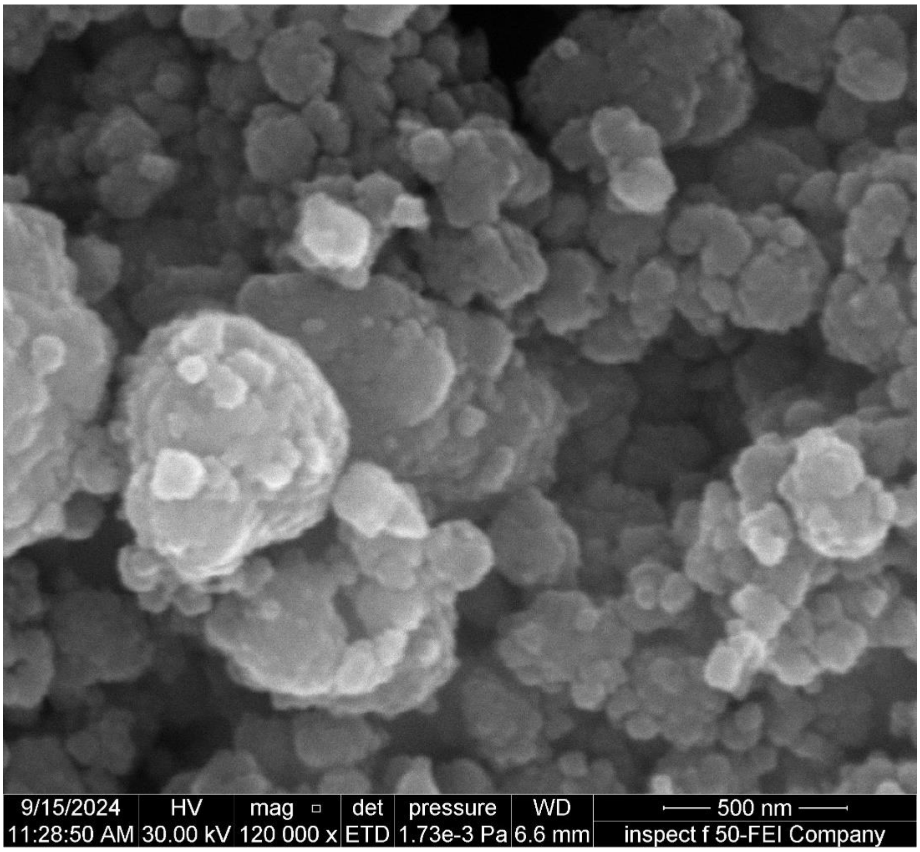

Fig. 2. FE-SEM of nano Co_3O_4

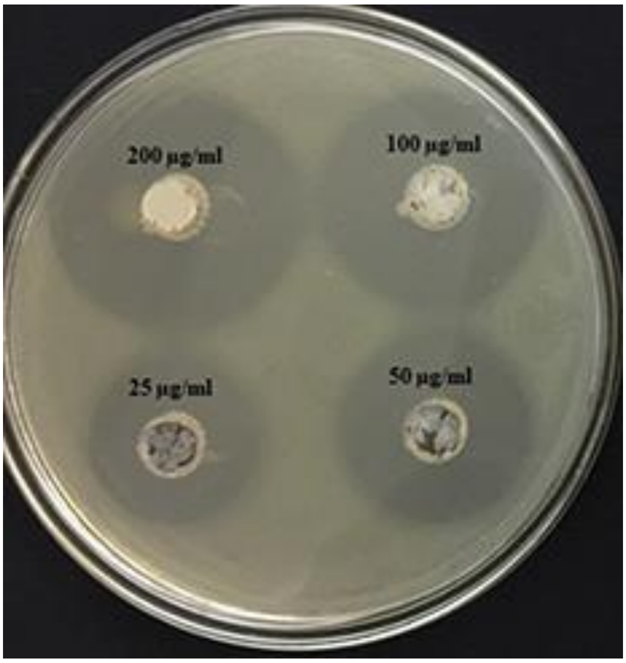

Fig. 3. Images of antibacterial activity of Co_3O_4 NPs against E. coli

Fig. 3 shows the antibacterial properties of the produced Co_3O_4 NPs. The results showed that the produced Co_3O_4 NPs significantly reduced the antibacterial activity of the harmful bacteria under study. Fig. 3 illustrates how nanocobalt oxide's capacity to eradicate Escherichia coli germs rises with its concentration.

