NANOPARTICLES: STRUCTURE, CLASSIFICATION SYNTHESIS AND THEIR UTILITY IN VETERINARY MEDICINE

Abstract

The distinctively small materials known as nanoparticles (NPs) are found on a nanometer size that varies from 1 to 100 nm. These NPs can take many different shapes. They can be divided into many classes according to their origin, characteristics, form, and size, for instance Organic, Inorganic, and Carbon-based NPs. It is feasible for the creation of materials of nano size with exceptional capability of magnetic, electrical, optical, mechanical, and catalytic properties which are significantly different from those of their heavy size and shapes. The utility of nano-technology in veterinary and human medicine has advanced significantly in recent years. For veterinary care, animal production, and other fields, nanotechnology holds great potential. A brief overview of nanomaterials and how they have been used to progress the development of nanotechnology is covered in this review. In particular, many top-down and bottom-up techniques to nanomaterial production are reviewed. This chapter also emphasizes the utility of nanoparticles in veterinary medicine.

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I. INTRODUCTION

Nanomaterials are nowadays considered as attractive materials that are highly preferred by researchers and manufacturers for a variety of uses. Regarding the size of nanometer we can simply understand that one nanometer is similar to either five atoms of silicon or ten lined up hydrogen atoms. Any materials are called nanomaterials when the size of material or any of its dimension is in range of 1 to 100 nm. The exact timeline for the use of nano items in human is difficult to point out but their use in humans have a long history and have unconsciously in use for different purposes for a very long time. It has been reported that humans started to use asbestos nanofibers firstly to strengthen ceramic mixes about 4500 years ago (Heiligtag and Niederberger, 2013).

In 1914 A.D., Richard Zsigmondy originally used the word "nanometer". The term "nanotechnology" was first used in a speech given in 1959 at the annual meeting of the American Physical Society by the American scientist and Nobel Prize winner Richard Feynman. This is regarded as the first scholarly presentation on nanotechnology (Santamaria A.,2012). Although nanotechnology was simply a topic of conversation prior to the 1980s, the idea was planted in researchers' imaginations with possibilities for future advancement. The term nanoparticle or tiny particle is any kind of substance particle with a dimension of between one and 100 nanometers (nm). Mainly because of their relatively smaller size and higher surface area, nanoparticles frequently display specific size-dependent characteristics. When the size of particle approaches the scale of nano and their length scale characteristic approaches and/or is less than the wavelength determined by de Broglie, who compared with the light wavelength, in which the smooth boundary of the crystals get abolished. (Guo *et al*., 2013).

In comparison to micromaterials or bulky substances, nanomaterials exhibit different surface effects, due to three primary causes: (a) scattered nano-materials possess a large surface area and a large quantity of particles/ unit of mass; (b) Increase at the surface by total percentage of particles; and (c) Presence of smaller quantity of atoms present in exterior portion of nano-materials than that of amount present in neighbors present directly. the atoms that are located at the exterior in nano-materials have a smaller amount direct neighbors (Roduner E., 2006). The chemical and physical characteristics of nano-materials are different from those of their larger-dimension counterparts as a result of each of these distinctions.

There have been a number of projects running worldwide in past and current years to develop technology of green synthesis which aids to manufacture nano-particles out of natural resources rather than risky chemicals. In "green synthesis," NPs are produced using biological processes because they are friendly to our ecosystem, clean, safer, economical, higher productive ability and bears no complication (Altammar KA , 2023). There are different nano-material varieties that can be created from diverse raw materials, such as nanorods, spherical, nanotubes, nanosheets, nanofibers, core-shell, and mesoporous, and their newly developed and have multiple uses in biological imaging, biological sensing, delivery of drugs, tissue engineering, and antibacterial activities, agro-foods, too. Nanomaterials can be employed as membranes, films, additives, moisturizers, and formulation modifiers depending on their architectural layout for example their size, their aspect ratio, their geometry and their porosity. The testing of effective nano-material dosages requires strict

regulation as their toxicity assessment depends on the sizes and morphological structure of nano-materials (Harish *et. al*, 2022).

