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Nanoparticles Toxicology Studies

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Review Article

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ABSTRACT

Commercial production of nanoparticles which are less than 100 nm in size has been rapidly increasing. These nanoparticles are major driving force in creating a revolution in industrial sector. Nanoparticles have a physiochemical and electrical properties different from other. These characteristics have made their usage in various fields like that of biotechnology, medical, electronics and many engineering departments has employed in work. Medical field are using these particles and many novel methods are being generated to use nanoparticles in many ways. These are used for delivery of drugs, antibodies, proteins and DNA.

INTRODUCTION

Metals, non-metals, bio-ceramics, and many polymeric materials are used to produce nanoparticles of the respective materials [1]. These are functional in producing liposomes, PEG and many more. Due to their small size nanoparticles has found to be interacting with human bodies same like of gases. After entering into our bodies [2-6], with ease their reach many vital parts of body like heart, brain, and liver. Once reaching these organs there can disrupt normal biochemical environment and can hamper their functionality.

Studies have shown that these nanoparticles trigger immune response against them. Since physical properties of these nanoparticles seems to be different so as the toxicity when compared to large size particles. Nanoparticles normally found in human lungs will be having half-life of 700 days, during their stay in lungs these nanoparticles poses a constant threat to respiratory system and human's life [7-15]. When compared to large size companion of these nanoparticles these show different physiochemical properties in different biological systems. There is huge gap of knowledge relating to toxicity effect of nanoparticles. Because of this gap many scientist are divided for the extensive usage of these nanoparticles [16-19].

To understand the toxicity caused by nanoparticles one should have an understanding what and how nanoparticles are coming in contact with our cells. After interaction how these are causing toxicity. What kind of disruption is caused to cells? Key important understanding one should have is dosage of nanoparticles considered as lethal, most of nanoparticles are used in daily purposes [20-22]. Likes of silver nanoparticles, Fe nanoparticles are used in many different methods exposing human to these nanoparticles on regular basis. We all know these have many advantages, although research has revealed about their toxic effect. By having the knowledge of function, mode of transfer, and amount of dosage safe for humans, and one can use these nanoparticles effectively, rather than getting effected more compared to benefitted from it. It has found the toxicity is inversely proportion to the size, the smaller the size greater is the toxicity of the nanoparticle. 2.5 nm of nanoparticles are more dangerous and toxic compared to same molecule of 100 nm size [23-25].

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However there are many studies made on these nanoparticles for assessing the toxicity, but there are no proper guidelines followed in conducting the studies. High concentration of Nanoparticles will cause cytotoxicity, for making sure toxicity is induced high concentration of nanoparticles used, these results are not appropriate for making guidelines. There are many discrepancies in in vitro and in vivo results. Basing on these results one single protocol cannot be proposed [26].

There are many types of nanoparticles to which human s are exposed constantly, these are nanoparticles exposure from dust storms, volcanic ash, our bodies has adapted to these harmful nanoparticles, our immune system can neutralize and destroy these nanoparticles entering into our body [27,28]. Since these nanoparticles have existed from very very long time, our bodies got adapted perfectly to these nanoparticles generated from smoke, ash of volcano eruptions etc., however the recently many new sources of nanoparticles are emerged these generate nanoparticles and release into air mainly industries smoke, vehicular smoke, combustion of fossil fuel [29,30].

These new technology are releasing new generation of nanoparticles. Advancement in technology has led to generation of smaller and smaller nanoparticles. Many studies have shown the capability of pollutant nanoparticles from air leads to many cardiovascular and respiratory diseases including cancer and mortality also in some cases [31-33].

