FEASIBILITY OF REMOVING NANOPARTICLES FROM WATER USING ACTIVATED CARBON-BASED ADSORPTIVE FILTER

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by

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CERTIFICATE

This is to certify that the thesis entitled **"Feasibility of Removing Nanoparticles from Water using Activated Carbon-Based Adsorptive Filter"**, being submitted by **Ms. Tropita Piplai**, to the **Indian Institute of Technology Delhi**, for the award of **'Doctor of Philosophy'** in Department of Civil Engineering is a record of the bonafide research work carried out by her under our supervision and guidance. She has fulfilled the requirements for the submission of this thesis, which to the best of our knowledge has reached the requisite standard.

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

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ABSTRACT

Nanoparticles (NP) are growing to be a major concern in today's world. Due to their ubiquitous presence, their removal from the environment is a necessity at present.

The objective of this study was to study the removal of nanoparticles using activated carbon by batch and column studies. Adsorption of nanoparticles (ZnO, CuO and their mixture) onto Activated Carbon (AC) were studied using batch and column techniques to investigate the feasibility of the removal of nanoparticles from water. The main sub-objectives were the removal of single and mixture of selected nanoparticles by Activated Carbon in batch studies and Activated Carbon filter bed in column studies and transport modelling of nanoparticles in the activated carbon column bed.

In batch studies, the influence of contact time, pH (5,6,7,8 and 9) and adsorbent dose (0.01, 0.1, 1, 10 and 100 g/L) on the removal process were studied. Results revealed that, overall adsorption capacities of AC for Zn (from ZnO nanoparticles) in deionized water was 0.9±0.028 mg/g (91.3% removal) and wastewater was 0.6±0.038 mg/g (78% removal) at pH 8 and for Cu (from CuO nanoparticles) in deionized water was 0.95±0.036 mg/g (95.6% removal) and wastewater was 0.75±0.078 mg/g (83% removal) at pH 6 respectively in a single solution. In a mixture colloidal solution of ZnO and CuO nanoparticles at optimum conditions, overall adsorption capacities of AC for Zn in deionized water was 0.71±0.051 mg/g (74.7% removal) and wastewater was 0.576±0.019 mg/g (69% removal) and for Cu in deionized water was 0.82±0.017 mg/g (81.2% removal) and wastewater was 0.6±0.032 mg/g (71.5 % removal). Pseudo Second Order, Langmuir and Weber Morris Models co-related the best with the adsorbed data from experimental studies. The models indicated that the adsorption of the nanoparticles onto AC was favourable.

In column studies, the influence of contact time, NP dose (1, 10 and 100 mg/L) and flowrate (0.5, 1, 1.5 mL/min) on the removal process were studied. At nanoparticle concentration of 1 mg/L, for single suspension, for ZnO nanoparticles, the time-to-breakthrough was found to be 53, 55.5 and 49 hours and for CuO nanoparticles, it was found to be 49.5, 53, 47 hours for flowrates 0.5, 1, 1.5 mL/min respectively. Similarly, for binary suspensions, for ZnO nanoparticles, the time-to-breakthrough was found to be 48.5, 49 and 45.5 hours and for CuO nanoparticles, it was found to be 43, 48.5 and 43.5 hours for flowrates 0.5, 1, 1.5 mL/min respectively. Thus it was seen, that the breakthrough was reached faster for Cu than Zn. Column performance models were applied and the values supported the applicability of Thomas model for the removal of ZnO and CuO nanoparticles. The filtration parameters, such as attachment efficiency (α_{pc}), NP deposition rate (k_d) and filter coefficient (λ) were also observed to be dependent on the variation in flowrate as well as NP concentration. The total % of Zn (single) leached was 66.3% and total % of Cu (single) leached was 63.2%**.** In binary suspension, the total % of Zn leached was 55.9% and total % of Cu leached was 48.6%. It was reported that Zn was leached more than Cu. Furthermore, qualitative characterization analysis was done through SEM, EDX, FTIR, XRD, DLS and Zero Charge for the confirmation of nanoparticle removal using activated carbon. This study provided a detailed analysis of the removal of ZnONPs and CuONPs and an insight on the removal capacity of activated carbon for the removal of these nanoparticles from wastewater. Conclusions from this study would help to establish more treatment plants especially for the removal of nanoparticles from water.

Keywords: Nanoparticles, Activated Carbon, Adsorption, Filtration, Adsorptive filter bed, Leaching

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NOMENCLATURE

AAS	Atomic Absorption Spectrophotometer
AC	Activated Carbon
Ag_2ONPs	Silver oxide Nanoparticles
ANOVA	Analysis of variance
BET	Brunauer, Emmett and Teller Analysis
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CuONPs	Copper oxide Nanoparticles
DI	Deionized Water
DLS	Dynamic Light Scattering
DWTPs	Drinking Water Treatment Plants
EDX	Energy-Dispersive X-Ray Spectroscopy
FTIR	Fourier Transform Infrared Spectroscopy
HSD	Tukey's Honest Significant Difference Test
NOM	Natural Organic Matter
NP	Nanoparticle
NP/AC	Nanoparticle/Activated Carbon Concentration Ratio
OECD	Organisation for Economic Co-operation and Development
pH_0	Initial pH
pH_f	Final pH
pHpzc	Point of Zero Charge
pK_h	Hydrolysis Constant
SEM	Scanning Electron Microscopy
TDS	Total Dissolved Solids
TEM	Transmission Electron Microscopy
TOC	Total Organic Carbon

TiO_2NPs	Titanium oxide Nanoparticles
TSS	Total Suspended Solids
USEPA	United State Environmental Protection Agency
WW	Wastewater
WWTPs	Wastewater Treatment Plants
XRD	X-Ray Diffraction
ZnONPs	Zinc oxide Nanoparticles