CONCLUSION

The prepared cobalt oxide (Co_3O_4) material was successfully characterized and its properties analyzed. X-ray diffraction (XRD) analysis confirmed the formation of Co_3O_4 with a cubic crystal system by matching with ICCD Card No. (96-900-5889). The surface morphology of Co_3O_4 prepared via the sol-gel technique was studied using field emission scanning electron microscopy (FE-SEM). At high magnification (120,000×), the surface exhibited densely packed grains with semi-spherical shapes resembling nano cauliflower, consistent with literature findings. The grains were uniformly distributed without significant defects such as fissures, indicating the successful synthesis and quality of the material. The antibacterial activity of Co_3O_4 nanoparticles (NPs) was evaluated against harmful bacteria, specifically *Escherichia coli*. The results demonstrated a concentration-dependent antibacterial effect, with increasing Co_3O_4 NP concentrations showing enhanced bacterial eradication. This highlights the potential of Co_3O_4 NPs for applications in antimicrobial treatments and related fields. In conclusion, the prepared Co_3O_4 nanoparticles exhibit desirable structural, morphological, and antibacterial properties, making them suitable candidates for advanced material applications.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

REFERENCES

1. Zabeo A, Keisler JM, Hristozov D, Marcomini A, Linkov I. Value of information analysis for assessing risks and benefits of nanotechnology innovation. Environmental Sciences Europe. 2019;31(1).
2. Larsson S, Jansson M, Boholm Å. Expert stakeholders' perception of nanotechnology: risk, benefit, knowledge, and regulation. J Nanopart Res. 2019;21(3).
3. Arciénaga Morales AA, Nielsen J, Roveris Gomes E, Rasmusen LB, Bacarini H, Thomsen B. Some insights into nanotechnology innovation processes and patterns for advanced materials. Contaduría y Administración. 2018;64(1):74.
4. Zhang H, Tian Y, Jiang L. Fundamental studies and practical applications of bio-inspired smart solid-state nanopores and nanochannels. Nano Today. 2016;11(1):61-81.
5. Cai P, Leow WR, Wang X, Wu YL, Chen X. Biointegrated

