ARSENIC REMOVAL FROM DRINKING WATER BY FIXED BED ADSORPTION

by

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CERTIFICATE

This is to certify that the thesis entitled, "**ARSENIC REMOVAL FROM DRINKING WATER BY FIXED BED ADSORPTION**" being submitted by **Mr. Tony Sarvinder Singh** to the Indian Institute of Technology, Delhi for award of Doctor of Philosophy is a record of bonafide research work carried out by him under my guidance and supervision in conformity with the rules and regulations of Indian Institute of Technology, Delhi.

The research report and results presented in this thesis have not been submitted, in part or full, to any other university or institute for the award of any degree or diploma.

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TO

MY PARENTS

(SARDARNI & S. SHER SINGH)

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ABSTRACT

Contamination of drinking water by arsenic has become a key environmental problem of 21 st Century. Millions of peoples are suffering from ill effects of arsenic contaminated drinking water in various parts of the world. Effects are being made to provide arsenic free drinking water in rural areas using low cost adsorbents. In the present study removal of arsenic ions [As(III) and As(V) ions] from water using activated alumina and iron oxide impregnated activated alumina were investigated. The experiments were carried out in batch and fixed bed mode. Preliminary experiments were carried out with a series of sorbents in order to find out a suitable adsorbent for the effective removal of arsenic ions. Five different sorbents were chosen out of which two were different grades of activated alumina (AA). Other sorbents activated carbon prepared from rice husk, MnO_2 impregnated AA and iron oxide impregnated AA were used. Based on preliminary experiments AA (AD 101, IPCL grade) and IOIAA had shown maximum percent arsenic removal and highest sorption capacity. Further investigations were made with these two sorbents on As (III) and As (V) removal. The effect of pH, initial sorbate concentration and amount of sorbent in batch mode was studied. pH has shown to be a decisive factor on arsenic removal. Equilibrium, Kinetics and Thermodynamics studies were carried in order to evaluate sorption parameters. The adsorption isotherms were well fitted by Langmuir and Freundlch isotherm. First order kinetics parameters were fitted by Lagergren kinetics and pseudo second order kinetics. Diffusion effect in a solid pellet was also investigated to understand the mechanism of adsorption. Presences of other ions such as PO_4^{3-}, SO_4^{2-}, Cl^- and F^-, which are generally present in ground water

sources, were also investigated on the arsenic removal efficiency. It was observed that removal was strongly affected because of presence of these ions and PO_4^{3-} and F^- were the most interfering ions. Exhausted AA was regenerated by using NaOH solution and regeneration efficiency was tested for repeated regeneration cycles. Both weight loss of activated alumina during subsequent regeneration cycles and the effects of acid concentration on reactivation were studied.

The performance of the sorbent for arsenic removal was also studied in a continuous operation, as batch adsorption data do not predict the breakthrough behavior. The effect of inlet flow rate, initial arsenic concentration and bed height has been studied in a fixed bed of sorbent (25 mm ID column) based on the parameters of batch experiments. Experiments were carried out to evaluate the As (III) and As(V) removal efficiency on AA and IOIAA. Percent arsenic removal as a function of run time and uptake capacity related to flow volume was determined by evaluating the breakthrough curves at different flow rate, bed height and initial concentration. Data revealed that an early saturation and lower arsenic concentration in the effluent was observed at higher flow rate and higher arsenic concentration. The column experiments data were analysed by Bohart Adam model. This model satisfactorily explained the behavior during the initial period of breakthrough, but not in the final tailing zone. Therefore another one-dimensional model for non-isothermal, non-equilibrum and non-adiabatic, axial dispersed fixed bed adsorption was developed and solved numerically. The model includes the fluid velocity gradient across the axial direction of the bed. Predicted simulations based on the assumption of pore diffusion rate control condition matched the experimental data. The model results revealed that specific interaction between the solute and the sorbents increases the ion removal and adsorption equilibrium seems to become decisive factor, as the column tends to saturate. The results of this investigations suggested that activated alumina (AA) and iron oxide impregnated activated alumina (IOIAA) can be effectively used for the treatment of arsenic contaminated groundwater. The treatment of waste is not complete until there is a suitable method available for the disposal of solid waste generated. ANSI standards test methods are available for the safe disposal to various kinds of waste generated during treatment. In the present study investigation were also carried out for the safe disposal of arsenic sludge. The technique was employed to reduce the mobility of arsenic ions so as not to present any environmental hazard. Various matrices were prepared by adding cement, flyash, lime, polystyrene and poly-methyl-methaacrylate (PMMA). These matrices were prepared as per ANSI/ANS standards. The leaching experiments were carried out as per TCLP test method. Semi dynamic leachabilty test were also carried out to determine the leachability of contaminants from monolithic solidified waste forms. Based on results of solidifcation/stablisation studies, an efficient method for disposal of arsenic waste has been proposed.

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