Octa Journal of Biosciences
International peer-reviewed journal
Octa J. Biosci. Vol. 7(1):20-22

ISSN 2321 – 3663
Jan-June 2019

Octa Journal of Biosciences

journal homepage: www.sciencebeingjournal.com

Review Article

Ecological impact of nanoparticles: A review

Esha Bhati, Navneet Kaur, Nishtha Kapoor

1 Department of Biotechnology, Uttaranchal University, Dehradun-248007, India

ARTICLE INFO

Received 03 March 2019
Revised 28 April 2019
Accepted 30 May 2019
Available online 30 June 2019

Keywords: Nanotechnology, Nanoparticles, ecological impacts, plants, microbes

Email: ishcascade04@gmail.com

A B S T R A C T

In recent past significant amount of research has been conducted pertaining to synthesis of nanoparticles and their utility owing to their widespread application. Alongwith their application in healthcare and medicine mainly as drug carriers, potential to act as potent catalyst, role in bioremediation etc there has been a simultaneous concern related to their effect on environment upon their release. Studies conducted have implicated both positive effect as well as negative effect of nanoparticles on environment. The present review summarizes as to how the release of nanoparticles synthesized from different sources will influence the ecosystem and their potential impact on living organism once they enter into foodchain. Plant and soil microbes represent crucial component of ecosystem and effect of any chemical compound, biotic or abiotic factor on the same is of utmost importance. Hence with ongoing research so as to figure out the applications of nanoparticles simultaneous studies are required to assess their impact especially on plants, water and microbes.

INTRODUCTION

Nanoparticles are the ultrafine structure with dimensions in nanometre about 1nm= 10^{-9} meter. Nanoparticles has existed is nature since millions of years and in recent past synthetic synthesis of nanoparticles have increased exponentially (Guzman et al., 2006) . Due to sub microscopic size nanoparticles are known to possess unique characteristic. Major physical properties of nanoparticles include their are highly mobility in free state. Nanoparticles possesses considerably large surface area. Alongwith mobility and surface area nanoparticles also possess quantum effects. Synthesis of nanoparticles have gained momentum owing to their widespread application in field of medicine, engineering, catalysis, and environmental applications, cosmetics, pharmaceuticals, etc. In 2008 the International Organisation if Standardization (ISO) defines the nanoparticles as the nano-object which has all three dimensions less than 100nm. In 2011 European Union gave a more technical and wide range definition according to which, a object to be characterized as nano needs only one the characteristic dimension to range between 1-100nm. Nanoparticles are classified in various types, according to their shape, size, and material properties. Some classification distinguishes between organic and inorganic nanoparticles; the first group includes dendrimers, liposomes, and polymeric nanoparticles and the other group includes fullerene, quantum dots, and gold nanoparticles. Other classifications are done on the basis of carbon based, ceramic, semi conductive, or polymeric. Nanoparticles can also be classified as hard e.g., Titania or soft e.g., liposome's. The way of classification of nanoparticles depends on their application such as diagnosis, therapy base research, or the way they were produced. Nanoparticles have a widespread range of composition influenced by their use (Stephen king et al., 2010). The colloidal materials present in natural water include particles and macromolecules that range from size from 1 nm to 1 µm known as organic colloids. Natural as well as artificial combustion process results in production of particle of varying size. The natural nanoparticles may possess either atmospheric, geological or biological origin. Mineral nanoparticles are probably found to be present everywhere in soil, water, eological systems. Synthetic nanoparticles which are synthesized from organic polymers with an objective of specified application (Taghavi et al., 2013). Several techniques have been reported for nanoparticles preparation namely Gas condensation, Electrodepositing, Chemical vapour deposition, Mechanical attrition, Chemical precipitation, Vacuum deposition (Rajput 2015). Although nanoparticles have been reported to possess several application but yet there is concern related to their unexpected behaviour and impact once they start to accumulate in various components of ecosystem. Present review outlines major concerns related to impact of nanaoparticles on environment, plants and microbes.