Devices: Programmable Nano–Bio Interfaces for Functional Biointegrated Devices (Adv. Mater. 26/2017). Adv Mater. 2017;29(26).
6. Dettenhofer M, Ondrejovič M, Vásáry V, Kaszycki P, Twardowski T, Stuchlík S, et al. Current state and prospects of biotechnology in Central and Eastern European countries. Part I: Visegrad countries (CZ, H, PL, SK). Crit Rev Biotechnol. 2018;39(1):114-136.
7. Truong-Dinh Tran T, Ha-Lien Tran P, Tu Nguyen K, Tran V-T. Nano-Precipitation: Preparation and Application in the Field of Pharmacy. Curr Pharm Des. 2016;22(20):2997-3006.
8. Fedorov AN, Yurkova MS. Molecular Chaperone GroEL – toward a Nano Toolkit in Protein Engineering, Production and Pharmacy. NanoWorld Journal. 2018;04(01).
9. El-Sawy HS, Al-Abd AM, Ahmed TA, El-Say KM, Torchilin VP. Stimuli-Responsive Nano-Architecture Drug-Delivery Systems to Solid Tumor Micromilieu: Past, Present, and Future Perspectives. ACS Nano. 2018;12(11):10636-10664.
10. Sharifi M, Attar F, Saboury AA, Akhtari K, Hooshmand N, Hasan A, et al. Plasmonic gold nanoparticles: Optical manipulation, imaging, drug delivery and therapy. Journal of Controlled Release. 2019;311-312:170-189.
11. Pawar S, Shevalkar G, Vavia P. Glucosamine-anchored doxorubicin-loaded targeted nano-niosomes: pharmacokinetic, toxicity and pharmacodynamic evaluation. Journal of Drug Targeting. 2016;24(8):730-743.
12. Choi YH, Han H-K. Nanomedicines: current status and future perspectives in aspect of drug delivery and pharmacokinetics. Journal of pharmaceutical investigation. 2018;48(1):43-60.
13. Gamasaee NA, Muhammad HA, Tadayon E, Ale-Ebrahim M, Mirpour M, Sharifi M, et al. The effects of nickel oxide nanoparticles on structural changes, heme degradation, aggregation of hemoglobin and expression of apoptotic genes in lymphocytes. Journal of Biomolecular Structure and Dynamics. 2019;38(12):3676-3686.
14. Cui D, Huang J, Zhen X, Li J, Jiang Y, Pu K. A Semiconducting Polymer Nano-prodrug for Hypoxia-Activated Photodynamic Cancer Therapy. Angew Chem Int Ed. 2019;58(18):5920-5924.
15. Björnmalm M, Thurecht KJ, Michael M, Scott AM, Caruso F. Bridging Bio–Nano Science and Cancer Nanomedicine. ACS Nano. 2017;11(10):9594-9613.
16. Zheng Y, Li Z, Chen H, Gao Y. Nanoparticle-based drug delivery systems for controllable photodynamic cancer therapy. Eur J Pharm Sci. 2020;144:105213.
17. Ghafari M, Haghiralsadat F, Khanamani Falahati-pour S, Zavar Reza J. Development of a novel liposomal nanoparticle formulation of cisplatin to breast cancer therapy. J Cell Biochem. 2020;121(7):3584-3592.
18. Guo S, Vieweger M, Zhang K, Yin H, Wang H, Li X, et al. Ultra-thermostable RNA nanoparticles for solubilizing and high-yield loading of paclitaxel for breast cancer therapy. Nature communications. 2020;11(1):972-972.
19. Camcioglu Y, Sener Okur D, Aksaray N, Darendeliler F, Hasanoglu E. Factors affecting physicians' perception of the overuse of antibiotics. Med Mal Infect. 2020;50(8):652-657.
20. Boateng J, Catanzano O. Silver and Silver Nanoparticle-Based Antimicrobial Dressings. Therapeutic Dressings and Wound Healing Applications: Wiley; 2020. p. 157-184.
21. Gunputh UF, Le H, Lawton K, Besinis A, Tredwin C, Handy RD. Antibacterial properties of silver nanoparticles grown in situ and anchored to titanium dioxide nanotubes on titanium implant against Staphylococcus aureus. Nanotoxicology. 2019;14(1):97-110.
22. Yang X, Wei Q, Shao H, Jiang X. Multivalent Aminosaccharide-Based Gold Nanoparticles as Narrow-Spectrum Antibiotics in Vivo. ACS Applied Materials and Interfaces. 2019;11(8):7725-7730.
23. Zhou L, Yu K, Lu F, Lan G, Dai F, Shang S, et al. Minimizing antibiotic dosage through in situ formation of gold nanoparticles across antibacterial wound dressings: A facile approach using silk fabric as the base substrate. Journal of Cleaner Production. 2020;243:118604.
24. R N, S M, S JP, P P. Green synthesis and characterization of bioinspired silver, gold and platinum nanoparticles and evaluation of their synergistic antibacterial activity after combining with different classes of antibiotics. Materials Science and Engineering: C. 2019;96:693-707.
25. Deng T, Zhao H, Shi M, Qiu Y, Jiang S, Yang X, et al. Photoactivated Trifunctional Platinum Nanobiotics for Precise Synergism of Multiple Antibacterial Modes. Small. 2019;15(46).
26. Sharifi M, Hosseinali SH, Saboury AA, Szegezdi E, Falahati M. Involvement of planned cell death of necroptosis in cancer treatment by nanomaterials: Recent advances and future perspectives. Journal of Controlled Release. 2019;299:121-137.
27. Biswas MC, Tiimob BJ, Abdela W, Jeelani S, Rangari VK. Nano silica-carbon-silver ternary hybrid induced antimicrobial composite films for food packaging application. Food Packaging and Shelf Life. 2019;19:104-113.
28. Jayakumar A, K.V H, T.S S, Joseph M, Mathew S, G P, et al. Starch-PVA composite films with zinc-oxide nanoparticles and phytochemicals as intelligent pH sensing wraps for food packaging application. Int J Biol Macromol. 2019;136:395-403.
29. Wu Z, Xu H, Xie W, Wang M, Wang C, Gao C, et al. Study on a novel antibacterial light-cured resin composite containing nano-MgO. Colloids Surf B Biointerfaces. 2020;188:110774.
30. Soltani S, Akhbari K, White J. Synthesis, crystal structure and antibacterial activity of a homonuclear nickel(II) metal-organic nano supramolecular architecture. Polyhedron. 2020;176:114301.
31. Amiri S, Shokrollahi H. The role of cobalt ferrite magnetic nanoparticles in medical science. Materials Science and Engineering: C. 2013;33(1):1-8.
32. Zhu H, Deng J, Yang Y, Li Y, Shi J, Zhao J, et al. Cobalt nanowire-based multifunctional platform for targeted chemo-photothermal synergistic cancer therapy. Colloids Surf B Biointerfaces. 2019;180:401-410.
33. Zhu H, Deng J, Yang Z, Deng Y, Yang W, Shi X-L, et al. Facile synthesis and characterization of multifunctional cobalt-based nanocomposites for targeted chemo-photothermal synergistic cancer therapy. Composites Part B: Engineering. 2019;178:107521.
34. Lin W-C, Chuang C-C, Chang C-J, Chiu Y-H, Tang C-M. The Effect of Electrode Topography on the Magnetic Properties and MRI Application of Electrochemically-Deposited, Synthesized, Cobalt-Substituted Hydroxyapatite. Nanomaterials (Basel, Switzerland). 2019;9(2):200.
35. Lin WC, Chuang CC, Yao C, Tang CM. Effect of Cobalt Precursors on Cobalt-Hydroxyapatite Used in Bone Regeneration and MRI. J Dent Res. 2020;99(3):277-284.
36. Wang G, Ma Y, Wei Z, Qi M. Development of multifunctional cobalt ferrite/graphene oxide nanocomposites for magnetic

