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Mini Review

Reviews on Parameters to be Considered for Use of ZnO nanoparticles in Scientific Applications

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Abstract

The paper reviews the potential use of nanotechnology in treating wastewater using ZnO particles. The antibacterial activity and toxicity mechanism while interaction of ZnO particles with wastewater is discussed. The mechanism of process helps in understanding this new avenues of ZnO nanoparticles for the applications in industrial effluent treatment. The parameter like surface characteristics are highlighted in the presented mini review with the other parameters affecting the reaction strength of ZnO nano particles. Basic understanding of ZnO particles and mechanisms are focused to exhibit its potential use.

Keywords: ZnO Nanoparticles; Wastewater Treatment; Industrial Effluent

Abbreviations

ZnO-Np: Zinc Oxide Nanoparticles; ROS: Reactive Oxygen Species

Introduction

Nanotechnology has solution to many problems related to pollution and industries. Some of the work in this area in current times needs the approach from all fields like chemistry, physics, microbiology, chemical engineering and nano sciences etc. [1-6]. The breakdown of contaminants by nanoparticles catalyst is one of the means in treating contaminated water. Recent advances in the field of nanotechnology, particularly the ability to prepare highly ordered nano particulates of any size and shape, have led to development of new biocidal agents. Recent studies have shown that NP of some materials including metal oxides, can induce cell death in eukaryotic cells [7-11] and growth inhibition in prokaryotic cells due to cytotoxicity. Anti microbial activities of metal oxides by [12] was evaluated in culture media against Staphylococcus aureus, Escherichia coli or fungi and the generations of active oxygen species identified and exists because of metal oxide particles are the indicators of mechanisms by which antibacterial activity is assessed.

The presence inhibition of zone was tested by the well disc diffusion agar methods and its presence (Inhibition Zone) confirms the biocidal action of ZnO Nanoparticles as it is involved the disruption of membrane with high rate of generation of oxygen species and finally lead to the death of pathogen. According to their study, [11] growth inhibition increased with the the increasing concentration of ZnO particle because of proper diffusion of nanoparticles in the agar medium, as according to their results increasing concentration of ZnO particles decreases their growth of microbes. More Zn^{+2} ions needed for the more antimicrobial and antifungal activity. The confirmation of the fact was deduced that higher surface area to volume ratio of ZnO-Np would be achieved by smaller particle size. More production of reactive oxygen species gave more antimicrobial activity in smaller ZnO-Np.

Nano particles: Role in wastewater

ZnO nanoparticles has exhibited have a broad range of antibacterial activities. These activities were for both the type of bacterium- gram +ve as well as gram -ve. This activity was ensured with same nature of reactions and results in *Staphylococcus aureus*, *E. Coli*, and *Salmonella Listeria* Monocytogenes [13,14]. Other factors and many other microorganisms need to be investigated for its antimicrobial activity. However, it was suggested that the primary cause of the antibacterial function might be from the disruption of cell membrane activity [15].

Change in the morphology of the cells are a caused by ZnO Nanoparticles. The bactericidal or bacteriostatic effects can be interrogated. These actions of ZnO nanoparticles on and organisms like *C. jejuni* was bactericidal. The suggestive investigation in this case would be to check the duration of cell growth, antimicrobial activity mechanism and pH. The factor like oxidative stress also plays a vital role for such case of microorganism while its interaction with ZnO nanoparticles.

When there is a stress on bacterial culture in respect to its working environment, they tend to adopt a working style that governs the production of proteins for their defense. For example, protein like, superoxide dismutase, that destroys the ROS. This enzyme (protein) would help the defense by microorganism to the oxidative stress. The common proteins helping fight ROS and at the same time, stops the folding of the proteins again [16]. Such microorganisms need to be investigated for its use in effluent treatment plant.

The interactions of ZnO-Nps with the cell surfaces, it is noted that ZnO-Nps enter the cell wall with reasonable permeability of membrane. Here, nanoparticles enters the cell after breaking its wall and promotes the stress by oxidative potential. This needs experimentation investigating the cell growth inhibition and studies on its cell death. This data would be useful in designing the entire process arrangements for the nanoparticle-effluent setup made for interaction.

Biofilm formation and bacterial activity

Dwivedi., *et al*. studied the biofilm formation [4]. The formation of the biofilm and the growth pattern of bacteria, both, affects the mode of the use of Nanoparticles. This demands on data to check their biocidal activities. Such data should be interpreted for its use as antibiotics. The role of media selection is vital in this work. The microbial activities of *P. aeruginosa* were tested. The concluded state of it being bacteriostatic or bactericidal gave an idea it being producing some numbers of zones of inhibition with ZnO-at stipulated concentration.