Application and impact of nanoparticles on environment

The release of engineered nanomaterials in environment is expected to increase as an outcome of rapid research being conducted pertaining to synthesis of nanoparticles. However, comparatively scarce data is available pertaining to impact of nanoparticles of ecosystem and human health. There is requirement of substancial research to be conducted to analyze the fate, transport, bioaccumulation, stability, toxicity, persistancy and overall ecological impact of ENMs released in environment through various sources (Lowary et al., 2010, Taghavi et al., 2013, Bernd nowack et al., 2007). Nanoparticles can be absorbed by mammalian cells however rate of absorbtion depends upon the size and aggregation potential of nanoparticles. Transport of nanoparticles into subcellular organelles such as mitochondria can have toxic outputs on cellular metabolism, the toxic impact is attributed to their characteristic features including their ability to produce ROS (reactive oxygen species) (Koziare et al., 2003, Nel et al., 2006). NP's have been reported to cause inflammation, fibrosis, lung and cardiovascular disorder, NP's as a component of air pollution is extremely lethal especially to workers associated with industries such as coal, gas, Carbon electrodes , etc (Oberdorster et al., 2005, Armstrong et al., 2004). Aquatic organism pose a much higher risk to absorbtion and toxic effect of nanoparticles released into water bodies. Studies conducted have revealed accumulation and toxic impact of NP's on fish species, Daphnia (Zhu et al., 2006, Thill et al., 2006, Mansfield et al., 2015). Kaegi et al., 2008 have reported TiO2 nanoparticles to exert chemical impact on aquatic environment. Magnetic nanoparticles have been associated with corrosive nature towards environment. Co-precipitation; thermal decomposition and hydrothermal synthesis are some of the probable measures to control and manage shape and size of nanoparticles (An-hui Lu Dr. et al., 2007). Nanoparticle can potentially interact with a numerous molecules found to be present in water and sediments (Christain et al., 2008). Trantnyek and Richard 2006 reported Zero-valent iron nanoparticles to contaminate ground water. NP's not necessarily may have negative impact on environment. NP's may interact with toxic material and can decrease or increase the toxicity of the respective material.

Effect on nanoparticles on plants

In the recent past research in the field of nanotechnology has gained momentum owing to wide spread application of nanoparticles in health care, environmental applications, as catalyst, cosmetics, etc. Every technological advancement is associated with its own pros and cons. With rapid momentum in synthesis of nanoparticles from various sources application of same have raised simultaneous concern pertaining to the impact of release of nanoparticles into environment. Hence there is necessary requirement of analysis of impact of release of nanoparticles into environment before there commercial / large scale application (Yang et al., 2017; Tolaymat et al., 2015). Among different components of eco system impact of nanoparticles on growth, development and productivity of plant it at most important. Not only nanoparticles will directly affect plants

Table-1: Impact of different nanoparticles on ecosystem.

Types of nanoparticles	Ecological impact	Author
Zero-valent iron	Contaminate groundwater.	Paul G. Trantnyek, Richard L. Johnson 2006
Titanium oxide	Chemical impact on aquatic environment.	R. Kaegi *et al.,* 2008
Magnetic nanoparticles	Corrosive nature towards environment.	An-hui Lu Dr. *et al.,* 2007
Metal nanoparticles	Light scattering in complex environment.	K. Lance Kelly *et al.,* 2002
Iron nanoparticles	Not been studied to date.	Dale L. Huber Dr., 2005
Surface chemistry	Show interaction with surface water molecules.	Christain *et al.,* 2008
Silver nanoparticles	Readily transform in environment.	Quang Huy Tran *et al.* , 2013; Clement levard *et al.,* 2012

Table-2: Summarizes effect of nanoparticles on different plant species.

Nano Particales	Plant Species	Effect	Reference
Copper Oxide	Zucchini	No effect on germination , decrease in route length	Stampoules *et al* ., 2019
copper oxide	Maize	No effect on germination , decrease in route length	Wang *et al.,* 2012
Zinc oxide	Corn	No Inhibitory effect of growth	Zhang *et al.,* 2015
Titanium oxide + silicon DiOxide	Glyane Max	Positive impact	Lu *et al.,* 2001
Silver Nanoparticles	Phaseolus radiatus and Sorghum bicolor	Adverse effect on seed growth	Woo lee *et al.,* 2012
Zinc oxide	Tomato	No Inhibitory effect of growth	Md. Abdul Basith *et al.*, 2018
Silver Nanoparticles	*Bacopa monnieri*	No severe toxic effects were observed	C. Krishanaraj *et al.,* 2012
Nickel oxide	*Moringa oleifera*	No Inhibitory effect of growth	A. Angel ezhilarasi *et al.,* 2016
Zinc oxide	Onion	Increase gerimantion rate	S.V.Raskar and S.L.Laware 2014
zinc oxide (ZnO) and magnesium oxide	*Alternaria alternata, Fusarium oxysporum, Rhizopus stolonifer and Mucor plumbeus*	Inhibition in the germination	A. H. Wani and M. A. Shah 2012