Types of Nanoparticles Available

Aluminum oxide

Among all available nano sized chemicals, aluminium based nanoparticles are 20% of them. These Al-nanoparticles are used in textiles, paints, coating, polymers etc. toxic nature of these Al-nanoparticles are been studied by Chen et al [34]. Results have shown that AL-nanoparticles can disrupt cells, alter mitochondrial structure and function, oxidative stress, capable of disrupting blood brain barrier protein expression. Radzium et al [35] studied the toxic effect basing on concentrations of 10 µg/mL,50 µg/mL, 100 µg/mL, 200 µg/mL and 400 µg/mL and found that all these concentrations doesn't show any effect cell viability, however mitochondria has not been checked in those cells. Genotoxic properties of Al-Nanoparticles studied by Balasubramanyam et al [36] proved to have effect on cell, these studies are carried out by comet assay.

Gold

Gold nanoparticles are inert and non-toxic in nature, there have unique physiochemical properties, their react with amine and thiol groups [37-48], due to this reacting property gold-nanoparticles are used for surface modifications and used as drug carriers in cancer therapy. Studies have done looking for cytotoxicity against leukaemia cell line using 4, 12 and 18 nm size gold nano particles. Spherical gold nanoparticles are non-toxic at any concentration [49- 53].

Copper-oxide

Copper-oxide nano particles are utilized as anti-microbial reagent, intrauterine contraceptive devices, semiconductors and heat transfer fluids. Studies have revealed toxic effect of copper oxide on kidney and liver [54,55]. During the study copper oxide nanoparticles has been orally administrated into experimental animals, and found that these nanoparticles interact with gastric juices causing severe impairment of kidney, spleen and liver in the animals. In-vivo studies found genotoxic and cytotoxic effects leading to cell membrane integrity disturbance and causing oxidative stress [56-59].

Silver

Since old times many civilizations widely used silver as anti-bacterial substance. Silver nanoparticles have found its important role in different commercial products. Wound dressing, surgical instruments are coated with silver nanoparticles [60-70]. These nanoparticles reach different organs once it enters human body, brain, kidney, liver, and spleen any many organs seen with silver nanoparticles deposits in them [70-80]. More and more studies are coming on silver nanoparticles toxicity, they have effect on cell viability, reactive oxygen species (ROS) are produced, leakage of lactate dehydrogenase (LDH) [80-90].

Titanium Oxide

Although titanium oxide are inert compounds, but usage of titanium oxide nanoparticles has shown toxicity effects in experimental animals such as DNA damage, lung inflammation and genotoxicity as well. Titanium oxide of size range 5 to 200 nm has shown effect on immune system also. Experimental animal's lipid homeostasis is disrupted [91-98].

CONCLUSION

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Although the usage of nanoparticles is increasing exponentially, care should be taken against the usage. Most of the nanoparticles need to studied, although there are many types of studies can be done in-vivo studies should be done on priority, since these studies will helps us in understanding it effects on our health [99,100].
There should be few guidelines which all research and industrial organizations should follow, such that there should not be any varying results. These results can be utilized for general purpose.