When ZnO or other nano particles interact with the solution containing microorganisms, proper observations are needed to understand the ROS synthesis. This is due to fact that ROS is the main parameter in inhibition of microorganisms used. The action of ZnO-Np is broadly similar to that of their ions. Metal oxide ions (in this case Zinc oxides) are up-taken by the microorganisms. This metal oxides governs or sometimes totally restricts the work of enzymes. This steps comes to an outcome with the production of reactive oxygen species. As mentioned earlier in action of these oxidative species, they are harmful to the cell. Free ions of metal generates ROS.

Zinc oxide nanoparticles: Antibacterial activity and toxicity mechanism

Sirelkhatim., *et al*. discussed the toxicity mechanisms for ZnO [5]. ZnO exhibits significant anti-microbial activities when particle size is reduced to the nanometer range, then nano-sized ZnO can interact with bacterial surface and or with bacterial core where it enters inside the cell and subsequently exhibits distinct bactericidal mechanism [11].

The nanostructured ZnO has been emerged as a potential candidate for applications in sensors, energy, harvesting, and many electronic devices many pronounced applications are being currently explored in the biomedical and antiviral areas. This is a result of their potential biocompatibility over the other metal oxides, solubility in alkaline medium, and the Zn-O terminated polar surfaces [5].

Sirelkhatim., *et al*. tested the resultant ZnO samples, against three bacterial strains. ZnO containing samples exhibited considerably high activity that produced by undoped ZnO nanostructures. This means the activity of bacterial cultures with ZnO particles are subjected to the concentration of ZnO Nps and the type of microorganisms used. The study of nano particles are majorly bound with the parameters related to its structural properties and surface properties. The factors like pH of solution also matters.

The morphology has its own course in determining the bacterial activity in the presence of ZnO nano particles. Nano structured ZnO needs to be evaluated for all such activities in different microbial systems. Polar facets and non-polar facets of such nano structured ZnO results in different quantity of ROS generation and so they affect the activity (mainly photocatalytic) of ZnO [5].

It has been reported that functionalized ZnO surface leads to the best antibacterial activity responses. Annealing of ZnO powder has much effect in increasing the inhibition [12,13]. As these was confirmed by the researchers as they found that just 2mM of ZnO-NP's with reduced size and decreased bacterial growth by 97%. These result confirmed that the anti-bacterial activity also dependent on the size, and it was probably due to internalization and subsequent accumulation of NP's inside the cell until the particles reacted the cytoplasmic region. The tests was in dark, results In weaker antimicrobial properties. Then they concluded that only an ambient laboratory environment could achieve the optimum bactericidal effects.

The surface defects and surface chargers are also the factors that play major role in the mechanism of actions [20]. That the antibacterial action of ZnO-NP's is due to the membrane caused by defects such as edges and corners, which results from abrasive surface of ZnO. ZnO nanostructures and bacterial activity is surface dependent defect which in sequence are shape dependent.

ROS generation as the major cause of nanotoxicity, as deduced from many researches [20]. 12 nm showed best efficiency compared to other two sizes. This was attributed to ROS release on ZnO-NP's surface. The experiments were carried out under both Ultra Violet and visible light. The synthesis of reactive oxygen species by metal nano particles in the cell line has been studied by [21,22], and that on the inhibition of respiratory enzymes [23].

The chemistry view point of generation of ROS is necessary to know in any such system adopted for industrial purpose. Oxidation and reduction reactions of enzymes can help in understanding such system. The activity could be detected for specific pH range. Electrostatic Interactions between NP's and bacteria cell surface can reveal the relation amongst the growth and inhibiting factors [24].

It is interesting to know that the cell surface is negatively charged, and ZnO-NP's contain a positive charge in a water suspension [25]. This information can derive the electrostatic behavior of the system. ZnO antibacterial response in referred to the increased ROS production under UV light. And also with Zhang., *et al*. [25] who referred of the effect to a direct contact between NP's and the bacteria besicles ROS generation nearby bacteria membrane.

Base on the toxicity mechanism of ZnO-NP's review concludes that the toxicity differs from one study to another according to test further mechanism and research are currently being investigate the exact toxicity mechanism to deeply, elucidate the sensitivity of bacteria to ZnO-NP's as the results to date are promising.

Conclusions

ZnO nano particles have potential to treat industrial wastewater. It can further be explored for further applications like cancer treatment and applications. However the toxicity of the particles remains a question.

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Bibliography

1. Dharmesh H Sur and Mausumi Mukhopadhyay. "Role of zinc oxide nanoparticles for effluent treatment using Pseudomonas putida and Pseudomonas aureofaciens". *Bioprocess and Biosystems Engineering* 42.2 (2019): 187-198.