but will also will move in the food chain through the plant due to which nanoparticles may accumulate in higher concentration at successive tropic levels in food chain and food web (Zhu et al., 2018; Rice et al., 2011). The interaction of nanoparticles with plants shows several physiological, morphological, and genotoxic changes, and it is important to understand the effective use of nanotechnology in agriculture. Researchers suggested both positive and negative impact of nanoparticles on plant growth and development depending upon the properties of nanomaterials, mode of application as well as plant species (Remya nair 2016). In a study of the impact of aluminium oxide nanoparticles on the growth of plants roots, a slight reduction was seen in the growth of roots in the presence of uncoated alumina nanoparticles, but no reduction was observed when the nanoparticles were coated with phenanthrene. The surface properties of alumina show toxicity (Sayed Mohammad Taghavi et al., 2013;). Studies conducted so far have revealed positive, neutral as well as negative impact of nanoparticles on plants species. Table 2 summarizes impact of nanoparticles on some of the plant species.

Effect on soil and microbes

Microorganisms constitute an indispensable component of ecosystem. They play a significant role in recycling of elements, decomposition,bioremediation, etc. Microbes inhabiting rhizosphere have been reported to support growth and development of several plant species. Hence, it becomes utmost important to evaluate effect of any biotic / abiotic factor on survival, physiology and metabolism of microorganisms. In recent past there has been exponential increase in synthesis of NP's owing to their widespread application. Directly or indirectly sythesized nanocomposites will find their release into the environment. Hence, their potential impact on soil microflora becomes crucial so as to figure out if there will be any negative impact of release of microbes onto soil microbes.

Most common source of release of nanoparticles into soil and water comprise through disposal of products (such as cosmetics, glass coatings, etc) after use. Beside these a fraction of nanoparticles are produced as waste by product during production process such as glass. Many nanoparticles have been reported to possess antimicrobial activity, when released into soil and water they directly inhibit growth of microbes (Schilling et al., 2010, Piccinno et al., 2012,). Nanoparticles dissolved in water penetrate through cell wall of microbes and alter cellular conductivity (Samanta and Mandal 2017). Kibbey and Stravett (2019) conducted a study to evaluate the effect of nanoparticles on rhizopheric bacteria and growth of plant butter crunch. Out of three nanoparticles studied amide modified polystyrene nanosphere and TiO2 nanoparticles was found to decrease the number of bacteria in rhizosphere along with decrease in shoot and root growth. However the third nanoparticles, SO4 modified polystyrene nanoshpere were found to enhance count of rhizospheric bacteria with no noticeable effect on the plant growth. The study also reported that there is mandatory requirement of nanoparticles to attach to plant root so as to exert their effect as only amide modified nanoparticles were found to attach to roots. In an another study conducted by Chavan and Nadanathangam (2019) toxic effect of AgO and ZnO nanoparticles were studied on nitrogen fixing, phosphate solubilising and biofilm making bacteria and the study reported AgO nanoparticles to effect the abundance of soil microbes however there was negligible effect of ZnO nanoparticles. Awet et al .,(2018) reported polystyrene nanoparticles to negatively affect growth of soil bacteria and activity of several enzymes, however rate of respiration and metabolic quotient was found to increase. Frank et al., (2013) studied effect of CuO and Fe_3O_4 nanoparticles on bacteria of two soil types sandy loam and sandy clay loam.