REFERENCE

1. De Berardis B et al. Exposure to ZnO nanoparticles induces oxidative stress and cytotoxicity in human colon carcinoma cells. Toxicology and Appl Phar. 2010;246:116-127.
2. Nowrouzi A et al. Cytotoxicity of subtoxic AgNP in human hepatoma cell line (HepG2) after long-term exposure. Iranian Biomed j. 2010;14:23-32.
3. De Jong WH and Borm PJ. Drug delivery and nanoparticles: applications and hazards. International Journal of Nanomedicine. 2008;3:133-149.
4. Lewinski N, et al. Cytotoxicity of nanoparticles. Small. 2008;4(1):26-49.
5. Esposito E, et al. Production, Physico-Chemical Characterization and Biodistribution Studies of Lipid Nanoparticles. J Nanomed Nanotechnol. 2015;6:256.
6. El-Feky GS, et al. Utilization of Crosslinked Starch Nanoparticles as a Carrier for Indomethacin and Acyclovir Drugs. J Nanomed Nanotechnol. 2015 6:254.
7. Szekeres M, et al. Hemocompatibility and Biomedical Potential of Poly(Gallic Acid) Coated Iron Oxide Nanoparticles for Theranostic Use. J Nanomed Nanotechnol. 2015;5:252.
8. Beny Baby, et al. Formulation and Evaluation of Levofloxacin Nanoparticles by Ionic Gelation Method 2014; 3;201-210.
9. Mato E, et al. Selective Antitumoral Effect of Sorafenib Loaded PLGA Nanoparticles Conjugated with Cetuximab on Undifferentiated/Anaplastic Thyroid Carcinoma Cells. J Nanomed Nanotechnol. 2015;6:281.
10. Aftabtalab A and Sadabadi H. Application of Magnetite (Fe3O4) Nanoparticles in Hexavalent Chromium Adsorption from Aquatic Solutions. J Pet Environ Biotechnol. 2015;6:200.
11. Kakran M, et al. Fabrication of Nanoparticles of Silymarin, Hesperetin and Glibenclamide by Evaporative Precipitation of Nanosuspension for Fast Dissolution. Pharm Anal Acta 2015;6:326.
12. Devrim B and Bozkır A. Design and Evaluation of Hydrophobic Ion-Pairing Complexation of Lysozyme with Sodium Dodecyl Sulfate for Improved Encapsulation of Hydrophilic Peptides/Proteins by Lipid-Polymer Hybrid Nanoparticles. J Nanomed Nanotechnol. 2015;6:259.
13. Bassit ACF, et al. The Potential Use of Nanoparticles for Noggin siRNA Delivery to Accelerate Bone Formation in Distraction Osteogenesis. J Nanomed Nanotechnol. 2015;6:257.
14. Ben-Slama I, et al. Sub-Acute Oral Toxicity of Zinc Oxide Nanoparticles in Male Rats. J Nanomed Nanotechnol. 2015;6:284.
15. Mgbemeje EA, et al. Influence of Annealing Temperatures on the Structural, Morphological, Crystalline and Optical properties of BaTiO3 and SrTiO3 Nanoparticles. J Material Sci Eng. 2016;5: 277.
16. Kumar P, et al. Synthesis of Dox Drug Conjugation and Citric Acid Stabilized Superparamagnetic Iron-Oxide Nanoparticles for Drug Delivery. Biochem Physiol. 2016;5:194.

17. Levy I, et al. Tumor Necrosis Factor Related Apoptosis Inducing Ligand-conjugated Near IR Fluorescent Iron Oxide/Human Serum Albumin Core-shell Nanoparticles of Narrow Size Distribution for Cancer Targeting and Therapy. J Nanomed Nanotechnol. 2015;6:333.

18. Fayemi OE, et al. Metal Oxide Nanoparticles/ Multi-walled Carbon Nanotube Nanocomposite Modified Electrode for the Detection of Dopamine: Comparative Electrochemical Study. J Biosens Bioelectron. 2015;6:190.

19. Krukemeyer MG, et al. History and Possible Uses of Nanomedicine Based on Nanoparticles and Nanotechnological Progress. J Nanomed Nanotechnol. 2015;6:336.

20. Sader M, et al. Functionalization of Iron Oxide Magnetic Nanoparticles with the Multivalent Pseudopeptide N6l for Breast Tumor Targeting. J Nanomed Nanotechnol. 2015;6:299.

21. Vincze Gy, et al. Nanoheating without Artificial Nanoparticles. Biol Med (Aligarh) 2015;7:249.

22. Abdellatif AAH. Targeting of Somatostatin Receptors using Quantum Dots Nanoparticles Decorated with Octreotide. J Nanomed Nanotechnol. 2015;S6:005.

23. Bhambere D, et al. Effect of Polymer and Formulation Variables on Properties of Self-Assembled Polymeric Micellar Nanoparticles. J Nanomedine Biotherapeutic Discov. 2014;4:129.

