Antimicrobial and Anticancer Activity of Metal Oxide Nanoparticles: A Review

Neera Sharma
Department of Physics, Agra College, Agra, U.P., India
E-mail: neerasharma09@yahoo.in

In this paper antimicrobial and anticancer activities of metal oxide nanoparticles are discussed. From the literature review, it is clear that metal oxide nanoparticles can be potential candidate as antimicrobial and anticancer agents. These nanoparticles are effective on both gram-positive and gram-negative bacteria and these can be used in the diagnosis and treatment of different types of cancers, without effecting healthy cells.

Keywords: Metal oxide nanoparticles, Antimicrobial activity, Anticancer activity.

1. INTRODUCTION

Due to large surface to volume ratio, nanoparticles are considered for many industrial applications. These materials are used in medical industry in many ways such as for targeted drug delivery, as antimicrobial agents, for the diagnosis and treatment of different types of cancers, etc. For more than 30 years, nanomaterials have been used in pharmaceutical industry.

In the recent years, metal oxide nanoparticles attracted interest of researchers due to their effect on bacteria. The conventional drugs used to kill bacteria have limitations that can overcome by the use of metal oxide nanoparticles. The nanoparticles have ability to change the metabolic activity of bacteria [1]. Bacteria are classified in two groups-gram positive bacteria and gram negative bacteria. It is found that metal oxide nanoparticles can be used on both types of bacteria. It is observed that metal oxide nanoparticles disrupt the membrane of bacteria [2]. Physico-chemical activity of metal oxide nanoparticles plays an important role in their antimicrobial activity [3].

Cancer is one of the leading causes of mortality all over the world. There are different types of cancers like lung cancer, liver cancer, breast cancer, stomach cancer, bone cancer, breast cancer, etc. [4]. Many therapies are available to treat cancer; chemotherapy is one of them [5]. Chemotherapy has many undesirable side effects [6]. Application of nanoparticles for the treatment of cancer can be a good strategy. From the researches, it is clear that oxide nanoparticles can be used in diagnosis and treatment of cancer [7]. Nanoparticles have antioxidant properties that reduce the rate of tumor progression [8]. The carrier properties of nanomaterials are used in the treatment of cancer. These materials can be used to treat cancer by two processes either active or passive [9].

In this review article, antimicrobial and anticancer activities of metal oxide nanoparticles (Al_2O_3, Cr_2O_3, ZnO, etc.) are discussed.

2. ANTIMICROBIAL ACTIVITY OF METAL OXIDE NANOPARTICLES

Researchers show that Zinc oxide nanoparticles are good antimicrobial agents against both gram-positive and gram-negative bacteria. The antimicrobial activity of Zinc oxide nanoparticles is investigated against *E.coli* [10,11] and *S.aureus* [11]. It was observed that these nanoparticles are good antimicrobial agents against these bacteria. The antimicrobial activity of cobalt doped zinc oxide nanoparticles was also investigated against *E. coli*, *Klebsiella pneumonia*, *Shigelladysenteriae*, *Salmonella typhi*, *Psudomonasaeruginosa*, *Bacillus subtilis* and *S.aureus* [12]. It was found that these nanoparticles are good antimicrobial agents against all these bacteria.

Silica-Ag nanoparticles show antimicrobial activity against *S. enterica* with 99% microbial reduction [13]. Research is going on over the years on the antimicrobial activity of Titanium oxide nanoparticles [14] and it is found that they are good antimicrobial agents against *E.coli* bacteria [15].

It is suggested by the studies that Alumina-silver composite nanoparticles have immense potential as antimicrobial agents [16]. Antimicrobial effect of Alumina nanoparticles on *E. coli* [17], *P. aeruginosa*, *B. subtilis* [18] was investigated and these particles were very effective against these bacteria.

3. ANTICANCER ACTIVITY OF METAL OXIDE NANOPARTICLES

The metal oxide nanoparticles used for the diagnosis and treatment of cancer are Iron oxide [19], Titanium dioxide [20], Cerium oxide [21], Zinc oxide [22], Copper oxide [23], Silicon oxide or Silica [24], etc.

Iron oxide nanoparticles are magnetic nanoparticles. These NPs can be easily targeted to the tumor site by the application of external magnetic field. Therefore, these can be selectively used to kill cancer cells, transforming radiant energy into heat. By this method healthy tissues can be protected from being damaged, which is the most dangerous side effect of chemotherapy. Spherical Iron oxide nanoparticles are approved as a medical device for hypothermia [25] and prostate cancer [26].