Iron oxide and gold nanoparticles has been reported to exhibit cellular growth effect against Escherichia coli (Saptarshi Chatterjee et al., 2011). Nanoparticles release in water bodies and uptake of same by aquatic organisms results in smooth entry of NP's into food chain and food web. Hence there is necessary requirement to analyze and predict probable impact and behaviour of nanoparticles once released into the environment (Eugene Krysanor et al., 2010).

Disclosure statement: No potential conflict of interest was reported by the author.

Financial and proprietary interest: Nil

REFERENCES

1. Armstrong B, Hutchinson E, Unwin J, Fletcher T (2004). Lung cancer risk after exposure to polycyclic aromatic hydrocarbons: a review and metaanalysis. Environ. Health Perspect. 112:970–978.
2. Awet, T. T., Kohl, Y., Meier, F., Straskraba, S., Grün, A. L., Ruf, T., Emmerling, C (2018). Effects of polystyrene nanoparticles on the microbiota and functional diversity of enzymes in soil. Environmental sciences Europe.30: 11. doi:10.1186/s12302-018-0140-6
3.Bernd Nowack and Thomas D.Bucheli (2007). Occurrence, behavior and effects of nanoparticles in the environment. Environmental Pollution. 150: 5-22.
4. Chatterjee S, Bandyopadhyay A and Sarkar K (2011). Effect of iron oxide and gold nanoparticles on bacterial growth leading towards biological application. J Nanobiotechnology. 9:34.
5. Christian, Von der KammerM. BaaloushaTh. Hofmann (2008). Ecotoxicology Nanoparticles: structure, properties, preparation and behaviour in environmental media. 17: 326–343.
6.Clément Levard, E. Matt Hotze Gregory V. Lowry Gordon E. Brown (2012). Environmental Transformations of Silver Nanoparticles: Impact on Stability and Toxicity. Environ. Sci. Technol.2012. Environ. Sci. Technol.46:6900-6914
7.Dale L. Huber Dr. (2005). Synthesis, Properties, and Applications of Iron Nanoparticles. Small nano imcro.1:482-501.
8. Einat cohen sela, Michael chorny, Nikolay koroukhov, Haim D. Danenberg, Gershon golomb, (2009) J. Of controlled release: A new double emulsion solvent diffusion technique for encapsulation hydrophilic molecule in PLGA nanoparticles. 133, (2) 90-95.
9. Ernest M. Hotze, Tanapon Phenrat and Gregory V. Lowry (2010). Nanoparticle Aggregation: Challenges to Understanding Transport and Reactivity in the Environment. J environmental quality. 1909-1924
10. Frenk S, Ben-Moshe T, Dror I, Berkowitz B, Minz D (2013). Effect of Metal Oxide Nanoparticles on Microbial Community Structure and Function in Two Different Soil Types. PLoS ONE 8(12): e84441. https://doi.org/10.1371/journal.pone.0084441.
11. Guzman KAD, Taylor MR, Banfield JF.(2006). Environmental risks of nanotechnology: national nanotechnology initiative funding, 2000–2004. Environ. Sci. Technol. 40:1401–1407.
12. Helen Jarvie Stephen King Peter Dobson, ENCYCLOPAEDIA BRITANNICA: Nanoparticles. March 17, 2010.
13.Kaegi, Ulrich, B. Sinnet, R.Vonbank, A. Wichser, S. Zuleeg, H.Simmlerb, Brunner, H.Vonmont, M, Burkhardt, Boller (2008). Synthetic TiO2 nanoparticle emission from exterior facades into the aquatic environment. Envirn Pollut. 15:233-239.
14. Kelly K L, Eduardo Coronado, Lin Lin Zhao, George C. Schatz (2003). The Optical Properties of Metal Nanoparticles: The Influence of Size, Shape, and Dielectric Environment. J phys. Chemistry. 107:668-677.
15. Kibbey and Strevett (2019). The effect of nanoparticles on soil and rhizosphere bacteria and plant growth in lettuce seedlings. Chemosphere. 221:703-707.