24. Le TTD, et al. Anti-Tumor Activity of Docetaxel PLGA-PEG Nanoparticles with a Novel Anti-HER2 scFv. 2015; 6:267.

25. Wu CY, et al. Using Glucose-bound Fe3O4 Magnetic Nanoparticles as Photothermal Agents for Targeted Hyperthermia of Cancer Cells. J Nanomed Nanotechnol. 2015;6:264.

26. Wen H, Li Y (2014) Redox Sensitive Nanoparticles with Disulfide Bond Linked Sheddable Shell for Intracellular Drug Delivery. Med chem 4:748-755.

27. Moore TL, et al. Polymer-Coated Hydroxyapatite Nanoparticles for the Delivery of Statins. J Nanomed Nanotechnol. 2014;5:237.

28. Pantidos N and Horsfall LE. Biological Synthesis of Metallic Nanoparticles by Bacteria, Fungi and Plants. J Nanomed Nanotechnol. 2014;5:233.

29. Sonkusre P, et al. Improved Extraction of Intracellular Biogenic Selenium Nanoparticles and their Specificity for Cancer Chemoprevention. J Nanomed Nanotechnol. 2014;5:194.

30. Vinoda BM, et al. Photocatalytic Degradation of Toxic Methyl Red Dye Using Silica Nanoparticles Synthesized from Rice Husk Ash. J Environ Anal Toxicol. 2015;5:336.

31. Hsiao I, et al. Size and Cell Type Dependent Uptake of Silica Nanoparticles. J Nanomed Nanotechnol. 2014;5:248.

32. Higashisaka K, et al. Neutrophilia Due to Silica Nanoparticles Induces Release of Double-Stranded DNA. J Nanomed Nanotechnol. 2014;5:236.

33. Farooq A, et al. Restored Endothelial Dependent Vasodilation in Aortic Vessels after Uptake of Ceria Coated Silica Nanoparticles, ex vivo. J Nanomed Nanotechnol. 2014;5:195.

34. Chen L, et al. Manufactured aluminum oxide nanoparticles decrease expression of tight junction proteins in brain vasculature. J of neuroimmuno pharmacology.2008;3:286-295.

35. Radziun E, et al. Assessment of the cytotoxicity of aluminium oxide nanoparticles on selected mammalian cells. Toxicology in vitro. 2011;25:1694-1700.

36. Balasubramanyam A, et al. In vivo genotoxicity assessment of aluminium oxide nanomaterials in rat peripheral blood cells using the comet assay and micronucleus test. Mutagenesis. 2009;24:245-251.

37. Abdulla S, et al. Controlled Fabrication of Highly Monodispersed, Gold Nanoparticles Grafted Polyaniline (Au@PANI) Nanospheres and their Efficient Ammonia Gas Sensing Properties. J Biosens Bioelectron. 2015;6:165.

38. Li D, et al. Detection and Discrimination of Bioanalytes by Means of Colorimetric Sensor Array Based on Unmodified Gold and Silver Nanoparticles. J Bacteriol Parasitol. 2016;7:283.

39. Ghosh S, et al. Gloriosa superba Mediated Synthesis of Silver and Gold Nanoparticles for Anticancer Applications. J Nanomed Nanotechnol. 2016;7:390.

40. Alaqad K and Saleh TA. Gold and Silver Nanoparticles: Synthesis Methods, Characterization Routes and Applications towards Drugs. J Environ Anal Toxicol 2016;6:384.

41. Kumari VG, et al. Synthesis and Characterization of Pectin Functionalized Bimetallic Silver/Gold Nanoparticles for Photodynamic Applications. J Phys Chem Biophys. 2016;6:221.

42. Kumar B, et al. Aqueous Phase Lavender Leaf Mediated Green Synthesis of Gold Nanoparticles and Evaluation of its Antioxidant Activity. Biol Med. 2016;8: 290.

