NANOPARTICLES UPTAKE AND TOXICITY IN PLANTS: IMPLICATION ON REUSE POTENTIAL OF WASTEWATER FOR IRRIGATION

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NANOPARTICLES UPTAKE AND TOXICITY IN PLANTS: IMPLICATION ON REUSE POTENTIAL OF WASTEWATER FOR IRRIGATION

by

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to the

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This thesis is devoted to my parents

For their endless love, support and sacrifices....

CERTIFICATE

This is to certify that the thesis entitled **"NANOPARTICLES UPTAKE AND TOXICITY IN PLANTS: IMPLICATION ON REUSE POTENTIAL OF WASTEWATER FOR IRRIGATION"** being submitted by **Miss. DIVYA SINGH** to the Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy** is a record of the original bonafide research work carried out by her under my guidance and supervision. The thesis work, in my opinion, has reached the requisite standards fulfilling the requirement for the Degree of Doctor of Philosophy.

The results contained in this thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

Amid growing competition for freshwater from household and industry, coupled with scarcity of water and exceeding the minimum recharge levels, there is a rapid increase in the use of treated wastewater for irrigation and other purposes worldwide. Widespread use of Nanoparticles (NPs) in various consumer products have raised global concerns. However, investigations of the potential impacts of NPs on both short term and long term effect on plants are sparse.

The main objective of this study was to understand potential suitability of NP contaminated water for irrigation of edible plants and this was achieved throughthree sub-objectives. The first sub-objective was to understand short term effect (seed germination) and long term effects of NP exposure to plant. NPs (CuO andZnO) and ions as single and in binary mixture were exposed to plants (*Vigna radiata and Raphanus sativus*) in concentration range 0.1, 1, 10, 100, 1000 mg/L. Results shows that, at seed germinetion stage root length, shoot length and dry weight of seedlings were found to decrease due to exposure of CuO and ZnO NPs (compared to control at concentration >10 mg/L). Ions were to be more toxic to seedlings than NPs. For CuO and ZnO NPs in mixture interaction were found to be of antagonistic nature for all concentration. CuO NPs has more tendency to get adsorbed on the seedling surface than ZnO NPs when exposed as single as well as binary mixture. In long term effect (full scale) of NP (CuO and ZnO as single and in binary mixture) were exposed to plants (*Spinacia oleracea and Raphanus sativus*) in a concentration range 10, 100, 1000 mg/L in soil media. More uptake of ZnO NPs was found as compared to CuO NPs. Translocation factor (Tf) was found more for ions than NPs. *S. oleracea* was grown on soil amended with CuO NPs, increase in shoot length and fresh weight was observed at 10 mg/kg for CuO NPs.The chlorophyll and carotenoid content in leaves (in mg/g fresh leaf

tissue) of the treated groups were significantly higher than those of the control. *R. sativus* plants were irrigated with water containing CuO and ZnO NPs as single compound and in binary mixture throughout their life cycle and it's effect on 2ndgeneration seeds were seen. Germinated 2nd generation seeds had reduced root length, shoot length and fresh weight as compared to control. Maximum uptake was found in case of ZnO NPs followed by binary mixture of CuO+ZnO NPs and minimum for CuO NPs. The order of toxicity were found as CuO NPs > Binary Mixture (CuO+ZnO) NPs > ZnO NPs. These findings indicate the mixture of NPs effects plant physiology and ions are taken up during seed germination. Results obtained in this sub objective can be used for exposure assessment part of risk assessment. Full scale studies of plants in soil media for mixture of NPs was conducted for the first time as per author's knowledge. The third sub-objective elaborates and compiles data gaps in quantitative health risk assessment of exposures of NPs from edible plants, irrigated with NPs-contaminated wastewater.Concentration of NPsin edible portion of plant (in terms of mg NPs/g of plant) was found to be lacking and need to be studied further. Development of a health risk-based criteria for deciding treatment goals of NPs in wastewater effluent before it can be used for irrigation activities in important. Analysis indicated that there is a data gap on (1) co-occurrence of NPs in irrigated wastewater and plants;(2) mixture toxicity for oral exposure route; (3) Conduct uptake studies using mixture of NPs and interaction between them; (4) Develop groups of co-occurring NPs influencing a given endpoint from oral exposure route and obtain dose-response data during exposures of mixture of NPs to animals.

This study provides quantitative estimate of toxic effect and uptake of ions in mixture of two NPs to plants grown for short and long duration. Findings of this study are expected to be useful for the agencies to informguidelines for for irrigational water and also suitability of treated wastewater for agriculture.

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List of Acronyms

- ECs: Emerging Contaminants
- NPs: NPs
- HHRA: Human Health Risk Assessment
- WW: Wastewater
- WWTP: Wastewater treatment plant
- T_f: Translocation factor
- NPs: Engineered Nanomaterials