A method used to treat cancer is photodynamic therapy. In photodynamic therapy, TiO_2 nanoparticles can be used as photo-sensitizing agents [27,28,29]. These nanoparticles are nontoxic and stable without light irradiation.

Cerium oxide nanoparticles have capacity to selectively induce the death of irradiated cancer cells [30] and surrounding issues are not damaged by this process. These nanoparticles can act both as radio-protecting and radio-sensitizing agents [31].

A very low concentration of ZnO nanoparticles can be used to treat liver and breast cancer cells. These nanoparticles can be used to make cancer vaccines [32]. From the research, it is clear that ZnO nanoparticles can be used as efficient agent to enhance drug delivery in leukemia cancer cells [33].

From the research, it is observed that Copper oxide nanoparticles synthesized by different plant leaf extract show cytotoxic effect on lung and breast cancer cells [34,35].

Silica nanoparticles are good carriers of anticancer drugs in the treatment of pancreas cancer [36]. These nanoparticles can be used to store drugs and prevent their premature release and degradation before reaching the target.

4. CONCLUSION

From the review, it is concluded that metal oxide nanoparticles can be used as antimicrobial agents and they can be better than antibacterial drugs. Combination of nanoparticles with cancer drugs allows the reduction of drug dose with the reduction of side effects. The use of metal oxide nanoparticles for the cancer treatment is increased in recent years. For more information about the distribution, biocompatibility and low toxicity for healthy cells is necessary. Research is needed in this field.

REFERENCES

[1] A. Kanakalakshmi, V. Janaki, K. Shanthi and S. Kamala-Kannan; "Biosynthesis of Cr (III) nanoparticles from electroplating wastewater using chromium-resistant Bacillus subtilis and its cytotoxicity and antibacterial activity", Artificial Cells, Nanomedicine, and Biotechnology, Vol. 45(7), pp. 1304-1309, 2017. DOI: 10.1080/21691401.2016.1228660

[2] R. Brayner, R. Ferrari-Iliou, N. Brivois, S. Djediat, M.F. Benedetti and F. Fiévet; "Toxicological impact studies based on Escherichia coli bacteria in ultrafine ZnO nanoparticles colloidal medium", Nano letters, Vol. 6(4), pp. 866-870, 2006. DOI: 10.1021/nl052326h

[3] M.R. Wiesner, G.V. Lowry, P. Alvarez, D. Dionysiou and P. Biswas; "Assessing the risks of manufactured nanomaterials", Environ. Sci. Technol., Vol. 40(14), pp. 4336-4345, 2006.

[4] "World cancer report 2014", Edited by Bernard W. Stewart. Geneva and Christopher P. Wild, Switzerland: World Health Organization, 2014.

[5] H.L. Wong, R. Bendayan, A.M. Rauth, H.Y. Xue, K. Babakhanian and X.Y. Wu; "A mechanistic study of enhanced doxorubicin uptake and retention in multidrug resistant breast cancer cells using a polymer-lipid hybrid nanoparticle system", Journal of Pharmacology and Experimental Therapeutics, Vol. 317(3), pp. 1372-1381, 2006. DOI: 10.1124/jpet.106.101154

[6] P.G. Komarov, E.A. Komarova, R.V. Kondratov, K. Christov-Tselkov, J.S. Coon, M.V. Chernov and A.V. Gudkov; "A chemical inhibitor of p53 that protects mice from the side effects of cancer therapy", Science, Vol. 285(5434), pp. 1733-1737, 1999. DOI: 10.1126/science.285.5434.1733

[7] M. Ovais, A.T. Khalil, A. Raza, M.A. Khan, I. Ahmad, N.U. Islam, M. Aravanan, M.F. Ubaid, M. Ali and Z.K. Shinwari; "Green synthesis of silver nanoparticles via plant extracts: beginning a new era in cancer theranostics", Nanomedicine, Vol. 11(23), pp. 3157-3177, 2016. DOI: 10.2217/nnm-2016-0279

[8] F. Caputo, M. De Nicola and L. Ghibelli; "Pharmacological potential of bioactive

engineered nanomaterials", Biochemical pharmacology, Vol. 92(1) pp. 112-130, 2014. DOI: 10.1016/j.bcp.2014.08.015

[9] F. Danhier, O. Feron and V. Préat; "To exploit the tumor microenvironment: passive and active tumor targeting of nanocarriers for anti-cancer drug delivery", Journal of controlled release, Vol. 148(2), pp. 135-146, 2010. DOI: 10.1016/j.jconrel.2010.08.027