43. Shareena Dasari TP, et al. Antibacterial Activity and Cytotoxicity of Gold (I) and (III) Ions and Gold Nanoparticles. Biochem Pharmacol (Los Angel). 2015;4:199.

44. Comber JD and Bamezai A. Gold Nanoparticles (AuNPs): A New Frontier in Vaccine Delivery. J Nanomedine Biotherapeutic Discov. 2015;5:e139.

45. Curtis A, et al. Heat Dissipation of Hybrid Iron Oxide-Gold Nanoparticles in an Agar Phantom. J Nanomed Nanotechnol. 2015;6:335.

46. Turani M, et al. Regeneration of Limbal Stem Cells in the Presence of Silver and Gold Nanoparticles. J Environ Anal Toxicol. 2015;5:318.

47. Gunjan B, et al. Impact of Gold Nanoparticles on Physiological and Biochemical Characteristics of Brassica juncea. J Plant Biochem Physiol. 2014;2:133.

48. El Behiry A. Diagnostic Aspects and Novel Approach for Treatment of Antibiotic-Resistant Bacteria Isolated from Diarrheal Calves using Silver, Gold and Copper Nanoparticles. J Bacteriol Parasitol. 2014;5:195

49. Thanighaiarassu RR, et al. Green Synthesis of Gold Nanoparticles Characterization by using Plant Essential Oil Menthapiperita and their Antifungal Activity against Human Pathogenic Fungi. J Nanomed Nanotechnol. 2014;5:229.

50. Braham Y, et al. Characterization of Urea Biosensor Based on the Immobilization of Bacteria Proteus Mirabilis in Interaction with Iron Oxide Nanoparticles on Gold Electrode. J Biosens Bioelectron. 2015;6:160.

51. Frontasyeva MV, et al. Redistribution of Elements in Microbial Biomass in the Process of Silver and Gold Nanoparticles Synthesis Studied by Neutron Activation Analysis. J Bioremed Biodeg. 2013;S18:001.

52. Singh M, et al. Drug Delivery System for Controlled Cancer Therapy Using Physico-Chemically Stabilized Bioconjugated Gold Nanoparticles Synthesized from Marine Macroalgae, Padina Gymnospora. J Nanomed Nanotechol. 2014;S5:009.

53. Connor EE, et al. Gold Nanoparticles is taken up by human cells but do not cause acute cytotoxicity. Small. 2005;1:325-327.

54. Chen Z, et al. Acute toxicological effects of copper nanoparticles in vivo. Toxicology letters.2006;163:109–120.

55. Meng H, et al. Ultrahigh reactivity provokes nanotoxicity: explanation of oral toxicity of nano-copper particles. Toxicology letters. 2007;175:102-110.

56. Ahamed M, et al. Genotoxic potential of copper oxide nanoparticles in human lung epithelial cells. Biochemical and biophysical research Communication.2010;396:578-583.

57. Manikandan A and Sathiyabama M. Green Synthesis of Copper-Chitosan Nanoparticles and Study of its Antibacterial Activity. J Nanomed Nanotechnol. 2015;5:251.

58. Rajgovind, et al. Pterocarpus marsupium Derived Phyto-Synthesis of Copper Oxide Nanoparticles and their Antimicrobial Activities. J Microb Biochem Technol. 2015;7:140-144.

59. Ghosh S, et al. Antidiabetic and Antioxidant Properties of Copper Nanoparticles Synthesized by Medicinal Plant Dioscorea bulbifera. J Nanomed Nanotechnol. 2015;S6:007.

60. Chen X and Schluesener HJ. Nanosilver: A nanoproduct in medical application. Toxicology letters. 2008;176:1-12.

61. Tang J, et al. Distribution, translocation and accumulation of silver nanoparticles in rats. Journal of nanoscience and nanotechnology. 2009;9:4924-4932.

