STUDY ON SOIL CONTAMINATION AND EFFECT OF PERIODIC RAINFALL ON THE CONTAMINANT TRANSPORT

by

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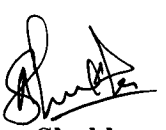
CERTIFICATE

This is to certify that the thesis entitled "**Study on Soil contamination and Effect of Periodic Rainfall on Contaminant Transport**" submitted by **Anwar Ali Khan** to the Indian Institute of Technology, Delhi for the award of the Degree of Doctor of Philosophy, is a bonafide record of research work carried out by him under our guidance and supervision in conformity with the rules and regulations of Indian Institute of Technology, Delhi. The research report and results embodied in this thesis have not been submitted for any other degree or diploma in any other University or Institute.



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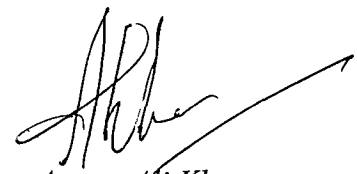

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ABSTRACT

Contamination of groundwater and soil has been and continues to be a worldwide phenomenon that has attracted a great deal of concern from governmental and regulatory bodies anxious to prevent further deterioration of valuable resources and to examine possible methods of remediation of the contaminated soil/groundwater. The large scale industrialization has resulted in the discharge of huge quantity of solid and liquid waste on soil, which is a source of danger to the health of people, even to those living in cities. The water flow through the soil has the potential to leach the contaminants and carry them to the food chain and ultimately to the ground water table. The consequence is that soil or groundwater water may be contaminated through direct or indirect dumping of contaminants on improperly designed landfills or on land. This transport of leachate from dumping sites to soils is subjected to various physical, chemical and biological processes that affect the eventual concentration of pollutants in soil and groundwater. Since these activities cannot be eliminated, the ground water protection efforts must be directed to the control and management of these sources to ensure that the released pollutants will be sufficiently attenuated within the subsurface to maintain groundwater quality parameters stipulated by World Health organization (WHO), Central Public Health Organization (CPHO) and others.

Mathematical models can serve as important tools to evaluate the effects of infiltrating leachate and design remedial options. Various mathematical models have been developed to simulate the transport of pollutants in soils and evaluate the potential of various soil remediation techniques.

Chromium is used in many applications in industries because of its high mechanical strength, decorative and non corrosive nature. Besides its usage in metallurgical and

mechanical industries in the metal form, large quantities of chromium are also used in chemical compound form (trivalent, Cr^{+3} and hexavalent, Cr^{+6}) in leather electroplating and wood processing industries. Cr^{+6} is a highly toxic and mobile in nature. Even a relatively small amount can cause cancer, kidney damage and other damage to flora and fauna.

Rainwater infiltration through soil, landfills and other waste sites containing chromium results in continuous release of chromium leachate into the underground environment and exacerbate groundwater quality severely. Due to the highly mobile and high solubility nature of hexavalent chromium, it pose direct threat to the groundwater quality and consequently to the human health dependent on groundwater resources. Chromium migrates through the soil through physical and biological processes like advection, dispersion, and sorption. Due to continuous adsorption/desorption of chromium, soils are progressively cleansed by the movement of rainwater and contaminant concentration diminishes with time once the dumping of chromium waste is stopped. It is important to be able to predict the time period for such cleansing as well as that required for the ground water contamination to develop.

In the present study, the adsorption of Cr (VI) from aqueous solution by soil was investigated in both batch and continuous mode of operations. The effects of pH, initial Cr (VI) concentration and soil dose on the adsorption was examined. It was found that maximum adsorption takes place at a low pH value of 2. The adsorption data were fitted using Langmuir and Freundlich isotherms. Both isotherms gave a good fit for experimental data. This was primarily due to low adsorptive capacity of the soil. Continuous flow soil Column breakthrough curve analysis revealed that early bed saturation takes place at higher flow rates and at higher solute concentrations and low

pH. Higher flow rate of solvent also resulted in lower Cr (VI) concentration in the extracted liquid.