[10] T. Gordon, B. Perlstein, O. Houbara, I. Felner, E. Banin and S. Margel; "Synthesis and characterization of zinc/iron oxide composite nanoparticles and their antibacterial properties", Colloids and Surfaces A: Physicochemical and Engineering Aspects, Vol. 374(1-3), pp. 1-8, 2011. DOI: 10.1016/j.colsurfa.2010.10.015

[11] M.G. Nair, M. Nirmala, K. Rekha and A. Anukaliani; "Structural, optical, photo catalytic and antibacterial activity of ZnO and Co doped ZnO nanoparticles", Materials Letters, Vol. 65(12), pp. 1797-1800, 2011. DOI: 10.1016/j.matlet.2011.03.079

[12] S.D. Oh, S. Lee, S.H. Choi, I.S. Lee, Y.M. Lee, J.H. Chun and H.J. Park; "Synthesis of Ag and Ag–SiO_2 nanoparticles by γ-irradiation and their antibacterial and antifungal efficiency against Salmonella enterica serovar Typhimurium and Botrytis cinerea", Colloids and Surfaces A: Physicochemical and Engineering Aspects, Vol. 275(1-3), pp. 228-233, 2006. DOI: 10.1016/j.colsurfa.2005.11.039

[13] S. Gelover, L.A. Gómez, K. Reyes and M.T. Leal; "A practical demonstration of water disinfection using TiO_2 films and sunlight", Water research, Vol. 40(17), pp. 3274-3280, 2006. DOI: 10.1016/j.watres.2006.07.006

[14] K.P. Kühn, I.F. Chaberny, K. Massholder, M. Stickler, V.W. Benz, H.G. Sonntag and L. Erdinger; "Disinfection of surfaces by photocatalytic oxidation with titanium dioxide and UVA light", Chemosphere, Vol. 53(1), pp. 71-77, 2003. DOI: 10.1016/S0045-6535(03)00362-X

[15] T. Bala, G. Armstrong, F. Laffir and R. Thornton; "Titania–silver and alumina–silver composite nanoparticles: novel, versatile synthesis, reaction mechanism and potential antimicrobial application", Journal of Colloid and Interface Science, Vol. 356(2), pp. 395-403, 2011. DOI: 10.1016/j.jcis.2011.01.044

[16] I.M. Sadiq, B. Chowdhury, N. Chandrasekaran and A. Mukherjee; "Antimicrobial sensitivity of Escherichia coli to alumina nanoparticles", Nanomedicine: Nanotechnology, Biology and Medicine, Vol. 5(3), pp. 282-286, 2009. DOI: 10.1016/j.nano.2009.01.002

[17] A. Dey, T. Das and S. Mukherjee; "In vitro antibacterial activity of n-Hexane fraction of methanolic extract of Plumeria rubra L.(Apocynaceae) stem bark", Journal of Plant Sciences, Vol. 6(3), pp. 135-142, 2011.

[18] S. Klein, A. Sommer, L.V.R. Distel, J.L. Hazemann, W. Kröner, W. Neuhuber, P. Müller, O. Proux and C. Kryschi; "Superparamagnetic iron oxide nanoparticles as novel X-ray enhancer for low-dose radiation therapy", The Journal of Physical Chemistry B, Vol. 118(23), pp. 6159-6166, 2014. DOI: 10.1021/jp5026224

[19] P. Thevenot, J. Cho, D. Wavhal, R.B. Timmons and L. Tang; "Surface chemistry

influences cancer killing effect of TiO_2 nanoparticles", Nanomedicine: Nanotechnology, Biology and Medicine, Vol. 4(3), pp. 226-236, 2008. DOI: 10.1016/j.nano.2008.04.001

[20] M.S. Wason, J. Colon, S. Das, S. Seal, J. Turkson, J. Zhao and C.H. Baker; "Sensitization of pancreatic cancer cells to radiation by cerium oxide nanoparticle-induced ROS production", Nanomedicine: Nanotechnology, Biology and Medicine, Vol. 9(4), pp. 558-569, 2013. DOI: 10.1016/j.nano.2012.10.010

[21] R. Wahab, S. Dwivedi, A. Umar, S. Singh, I.H. Hwang, H.S. Shin, J. Musarrat, A.A. Al-Khedhairy and Y.S. Kim; "ZnO nanoparticles induce oxidative stress in Cloudman S_{91} melanoma cancer cells", Journal of biomedical nanotechnology, Vol. 9(3), pp. 441-449, 2013. DOI: 10.1166/jbn.2013.1593

[22] C. Liu, W. Duan, R. Li, S. Xu, L. Zhang, C. Chen, M. He, Y. Lu, H. Wu, H. Pi, X. Luo, Y. Zhang, M. Zhong, Z. Yu and Z. Zho; "Exposure to bisphenol A disrupts meiotic progression during spermatogenesis in adult rats through estrogen-like activity", Cell death & disease, Vol. 4(6), pp. e676, 2013.