62. Hussain SM, et al. In vitro toxicity of nanoparticles in BRL 3A rat liver cells. Toxicology in vitro. 2005;19:975-983

63. Chen X and Schluesener HJ. Nanosilver: A Nanoproduct in medical application. Toxicology letters .2008;176:1-12.

64. Tang J, et al. Distribution, translocation and accumulation of silver nanoparticles in rats. Journal of nanoscience and nanotechnology. 2009;9:4924–4932.

65. Hussain SM, et al. In vitro toxicity of nanoparticles in BRL 3A rat liver cells. Toxicology in vitro. 2005;19:975–983.

66. Foldbjerg R, et al. Cytotoxicity and genotoxicity of silver nanoparticles in the human lung cancer cell line, A549. Archives of toxicology. 2011;85:743–750.

67. Haase A, et al. Toxicity of silver nanoparticles in human macrophages: uptake, intracellular distribution and cellular responses. Journal of Physics. 2011;304:012030.

68. Singh K, et al. Evaluation of Antimicrobial Activity of Synthesized Silver Nanoparticles using Phyllanthus amarus and Tinospora cordifolia Medicinal Plants. J Nanomed Nanotechnol. 2014;5:250.

69. Brindha Durairaj, et al. Larvicidal Potential of Fungi Based Silver Nanoparticles Against Culex Quinquefasciatus Larvae (II and III Instar). J of Pharmacology and Toxicological Studies. 2014;4:1-8.

70. Isabel Maestre-López M, et al. Antimicrobial Effect of Coated Leather Based on Silver Nanoparticles and Nanocomposites: Synthesis, Characterisation and Microbiological Evaluation. J Biotechnol Biomater. 2015;5:171.

71. Hungund BS, et al. Comparative Evaluation of Antibacterial Activity of Silver Nanoparticles Biosynthesized Using Fruit Juices. J Nanomed Nanotechnol. 2015;6:271.

72. Berton V, et al. Study of the Interaction between Silver Nanoparticles and Salmonella as Revealed by Transmission Electron Microscopy. J Prob Health. 2015;3:123.

73. Krishnan V, et al. Green Synthesis of Silver Nanoparticles Using Piper nigrum Concoction and its Anticancer Activity against MCF-7 and Hep-2 Cell Lines. J Antimicro 2016;2:123.

e-ISSN:2322-0139
p-ISSN:2322-0120

74. Yadav JP, et al. Characterization and Antibacterial Activity of Synthesized Silver and Iron Nanoparticles using Aloe vera. J Nanomed Nanotechnol. 2016;7:384.

75. Gandhi H and Khan S. Biological Synthesis of Silver Nanoparticles and Its Antibacterial Activity. J Nanomed Nanotechnol. 2016;7:366.

76. Bhakya S, et al. Catalytic Degradation of Organic Dyes using Synthesized Silver Nanoparticles: A Green Approach. J Bioremed Biodeg. 2015;6:312.

77. Suresh AK, et al. Size-Separation of Silver Nanoparticles Using Sucrose Gradient Centrifugation. J Chromatogr Sep Tech. 2015;6:283.

78. Ahmed S and SIkram S. Silver Nanoparticles: One Pot Green Synthesis Using Terminalia arjuna Extract for Biological Application. J Nanomed Nanotechnol. 2015;6:309.

79. Ghozali SZ, et al. Biosynthesis and Characterization of Silver Nanoparticles Using Catharanthus roseus Leaf Extract and its Proliferative Effects on Cancer Cell Lines. J Nanomed Nanotechnol. 2015;6:305.

80. Prasad CH, et al. Catalytic Reduction of 4-Nitrophenol Using Biogenic Silver Nanoparticles Derived from Papaya (Carica papaya) Peel extract. Ind Chem Open Access. 2015;1:104.

81. El-Deeb NM, et al. Novel Trend in Colon Cancer Therapy Using Silver Nanoparticles Synthesized by Honey Bee. J Nanomed Nanotechnol. 2015;6:265.