resonance imaging and controlled drug delivery. Chem Eng J. 2016;289:150-160.
37. Dey C, Baishya K, Ghosh A, Goswami MM, Ghosh A, Mandal K. Improvement of drug delivery by hyperthermia treatment using magnetic cubic cobalt ferrite nanoparticles. J Magn Magn Mater. 2017;427:168-174.
38. Anbouhi TS, Esfidvajani EM, Nemati F, Haghighat S, Sari S, Attar F, et al. Albumin binding, anticancer and antibacterial properties of synthesized zero valent iron nanoparticles. International journal of nanomedicine. 2018;14:243-256.
39. Behzadi E, Sarsharzadeh R, Nouri M, Attar F, Akhtari K, Shahpasand K, et al. Albumin binding and anticancer effect of magnesium oxide nanoparticles. International journal of nanomedicine. 2018;14:257-270.
40. Sohrabi MJ, Dehpour A-R, Attar F, Hasan A, Mohammad-Sadeghi N, Meratan AA, et al. Silymarin-albumin nanoplex: Preparation and its potential application as an antioxidant in nervous system in vitro and in vivo. Int J Pharm. 2019;572:118824.
41. Esfandfar P, Falahati M, Saboury A. Spectroscopic studies of interaction between CuO nanoparticles and bovine serum albumin. Journal of Biomolecular Structure and Dynamics. 2016;34(9):1962-1968.
42. Hassanian M, Aryapour H, Goudarzi A, Javan MB. Are zinc oxide nanoparticles safe? A structural study on human serum albumin using in vitro and in silico methods. Journal of Biomolecular Structure and Dynamics. 2020;39(1):330-335.
43. Shaklai N, Garlick RL, Bunn HF. Nonenzymatic glycosylation of human serum albumin alters its conformation and function. J Biol Chem. 1984;259(6):3812-3817.
44. Aghili Z, Taheri S, Zeinabad HA, Pishkar L, Saboury AA, Rahimi A, et al. Investigating the Interaction of Fe Nanoparticles with Lysozyme by Biophysical and Molecular Docking Studies. PLoS One. 2016;11(10):e0164878-e0164878.
45. Zeinabad HA, Kachooei E, Saboury AA, Kostova I, Attar F, Vaezzadeh M, et al. Thermodynamic and conformational changes of protein toward interaction with nanoparticles: a spectroscopic overview. RSC Advances. 2016;6(107):105903-105919.
46. Hussain A, Begum A, Rahman A. Electrical and optical properties of nanocrystalline lead sulphide thin films prepared by chemical bath deposition. Indian Journal of Physics. 2012;86(8):697-701.