16. Koziara JM, Lockman PR, Allen DD, Mumper RJ (2003). In situ bloodebrain barrier transport of nanoparticles. Pharm. Res. ;20:1772–1778
17. Krishnaraj , E.G.Jagan, R.Ramachandran, S.M.Abirami, N.Mohan, P.T.Kalaichelvan (2012). Effect of biologically synthesized silver nanoparticles on Bacopa monnieri (Linn.) Wettst. plant growth metabolism. Process Biochemistry. 47: 651-658
18. Krysanov, Eugene & Pavlov, Dmitrii & Demidova, Tatiana & Dgebuadze, Yury (2010). Effect of nanoparticles on aquatic organism. Biology Bulletin. 37. 406-412
19. Lowry GV, Ernest M. Hotze, Emily S. Bernhardt, Dionysios D. Dionysiou, Joel A. Pedersen, Mark R. Wiesner and Baoshan Xing (2010). Environmental Occurrences, Behavior, Fate, and Ecological Effects of Nanomaterials: An Introduction to the Special Series. J environmental quality. 6:1867-1874.
20.Shah M. T., A. Balouch and E. Alveroglu (2018). Sensitive fluorescence detection of Ni2+ ions using fluorescein functionalized Fe3O4 nanoparticles . Journal of Materials Chemistry. 6:105-115.
21. Mansfield CM, Alloy MM, Hamilton J, Verbeck GF, Newton K, Klaine SJ, Roberts AP (2015). Photo-induced toxicity of titanium dioxide nanoparticles to Daphnia magna under natural sunlight. Chemosphere 120: 206–210.
22. Nel A, Xia T, Mädler L, Li N (2006) Toxic potential of materials at the nanolevel. Science. 311:622–627.
23. Oberdorster G, Oberdorster E, Oberdorster J (2005). Nanotoxicology: an emerging discipline evolving from studies of ultrafine particles. Environ. Health Perspect.113:823–839
24. Piccinno F, Gottschalk F, Seeger S, Nowack B (2012). Industrial production quantities and uses of ten engineered nanomaterials in Europe and the world. J Nanopart Res 14: 1109.
25. Quang Huy Tran, Van Quy Nguyen and Anh-Tuan Le (2013). Silver nanoparticles: synthesis, properties, toxicology, applications and perspectives. Adv. Nat. Sci.: Nanosci. Nanotechnol. 9:049501
26. Remaya Nair, Plant Nanotechnology: Effect of nanoparticles on plant and development. 14 oct 2016 pp 95-118. The effect of nanoparticles on soil and rhizosphere bacteria and plant growth in lettuce seedlings. Volume 221, aiprl 2019, pp 703-707.
27. Samanta PK, Mandal AK (2017). Effect of Nanoparticles on Biodiversity of Soil and Water Microorganism Community. J Tissue Sci Eng 8:196. doi:10.4172/2157-7552.1000196
28.Sayed Mohammad Taghavi, Mahdiye Momenpour, Maryam Azarian, Mohammad Ahmadian, Faramarz Souri, Sayed Ali Taghavi, Marzieh Sadeghain, and Mohsen Karchani, (2013). Electron Physician: effect of nanoparticles on the environment and outdoor workplaces. 5(4): 706–712.
29. Schilling K, Bradford B, Castelli D, Dufour E, Nash JF (2010). Human safety review of "nano" titanium dioxide and zinc oxide. Photochem Photobiol Sci 9: 495-509.
30. Taghavi, S. M., Momenpour, M., Azarian, M., Ahmadian, M., Souri, F., Taghavi, S. A., Karchani, M. (2013). Effects of Nanoparticles on the Environment and Outdoor Workplaces. Electronic physician. 5(4), 706–712. doi:10.14661/2013.706-712.
31. Thill A, Zeyons O, Spalla O, Chauvat F, Rose J, Auffan M, Flank AM (2006). Cytotoxicity of CeO2 nanoparticles for Escherichia coli. Physico-chemical insight of the cytotoxicity mechanism. Environ. Sci. Technol. 40:6151–6156.
32. Tratnyek P and Johnson R (2006). Nanotechnologies for environmental cleanup. Nanotoday. 1: 44-48.
33. Wani A N and Shah M A (2012). A unique and profound effect of MgO and ZnO nanoparticles on some plant pathogenic fungi. J of applied pharma. Sci.02:40-44
34. Zhu Y, Zhao Q, Li Y, Cai X, Li W (2006). The interaction and toxicity of multi-walled carbon nanotubes. Nanotechnol. 6:1357–1364.