An attempt has been made to model the transport of Cr (VI) through soil column and estimate the time required for the contaminant to reach the water table. The approach considers the advective and dispersive transport of solutes dissolved in water, which may undergo linear sorption and consequent retardation and simple first-order decay due to Chemical/Biochemical reactions taking into account spatial variations of the contaminants. The last term becomes very important for organic contaminants, where either chemical or biological degradation becomes very important phenomenon for the ultimate transport of the solute component.

Measured concentrations of chromium by means of U.V spectrophotometer at the soil column outlets (breakthrough curves) were compared with those predicted by using the standard one-dimensional convection-dispersion –adsorption model. Simulated results of the one-dimensional model accounting for the dispersion & adsorption process, matches the experimental data.

The contaminant sources and its release to the soil environment may be described by two extreme cases: continuous release and instantaneous release. Continuous release implies a continuous influx of the contaminant as realized in the case of a landfill for relatively long periods of time, whereas instantaneous release implies a pulse or sudden influx of contaminant for a very short period of time as in the case of chemical spills. In most cases, further disposals are stopped after the initial dumping, but periodic rainfall causes further movement of the contaminant through the system. The rainwater washes the contaminant from the first few layers of soil to subsequent depths. As a result, there is a cyclic movement of contaminant, whereby the concentration of contaminant decreases in the top layers but gradually increases as we

move down the soil column. So far, most studies regarding the transport of contaminants have been conducted, considering leachate and or washing solvent flow as a continuous process. However, overreaching objective this research is to increase the understanding of groundwater contamination by the periodic movement of contaminants due to rainfall washouts, and to evaluate the feasibility of efficient and low cost remediation alternatives for a particular site.

The mathematical analysis of the experimental results obtained for cyclic washing of soil column of 30 cms by tap water (simulated with rainfall) was also done with the help of same one dimensional advection –dispersion – sorption model. It showed the same trend as predicted by the model. The adsorption and desorption experiments using the continuous flow column was simulated by the mathematical model developed for the flow through soil bed. The model predictions were compared with the experimental results with good agreement between the two sets of results. The major conclusion arrived from this exercise was that the relatively simple one dimensional model but with the incorporation of all the basic transported process system is quite adequate for predicting the transport of a contaminant through soil with reasonably good accuracy.

The model has been used for the simulation of most important natural soil redemption process taking place in nature. A patch of land within IIT Delhi campus from where the soil samples were collected for experimental analysis has been considered for the theoretical model analysis, especially with respect to the natural redemption. The land is presumed to be contaminated because of some indiscrete disposal of chemicals both organic and inorganic in nature. The inorganic contaminant consisted of hexavalent chromium whereas organic component was considered to be a biodegradable carbohydrate chemical.

The results show periodic downward movement of the inorganic chromium chemical front with time ultimately reaching the underground aquifer after a very prolonged period of natural cycles of rain fall. The retardation caused by the adsorption and desorption of the component caused extensive modulation of the front movement which delayed the transport as well as reducing the concentration to a very low value compared to that near the top of the soil layer.

The same analysis incase of organic component throws some interesting results. Under most conditions the biodegradability of organic chemicals causes the same to be degraded before it reaches the bottom layers and prevents the component to show up in the underground aquifer. Thus depending on the strength of the organic waste and the rain fall condition in the area a sustainable disposal loading may be estimated which will allow the underground water table to remain undisturbed. This opens up the possibility of allowing some partially treated/untreated waste water contaminated with biodegradable organic chemical to be disposed on the land without any significant repercussion on the underground water table. The analysis presented also highlights the necessity of careful consideration of all relevant factors like characteristics of soil and the contaminant chemical both, rain fall conditions its intensity and periodicity, soil bed depth and location of the underground water table . This forms one of the major outcome of the project and has immense potential in terms of its analysis for different case scenarios.

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