II. STRUCTURE OF NANOPARTICLES

The chemical structure of the material, total number and quantity of elements in that particular particle, and the interaction kind of chemical between the atoms all have a role in determining the physical makeup of a nanoparticle made of that substance. Nanoparticles can create a pseudoclose packing that is not described by any of the of the crystallographic structure groups, can be amorphous, or may possess a regular crystalline structure. Presence of definite quantity of the atoms in the structure of particles that are required to the best stable configurations in each one of the morphological structure of the nano-particle (Shevchenko *et. al.*,2002). The structure of nanoparticles (NPs) is complicated. There are between two and three layers in them. The first layer is a surface layer that get activated to function by various small/ tiny molecules, ions of metals, surfactants, or polymers. Central section of NPs is considered as the core material. Afetr the core there is presence of the second layer which is called as the shell layer that are added purposefully and is different from the core chemically. and the third layer is the central portion of NPs which bears core material (Shin *et. al*., 2016; Ealia S. A. M. & Saravanakumar M. P, 2019). The key factors used to categorize nanoparticles (NPs) are their structure, size, physical characteristics, and chemical composition. They are primarily divided into three categories: the first is organic NPs, second is inorganic NPs, and the third one is carbon-based NPs.

III. CLASSIFICATION OF NANOPARTICLES

Classification of nanoparticles is tabulated below:

Basis of Classification	Types	Examples and properties	References
On the basis of their dimensionalities	Four types (0- Dimensional), (1- Dimensional), (2- Dimensional) and (3- Dimensional)	O D Nano: Ex: quantum dots 1 D Nano: Ex: nanofibers 2 D Nano: Ex: nanofilms 3 D Nano: Ex: nanotubes	Joudeh and Linke (2022)
On the basis of their composition	proteins, carbohydrates, lipids, polymers, other organic compounds	Dendrimers, liposomes, micelles and D ferritin	Pan and Zhong (2016)
On the basis of carbon atoms	Fullerenes NPs, carbon quantum dots NPs, and carbon black NPs	A closed-cage symmetrical structure (fullerenes), grape-like aggregates (carbon black NPs), discrete, quasi-spherical carbon (carbon quantum dots)	Ealia and Saravanakumar (2017)
On the basis of carbon or organic	Metal NPs, semiconductor NPs,	Metal precursors are used to make metal types NPs,	Joudeh and Linke (2022)

materials	and ceramic NPs	Ceramic types NPs are made of carbides, carbonates, phosphates, metal oxides and metalloids whereas semiconductor types are made of semiconductor materials	

IV. PROPERTIES OF NANOPARTICLES

Physicochemical properties of Nanoparticles include Electronic and optical properties which states the interdependence between NPs' optical and electrical characteristics is stronger. As an example, Ideal metal nano-particles (NPs) have a characteristics of size-dependent optical wavelength and also have significant ultraviolet visible shrinking band which is not emitted from the spectrum of bulk metals (Ibrahim *et. al.*, 2019). The production of excitation band which is also known as "localized surface plasma resonance" (LSPR) due to wavelength of absorbed photon is similar with the excitation band produced due to cumulative of the electrons conduction. It is established fact that the size, morphology, and inter-particle spacing of the nano-particles, along with their own dielectric characteristics and also their immediate environment, that constitutes of the substrate, solvents, and adsorbates plays active role to affect wavelength at the highest point of the spectrum of LSPR (Eustis and El-Sayed, 2006). Surface area and particle size are key factors in how materials interact with biological systems. According to appearances, The appearance of materials get smaller when their surface area exponentially grows faster than their volume which leads to increase their reactivity toward one another and their environment present around them. It is the point that to be noted that the the size of the particles and surface area is determined by the reaction of the system, their distribution, and the elimination of the materials (Powers *et. al*., 2007). Surface area is a crucial component in presenting hazardous symptoms (lung as well as additional epithelial-induced inflammatory reactions) in rodents, according to various investigations using different classes of nanoparticles (Holgate, 2010). In addition, the size of nano-particles affects their toxicity in oral cavity because generally it has been observed that the oral toxicity enhanced when size of NPs get reduced. One study in 2006 concluded this fact with copper nano-particles is toxic when inhaled with decreased size. Larger particles in even higher dose rate were not dangerous in compare to smaller particles which were found marginally toxic (Chen et. al., 2006).