[23] H. Meng, M. Wang, H. Liu, X. Liu, A. Situ, B. Wu, Z. Ji, C.H. Chang and A.E. Nel; "Use of a lipid-coated mesoporous silica nanoparticle platform for synergistic gemcitabine and paclitaxel delivery to human pancreatic cancer in mice", ACS Nano, Vol. 9(4), pp. 3540-3557, 2014. DOI: 10.1021/acsnano.5b00510

[24] F.K.H. van Landeghem, K.M. Hauff, A. Jordan, K.T. Hoffmann, U. Gneveckow, R. Scholz, B. Thiesen, W. Brück and Andreas von Deimling; "Post-mortem studies in glioblastoma patients treated with thermotherapy using magnetic nanoparticles", Biomaterials, Vol. 30(1), pp. 52-57, 2009. DOI: 10.1016/j.biomaterials.2008.09.044

[25] M. Johannsen, B. Thiesen, P. Wust and A. Jordan; "Magnetic nanoparticle hyperthermia for prostate cancer", International Journal of Hyperthermia, Vol. 26(8), pp. 790-795, 2010. DOI: 10.3109/02656731003745740

[26] A.P. Zhang and Y.P. Sun; "Photocatalytic killing effect of TiO_2 nanoparticles on Ls-174-t human colon carcinoma cells", World Journal of Gastroenterology, Vol. 10(21), pp. 3191-3193, 2010. DOI: 10.3748/wjg.v10.i21.3191

[27] J.W. Seo, H. Chung, M.Y. Kim, J. Lee, I.H. Choi and J. Cheon; "Development of water-soluble single-crystalline TiO_2 nanoparticles for photocatalytic cancer-cell treatment", Small, Vol. 3(5), pp. 850-853, 2007. DOI: 10.1002/smll.200600488

[28] J. Colon, N. Hsieh, A. Ferguson, P. Kupelian, S. Seal, D.W. Jenkins and C.H. Baker; "Cerium oxide nanoparticles protect gastrointestinal epithelium from radiation-induced damage by reduction of reactive oxygen species and upregulation of superoxide dismutase 2." Nanomedicine: Nanotechnology, Biology and Medicine, Vol. 6(5), pp. 698-705, 2010. DOI: 10.1016/j.nano.2010.01.010

[29] M.Y. Bae, N.H. Cho and S.Y. Seong; "Protective anti-tumour immune responses by murine dendritic cells pulsed with recombinant Tat-carcinoembryonic antigen derived from Escherichia coli", Clinical & Experimental Immunology, Vol. 157(1), pp. 128-138, 2009. DOI: 10.1111/j.1365-2249.2009.03943.x

[30] D. Guo, C. Wu, H. Jiang, Q. Li, X. Wang and B. Chen; "Synergistic cytotoxic effect

of different sized ZnO nanoparticles and daunorubicin against leukemia cancer cells under UV irradiation", Journal of Photochemistry and Photobiology B: Biology, Vol. 93(3), pp. 119-126, 2008. DOI: 10.1016/j.jphotobiol.2008.07.009

[31] R. Sankar, R. Maheswari, S. Karthik, K.S. Shivashangari and V. Ravikumar; "Anticancer activity of Ficus religiosa engineered copper oxide nanoparticles", Mater. Sci. and Eng.: C Mater. Biol. Appl., Vol. 44(9), pp. 234-239, 2014. DOI: 10.1016/j.msec.2014.08.030

[32] R. Sivaraj, P.K.S.M. Rahman, P. Rajiv, S. Narendhran and R. Venckatesh; "Biosynthesis and characterization of Acalypha indica mediated copper oxide nanoparticles and evaluation of its antimicrobial and anticancer activity", Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, Vol. 129, pp. 255-258, 2014. DOI: 10.1016/j.saa.2014.03.027