2. Sangeetha Gunalan., *et al*. "Green synthesized ZnO nanoparticles against bacterial and fungal pathogens". *Progress in Natural Science: Materials International* 22.6 (2012): 693-700.

3. Yanping Xie., *et al*. "Antibacterial Activity and Mechanism of Action of Zinc Oxide Nanoparticles against Campylobacter Jejuni". *Applied and Environment Microbiology* (2011): 2325-2331.

4. Dwivedi S., *et al*. "Reactive oxygen species mediated bacterial biofilm inhibition via zinc oxide nanoparticles and their statistical determination". *PLoS One* 9.11 (2014): e111289.

5. Amna Sirelkhatim., *et al*. "Review on Zinc oxide Nanoparticles: Antibacterial Activity and toxicity mechanism". *Nano-micro Letter* 7.3 (2015): 219-242.

6. Sundan Baruah., *et al*. "Nanostructured Zinc Oxide for water treatment". *Nanoscience and Nanotechnology Asia* 2 (2012): 19-102.

7. Ak Gupta and M Gupta. "Cytotoxicity suppression and cellular uptake enhancement of surface modified magnetic nanoparticles". *Biomaterials* 26 (2005): 1565-1573.

8. TC Long., *et al*. "Titanium Dioxide (p25) produces reactive oxygen species in immortalized microglia (Bv2): implications for nanoparticle neurotoxicity". *Environmental Science and Technology* 40 (2006): 4346-4352.

9. S Magrez., *et al*. "Cellular toxicity of carbon based nanomaterials". *Nano Letters* 6 (2006): 1121-1125.

10. A Nel., *et al*. "Toxic potential of materials at the nano level". *Science* 311 (2006): 622-627.

11. W Rizwan., *et al*. "Formation of ZnO micro flowers prepared via solution process and their antibacterial activity". *Journal of Nanoscale Research Letters* 5 (2010): 1675-1681.

12. J Sawai., *et al*. "Quantitative evaluation of anti funal activity of metallic oxide powders (ZnO, MgO, CaO) by conductimetric assay". *Journal of Microbiological Methods* 54 (2003): 177-182.

13. Jones N., *et al*. "Antibacterial activity of ZnO nanoparticle suspensions on a broad spectrum of microorganisms". *FEMS Microbiology Letter* 279 (2008): 71-76.

14. Liu Y., *et al*. "Antibacterial activities of Zinc Oxide nanoparticles against E. Coli O157:H7". *Journal of Applied Microbiology* 107 (2009): 1193-1201.

15. Brayner R., *et al*. "Toxicological impact studies base on E. Coli bacteria in ultrafine ZnO Nanoparticles colloidal medium". *Nano Letter 6* (2006): 866-870.

16. Arsene., *et al*. "The heat shock response of E. Coli". *International Journal of Food Microbiology* 55 (2000): 3-9.

17. JT Seli and TJ Webster. "Antimicrobial applications of nanotechnology: methods and literature". *International Journal of Nanomedicine* 7 (2012): 2767-2781.

18. L Zhang., *et al*. "Investigation into the antibacterial behavior of suspensions of ZnO nanoparticles (ZnO nanofluids)". *Journal of Nanoparticle Research* 9.3 (2007): 479-489.

19. X Peng., *et al*. "Effect of morphology of ZnO Nanostructures on their toxicity to marine algae". *Aquation Toxicology* 102.3 (2011): 186-196.

20. N Padmavathy., *et al*. "Enhanced bioactivity of ZnO nanoparticles-an antimicrobial study". *Science and Technology of Advanced Materials* 9.3 (2008): 035004.

21. B Kalyanaraman., *et al*. "Measuring reactive oxygen and nitrogen species with fluroscent probes: challenges and limitations". *Free Radical Biology and Medicine* 52.1 (2012): 1-6.

22. R Wahab., *et al*. "ZnO nanoparticles induces cell death in malignant human T98G gliomas, Kb and non malignant HEK cells". *Journal of Biomedical Nanotechnology* 9.7 (2003): 1181-1189.

23. Y Matsumura., *et al*. "Mode of bactericidal action f silver zeolite and its comparison with that of silver nitrate". *Applied and Environmental Microbiology* 69.7 (2003): 4278-4281.

24. PK Stoimenov., *et al*. "Metal oxide nanoparticles as bactericidal agents". *Langumir* 18.17 (2002): 6679-6686.

25. L Zhang., *et al*. "ZnO nanofluids- a potential antibacterial agent". *Progress in Natural Science* 18.8 (2008): 939-944.