Other property is magnetic properties of Nano-particles. To study this researchers from different fields such as heterogeneous and homogeneous catalysis, biomedical science, magnetic fluids studies, data storage, magnetic resonance imaging tools, and environmental studies (water purification) etc. were found interested. According to the literature, NPs function most when their when their size is in between 10 and 20 nm (Reiss and Hütten, 2005). The reason of magnetic property of NPs is due to their unequal electrical dispersion. These features are also influenced by the synthetic methodology, and they can be prepared using a variety of synthetic techniques, including solvothermal synthesis (Qi et al., 2016), micro-emulsion, co-precipitation, flame spray synthesis and thermal decomposition (Wu et

al., 2008). Superparamagnetic nanoparticles are particularly intriguing because, while they display significant magnetic interactions in the external presence of magnetic field, these interactions get vanished when the external magnetic field get removed. Due to this fact that magnetic namoparticles can be stabilized in solutions and do not bear magnetic interactions when the external magnetic field is removed, this property enables the design of ferrofluids and permits in vivo performance in the form of cell marking. Recently, magnetic field guided drug system, agents for image contrast and generators for heat in hyperthermia treatments are proposed (Flores-Rojas *et. al*., 2022)

Machanical property of nanoparticles leads Researchers to search for application of nano-particles in different subjects of biology that includes application in tribology, engineering of surface, nano-fabrication, and nano-manufacturing due to their unparallel mechanical properties. In order to determine precise mechanical makeup of nano-particless, variety of mechanical properties including hardness, stress and strain of that material, elastic properties, adhesion, and friction of that nano- particles can be examined. Additionally, surface coating of materials, coagulation, and lubrication of materials used for nano synthesis also influence how mechanically strong NPs are (Guo et al., 2014). The volume, surface, and their quantum impact also provide them to exhibit exceptional mechanical properties. When nano-particles are used incorporated to a typical material, the nanoparticles refine the grain to some extent, creating an intragranular pattern or an intergranular framework, and there is improvement of machanical properties of that material due to improvement of grain boundary. (Zou *et. al*.,2006).

Thermal property is another important property of nano-particles. Metal Nano-particles are known to have thermal conductivities much more than conductivity of fluids in solid form. For example if we talk about copper it bears a thermal conductivity of approximately three thousand times higher than that of motor oil and seven hundred times higher than that of water at ambient temperature. We can also refer that thermal conductivity of oxides, like alumina, is greater as that of water. As a result, it can be anticipated that the fluids containing solid particles in suspension will significantly exhibit improved thermal conductivities in compare to those of traditional heat transfer fluids. Dispersing solid particles into liquids like water, ethylene glycol, or oils with nanometric scales results in nanofluids (Ibrahim *et. al.*, 2019).

V. NANOPARTICLES SYNTHESIS

To generate nano-particles (NPs) with perfect and regulated form, proper size, required dimensions, and relevant structure, a number of techniques have been proposed. Top-down and Bottom-up approaches are the two most important methods for the synthesis of NPs (Arole & Munde, 2014; Hasan, S., 2015). The heavy material is broken down into nano-sized particles using a top-down technique. This approach is detrimental. Top-down methods are easier and rely on either the removal, division, or reduction of heavy production processes to create the desired structure with the right characteristics. Few most in demand approaches for synthesis of nano-particles include milling of materials manually, technique of nanolithography, laser ablation technique, sputtering method, and breakdown with thermal induction. Mechanical milling is a high-energy impact procedure that commonly involves balls inside of containers and can be done in a variety of mills, including shaker and planetary mills (Gorrasi and Sorrentino, 2015). A useful method for producing resources at a nanoscale

from large quantities of material is mechanical milling. According to Baig et al. (2021), laser ablation method is most eco-friendly approach for creating ideal metal of nano-particles. Metal nanoparticles and other types of nanomaterials can be produced using this technique. Sputtering technique is an attractive technique due to its property of less expensive than that of electron-beam lithography method and produces nano-materials with a comparable composition to the material targeted for and with lesser impurities (Baig et al., 2021). In electron explosion method, plasma is created through the blast of a metallic wire with electrical approach, this method can create nano-particles from a Pt mixture without the addition of a substance that reduces them (Joh et al., 2013).