82. Omprakash V and Sharada S. Green Synthesis and Characterization of Silver Nanoparticles and Evaluation of their Antibacterial Activity using Elettaria Cardamom Seeds. J Nanomed Nanotechnol. 2015;6:266.

83. Aparna Mani KM, et al. Evaluation of In-vitro Anti-Inflammatory Activity of Silver Nanoparticles Synthesised using Piper Nigrum Extract. J Nanomed Nanotechnol. 2015;6:268.

84. Madhumathi K, et al. Silver and Gadolinium Ions Co-substituted Hydroxyapatite Nanoparticles as Bimodal Contrast Agent for Medical Imaging. Bioceram Dev Appl. 2014;4:079.

85. Coccini T, et al. Gene Expression Changes in Rat Liver and Testes after Lung Instillation of a Low Dose of Silver Nanoparticles. J Nanomed Nanotechnol. 2014;5:227.

86. Cramer S, et al. The Influence of Silver Nanoparticles on the Blood-Brain and the Blood-Cerebrospinal Fluid Barrier in vitro. J Nanomed Nanotechnol. 2014;5:225.

87. Lee TY, et al. The Immediate Mitochondrial Stress Response in Coping with Systemic Exposure of Silver Nanoparticles in Rat Liver. J Nanomed Nanotechnol. 2014;5:220.

88. Banu A and Rathod V. Biosynthesis of Monodispersed Silver Nanoparticles and their Activity against Mycobacterium tuberculosis. J Nanomed Biotherapeut Discov. 2013;3:110.

89. Singh K, et al. Antibacterial Activity of Synthesized Silver Nanoparticles from Tinospora cordifolia against Multi Drug Resistant Strains of Pseudomonas aeruginosa Isolated from Burn Patients. J Nanomed Nanotechnol. 2014;5:192.

90. Lee H Y, et al. A practical procedure for producing silver nanocoated fabric and its antibacterial evaluation for biomedical applications. Chem.Commun. 2007;28:2959-61.

91. Hussein FH and Shaheed MA. Preparation and Applications of Titanium Dioxide and Zinc Oxide Nanoparticles. J Environ Anal Chem. 2015;2:e109.

92. Nia Y et al. Determination of Ti from TiO_2 Nanoparticles in Biological Materials by Different ICP-MS Instruments: Method Validation and Applications. J Nanomed Nanotechnol. 2015;6:269.

e-ISSN:2322-0139
p-ISSN:2322-0120

93. Sujata Sirsat A and Jack Neal A. Titanium Dioxide Nanoparticles as an Environmental Sanitizing Agent. J Microb Biochem Technol. 2015;7:061-064.

94. Sagadevan S. Investigation of the Preparation and Characterization of Fe-doped TiO2 Nanoparticles. J Material Sci Eng. 2015;4:164.

95. López T et al. Preparation and Characterization of Antiepileptic Drugs En

96. capsulated in Sol-Gel Titania Nanoparticles as Controlled Release System. Med chem. 2015;S2:003.

97. López T et al. Ag/TiO_2-SiO_2 Sol Gel Nanoparticles to use in Hospital-Acquired Infections (HAI). J Material Sci Eng. 2015;4:196.

98. Liu H et al. Biochemical toxicity of nano-anatase TiO2 particles in mice. Biological trace element research. 2009;129:170-180.

99. Liu R et al. Small-sized titanium dioxide nanoparticles mediate immune toxicity in rat pulmonary alveolar macrophages in vivo. Journal of nanoscience and nanotechnology. 2010;10:5161-5169.

100. Kokura S et al. Silver nanoparticles as a safe preservative for use in cosmetics. Nanomedicine. 2010;6:570-74.

101. Pauluhn J. Pulmonary toxicity and fate of agglomerated 10 and 40 nm aluminium oxyhydroxides following 4-week inhalation exposure of rats: toxic effects are determined by agglomerated, not primary particle size. Toxicol Sci. 2007;109:152-167.