The other strategy that is used in alternate to top-down approach is bottom-up approach which uses building up process or constructive method, in bottom-up approach, nano-particles are generated from clusters of particles that are made up of atoms. Typically, this technique uses process for sedimentation and reduction. The technique is much more expensive comparatively because lesser trashes are produced in end. This method includes Sol-gel method, spinning process, synthesis of green nano, chemical deposition of vapour, pyrolysis method, and biosynthesis methods. these methods are frequently used for generation of nano- particles. Among all these methods sol-gel method and a wet-chemical technique, are frequently used to make nano-materials (Das and Srivasatava, 2016; Baig et al., 2021). When a solution is considered alkaxides of metal or precursors of metal undergo the process of condensation, hydrolysis, and thermal breakdown resulting with stable solution at the end. The gel becomes more viscous as a result of condensation or hydrolysis. when variation in the concentration of precursor their temperature, and pH levels are made the particle size can be observed. The process of removing the solvent, allowing Ostwald ripening to take place, and changing the phase during the mature stage—all of which are necessary for the formation of solid mass—may take a few days. Utilizing bioactive substances, such as plant matter, microorganisms, and other biowastes like waste from vegetables, peelings of fruits waste, eggshell, and agricultural waste, different metal nanoparticles can be created. The creation of "green" or "biological" nanoparticles using algae and other organisms is known (Kumari et al., 2021). Nanoparticles are produced by microbes using metal capturing, enzymatic reduction, and capping. Ions of metals are primarily retained to the outermost layer or inner side of microbial cells before being transformed by enzymes into nanoparticles. It is quick, easy, and affordable to synthesize metallic nanoparticles using microorganisms, particularly marine bacteria (Patil and Kim, 2018).

VI. NANO- PARTICLE APPLICATION IN ASPECT OF VETERINARY MEDICINE

In literature we can get limited use of nano-particles in the veterinary medicine and livestock breeding aspects as it is very new field of research but nano-particles have a history of long uses as in therapeutic and in diagnostic agents in the field of human medicine. Due to growing concerns about microbial resistance of several antibiotic, the cattle and dairy industry has recently been facing a challenges of increased production pressures for which they rely on the use of growth promoters which are the drugs that are used also for therapeutic purpose. Regulations and legislation are also been amended to restrict the use of antibiotics in feed for husbandry of animal, these restrictions are made because many countries in world reported incline in the bacterial incidence which are antibiotics resistant.

This fact endorse the optimum requirement for acceptable substitutes to be developed for incorporation in feed.

By utilizing the huge broad surface and tiny amount of nano-particles, lab-on-a-chip technologies are improving healthcare diagnosis and food safety testing. Without the need for bulky benchtop instruments, these molecular technologies use fewer samples, have quicker run times, and simplify the user experience (Jain, 2005). To enhance profitability, livestock farmers need their livestock and flocks to quickly attain appropriate slaughter weights. Antibiotics are currently added to feed as a preventive measure to avoid disease and enhance growth, which shortens animal production cycles (Wang *et. al*., 2016). Use of nano-particle in the different field of animal production are tabulated below:

Field of application	Uses	Reference
Veterinary medicine	The nano-applications are currently being applied in the fields of animal welfare, animal rearing, animal proliferation, and animal nourishment. The ability to deliver the treatment directly to the targeted cells allows in use of extremely low dosages, gradually reducing medication buildup and withdrawal symptoms in farm animals.	Sayed and Kamel, 2018
Animal production	Despite the fact that employing nanotechnology limits the types of antibiotics utilized due to their Nano size, regular usage of antibiotics in livestock farming can still leave a residue affecting the ultimate consumer. To improve water quality by employing zeolites or hydrogels to absorb poisons, nanomaterials may be used in tandem with them.	Dong et. al., 2009 Lal, 2007
Animal health	Nanoparticles can also aid in controlling feed infections and enhancing rumen fermentation. One of the more promising nano-minerals, nano-zinc oxide, is used to treat illnesses that impact livestock reproduction and the conditions that affect growth	Yang and Sun, 2006

	rate and immunological response.	
Animal nutrition	The prevalence of mycotoxicosis is a significant issue that affects both humans and animals. About 25% of the time, they can be found in animal feed. A potent antimycotoxinin the form of nano successfully binds the aflatoxins and renders them inactive is thought to be made of nano-silica particles and oxide of nano- magnesium.	Moghaddam et. al., 2010
Animal breeding and reproduction	Nanotechnology can be used to address several reproductive issues, including retained placenta. Additionally, nano-particles plays a significant role in preserving and maintaining the release of reproductive hormones such steroid hormones and gonadotropic hormones.	Joanitti and Silva, 2014
Nanomeat production	"interactive" poultry meat Production that alters the color, flavor, or nutrients of meat according on the consumer preferences or health aspects is one of the important uses for nano-technology. The purpose of poultry meat design is to master over the distinctive features of meat its constituents in a creative way by manipulating atoms independently and placing them precisely where they are needed to generate the desired flavor and texture. Many of the molecular structure that determine these properties are in the nanometer category, and information on their origin can play a vital part in the design.	Muktar et. al;. 2015
cryopreservation of gametes	In order to accomplish ultra-fast cooling speeds and also	Tomanek and Enbody, 2000

	enable quick and homogenous warming up of biological materials under circumstances that are close to physiological, the use of biodegradable metal nanoparticles for cryogenic preservation of cells as well as tissues may become the next phase of cryopreservation technology. However, a small number of research are currently being conducted that employ nanoparticles to freeze tissues and cells.	

VII. CONCLUSION

Recent researchers around the world are engaged at the study of radioactive and molecular levels in order to research, handle, and implement phenomena of nano-meter dimension, the exciting and quickly developing field of nanotechnology. Nanoparticles has made new potential uses in molecular biology and biotechnology possible. By delivering in-depth information and revealing what is happening inside an organism's inner biology, nanotechnology has changed practically all of the veterinary medicine and animal science fields, particularly in wealthy nations. Quantum dots, nanoparticles with magnetic properties, polymeric nanoparticles nanopores, nanoshells, fullerenes, liposomes, and polymer-coated Nanocrystals, dendrimers are a few examples of the nanoparticles that are utilized for illness detection, therapy, medication administration, animal breeding, and reproduction. The creation of antibiotic nano-particles is crucial and has a fantastic effect on treating bacterial illnesses anywhere they have a strong therapeutic effect without unfavorable side effects. Comparative to other sister disciplines, nanotechnology is regarded as one of the major advancements now employed in a variety of fields, but it can be concluded that it is still in the early application phases to veterinary aspects.

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REFERENCES

[1] A Joanitti G, P Silva L., 2014. The emerging potential of by-products as platforms for drug delivery systems. *Curr Drug Targets*. 15:478–485. DOI: 10.2174/13894501113149990
A. Santamaria. 2012. Nanotoxicity. Humana Press, Totowa, NJ, 2012, pp. 1–12.
[2] Altammar KA. 2023. A review on nanoparticles: characteristics, synthesis, applications, and challenges. *Front. Microbiol*. 14:1155622. doi: 10.3389/fmicb.2023.1155622
[3] Arole, V. M., & Munde, S. V. 2014. Fabrication of nanomaterials by top-down and bottom-up approaches-an overview. *Journal of Material Science*. 1, 89-93

[4] Baig, N., Kammakakam, I., and Falath, W. 2021. Nanomaterials: A review of synthesis methods, properties, recent progress, and challenges. *Mater. Adv*. 2, 1821–1871.
[5] D. Guo, G. Xie, J. Luo. 2014. Mechanical properties of nanoparticles: basics and applications. *J. Phys. D Appl. Phys*. 47. 13001, 10.1088/0022-3727/47/1/013001
[6] Das, S., and Srivasatava, V. C. 2016. Synthesis and characterization of ZnO–MgOnanocomposite by co-precipitation method. *Smart Sci.* 4, 190–195.
[7] Dong X, Mattingly CA, Tseng MT, et al. 2009. Doxorubicin and paclitaxel-loaded lipid-based nanoparticles overcome multidrug resistance by inhibiting P-glycoprotein and depleting ATP. *Cancer Res.* 69:3918–3926.
[8] Ealia S. A. M., & Saravanakumar M. P. 2019. A review on the classification, characterisation, synthesis of nanoparticles and their application IOP Conf. Ser. *Mater. Sci. Eng.* 263 03.
[9] Ealia SAM, Saravanakumar MP.2017. A review on the classification, characterisation, synthesis of nanoparticles and their application. In: IOP Conference Series: *Materials Science and Engineering. IOP Publishing*. p. 32019.
[10] El-Sayed A, Kamel M. 2018. Advanced applications of nanotechnology in veterinary medicine. *Environ Sci Pollut Res*. 10:1–14.
[11] F. J. Heiligtag and M. Niederberger. 2013. *Mater. Today*, 16, 262–271.
[12] Flores-Rojas, G.G.; López-Saucedo, F.; Vera-Graziano, R.; Mendizabal, E.; Bucio, E.2022. Magnetic Nanoparticles for Medical Applications: Updated Review. *Macromol* 2, 374-390. https://doi.org/10.3390/macromol2030024
[13] G. Reiss, A. Hütten. 2005. Magnetic nanoparticles: applications beyond data storage. *Nat. Mater.*, 4, pp. 725-726, 10.1038/nmat1494
[14] Gorrasi, G., and Sorrentino, A. 2015. Mechanical milling as a technology to produce structural and functional bio-nanocomposites. *Green Chem.* 17, 2610–2625.
[15] Guo, D., Xie, G., and Luo, J. 2013. Mechanical properties of nanoparticles: basics and applications. *J. Phys.* D 47:013001.
[16] Harish, V.; Tewari, D.; Gaur, M.; Yadav, A.B.; Swaroop, S.; Bechelany, M.; Barhoum, A.2022. Review on nanoparticles and Nanostructured Materials: Bioimaging, Biosensing, Drug Delivery, Tissue Engineering, Antimicrobial, and Agro-Food Applications. *Nanomaterials*. 12, 457. https://doi.org/10.3390/ nano12030457
[17] Hasan, S. 2015. A review on nanoparticles: their synthesis and types. *Res. J. Recent Sci*. 2277, 2502.
[18] Ibrahim Khan, Khalid Saeed, Idrees Khan. 2019. Nanoparticles: Properties, applications and toxicities, *Arabian Journal of Chemistry*, Volume 12, Issue 7, Pages 908-931, ISSN 1878-5352, https://doi.org/10.1016/j.arabjc.2017.05.011.
[19] Jain KK. 2005. Nanotechnology in clinical laboratory diagnostics. *Clin Chim Acta.* 2005;385:37–54.
[20] Joh, D.-W., Jung, T.-K., Lee, H.-S., and Kim, D.-H. 2013. Synthesis of nanoparticles using electrical explosion of Ni wire in Pt solution. *J. Nanosci. Nanotechnol*. 13, 6092–6094. doi: 10.1166/jnn.2013.7677
[21] Joudeh, N., Linke, D.2022. Nanoparticle classification, physicochemical properties, characterization, and applications: a comprehensive review for biologists. *J Nanobiotechnol* 20, 262 . https://doi.org/10.1186/s12951-022-01477-8
[22] K. W. Powers, M. Palazuelos, B. M. Moudgil, and S. M. Roberts. 2007. "Characterization of the size, shape, and state of dispersion of nanoparticles for toxicological studies," *Nanotoxicology*, vol. 1, no. 1, pp. 42–51.
[23] Kumari, S. C., Dhand, V., and Padma, P. N. 2021. Green synthesis of metallic nanoparticles: a review. *Nanomaterials*. 2021, 259–281.
[24] Lal R. 2007.Soil science and the carbon civilization. *Soli Sci Soc Am J*. 71:1425–1437
[25] M. Qi, K. Zhang, S. Li, J. Wu, C. Pham-Huy, X. Diao, D. Xiao, H. 2016. He Superparamagnetic Fe3O4 nanoparticles: synthesis by a solvothermal process and functionalization for a magnetic targeted curcumin delivery system. *New J. Chem*. 4480 , pp. 4480-4491, 10.1039/c5nj02441b
[26] Moghaddam SH, Jebali A, Daliri K. 2010. The use of MgO-Sio2 nano-composite for adsorption of aflatoxin in wheat flour samples. *Nanocon*. 10:12–14.
[27] Muktar Y, Bikila T, Keffale M. 2015. Application of Nanotechnology for Animal Health and Production Improvement. *World Applied Sciences Journal*. 33(10):1588-1596.
[28] Pan K, Zhong Q. 2016. Organic nanoparticles in foods: fabrication, characterization, and utilization. *Annu Rev Food Sci Technol*.7:245–66.
[29] Patil, M. P., and Kim, G.-D. 2018. Marine microorganisms for synthesis of metallic nanoparticles and their biomedical applications. *Colloids Surf. B Biointerf.* 172, 487–495.

[30] Roduner E. 2006. Size matters: why nanomaterials are different. *Chem Soc Rev*. 35(7):583–92.
[31] S. Eustis, M.A. El-Sayed. 2006. Why gold nanoparticles are more precious than pretty gold: noble metal surface plasmon resonance and its enhancement of the radiative and nonradiative properties of nanocrystals of different shapes. *Chem. Soc. Rev*., 35, pp. 209-217, 10.1039/B514191E
[32] S. T. Holgate. 2010. "Exposure, uptake, distribution and toxicity of nanomaterials in humans," *Journal of Biomedical Nanotechnology*, vol. 6, no. 1, pp. 1–19.
[33] Shevchenko, V.Y., Madison, A.E. 2002 Structure of Nanoparticles: I. Generalized Crystallography of Nanoparticles and Magic Numbers. *Glass Physics and Chemistry*. 28, 40–43 . https://doi.org/10.1023/A:1014201530029
[34] Shin W. K., Cho J., Kannan A. G., Lee Y. S. & Kim W., 2016. Cross- linked composite gel polymer electrolyte using mesoporous methacrylate functionalized SiO2 nanoparticles for lithium- ion polymer batteries, *Science Report*. 6, 26332
[35] Tomanek D, Enbody RJ. 2000. Revue scientifique technique International Office of Epizootics. 24(1):432.
[36] W. Wu, Q. He, C. 2008. Jiang Magnetic iron oxide nanoparticles: synthesis and surface functionalization strategies. *Nanoscale Res. Lett*. 3. pp. 397-415, 10.1007/s11671-008-9174-9
[37] Wang JB, Qi LL, Han F. 2016. Antibiotic with different antibacterial spectrum changed intestinal microflora structure and reduced immune response of Lingnan yellow broiler. *Res J Biotechnol.* 11:121–9.
[38] Yang Z, Sun L.2006. Effects of nanometer ZnO on growth performance of early weaned piglets. *J Shanxi Agric Sci*. 3:577–588.
[39] Z. Chen, H. A. Meng, G. M. Xing et al.2006. "Acute toxicological effects of copper nanoparticles in vivo," *Toxicology Letters*, vol. 163, no. 2, pp. 109–120.
[40] Zou B., Huang C.Z., Wang J., Liu B.Q. 2006. Effect of Nano-Scale TiN on the Mechanical Properties and Microstructure of Si3N4 Based Ceramic Tool Materials, Key Eng. Mater. 315-316, 154-158.10.4028/www.scientific.net/KEM.315-316.154

