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Simulation of Nickel in soils affected by wastewater and sludge by using Hydrus 1D

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Abstract

Transport of heavy metals in contaminated soils can cause groundwater pollution. In the present study Hudrus one dimensional software was used for nickel metal transfer from soil to groundwater. Concentrations of Ni was considered in wastewater and sludge as boundary conditions on the flow of incoming water, the concentration of Ni was considered in leaching water as the outlet boundary. Considering the equilibrium model Crank Nicholson and Galerkin finite element by software Haydrus. Concentration changes of Ni was simulated over irrigation period. For this purpose the software Haydrus numbered 1 to number of soil layers, Depth of 100 cm, the depth of groundwater. Time period of irrigation was 150 days. Distribution curves of Ni concentrations in the soil profile shows the experimental results with computational results obtained from the model are similar. And it can be applied in order to determine the concentration distribution of metals in the non- unsaturated zone soil and anticipated arrival time to a specified depth. It can be used to control metal concentrations in the soil and groundwater.

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Introduction

Hydrus-1D software is one of the most advanced software in conjunction with one-dimensional movement of water, salts in the soil (Ghorbani *et al*, 2009). Many or most subsurface pollution problems at the field scale involve such simultaneous processes as water flow, multicomponent solute transport, heat transport and biogeochemical processes and reactions.

Process-based models that integrate these various processes can be valuabl tools for investigating the mobility of a wide range of inorganic and organic contaminants subject to different hydrologic and geochemical conditions (Jacques *et al*, 2008). The transport of Cu, Pb and Zn in paddy soils was simulated by numerical modeling of non-equilibrium solute transport and adaptation of the Hydrus-1D model. The simulations show that leaching rates decrease in the order, Zn > Cu > Pb. This order is confirmed by the results of sequential extractions. Under constant flooded conditions at a water table of 20 cm, Cu, Pb and Zn were estimated to reach the soil depth of 1 m within 470, 495 and 370 days, respectively, emphasizing that reactive pollutants can reach groundwater in a relatively short time (Nguen *et al*, 2009).

The processes of evaporation and plant transpiration also exert a major influence on water and solute distributions in near-surface environments (vrugt *et al*, 2001). These processes concentrate salts by decreasing the amount of water in the soil, and when combined with irrigation in arid regions can lead to highly saline conditions. Ion activities for such chemical conditions should be calculated with expressions suitable for use in brines, rather than with the more standard formulations for dilute solutions (Sarvestani and Mirbagheri, 1982). The interaction of evapotranspiration, changing soil gas composition, ion exchange and soil-water reactions may cause precipitation and dissolution (Mirbagheri, 2004). The Hydrus-1D software package is for simulating one-dimensional variably saturated water flow, heat movement, and the transport of solutes involved in sequential first-order decay reactions.

To be able to simulate the salinization processes, we also implemented into the Hydrus software the carbon dioxide transport and production, and major ion chemistry (Simunek *et al.*, 2009).Hydrus computer program, and the Hydrus 1D interactive graphics-based user interface.

The Hydrus program numerically solves the Richards equation for saturated-unsaturated water flow and advection-dispersion type equations for heat and solute transport (Simunek *et al.*, 2006).The water flow equation incorporates a sink term to account forwater uptake by plant roots. Moradi research and modeling fellow cadmium transport below the root zone in arid soils amended with sludge at the arid regions of central Iran using a one-dimensional model showed Haydrus. Very little risk of groundwater pollution caused by prolonged use of sludge on soil (Moradi *et al*, 2005).

The most common relationship between the van Genuchten - Moallem (Šimůnek, 2006) as follows:

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{\left[1+(\alpha h)^n\right]^m}, \quad m = 1 - \frac{1}{n}, \quad n > 1$$

$$K(h) = K_s Se^{1}\left[1-(1-Se^{\frac{1}{m}})^m\right]^2$$

Ɵr: residual moisture, Ɵs: saturation moisture, l, m, n: experimental parameters, Ks is the saturated hydraulic conductivity and Se: relative saturation.

Hydrus-1D model for the simulation of water movement in soil, Richards equation solve using linear finite elements. Since in the case of one-dimensional, linear finite elements plan and finite difference is similar, in this respect, using an indirect plan finite difference is as follows

$$\frac{\theta_i^{j+1,k+1}-\theta_i^j}{\Delta t}=\frac{1}{\Delta x}\left(K_{i+1/2}^{j+1,k}\frac{h_{i+1}^{j+1,k+1}}{\Delta x_i}-K_{i-1/2}^{j+1,k}\frac{h_i^{j+1,k}-h_{i-1}^{j+1,k+1}}{\Delta x_{i-1}}\right)+\frac{K_{i+1/2}^{j+1,k}-K_{i-1/2}^{j+1,k}}{\Delta x}-S_i^j$$

$$\Delta t = t^{j+1}-t^j$$

$$\Delta x=\frac{x_{i+1}-x_{i-1}}{2}\quad,\quad \Delta x_i = x_{i+1}-x_i\quad,\quad \Delta x_{i-1}=x_i-x_{i-1}$$

$$K_{i+1/2}^{j+1,k}=\frac{K_{i+1}^{j+1,k}+K_i^{j+1,k}}{2}\quad,\quad K_{i-1/2}^{j+1,k}=\frac{K_i^{j+1,k}+K_{i-1}^{j+1,k}}{2}$$

Substituting the above equation in the original equation three diagonal equation will be resulted that can be solved by standard methods such as Gussian elimination.

Material and methods

The present study was done based on plot study. Five experimental plots of agricultural land, each size 2 by 10 m at South Tehran wastewater treatment plant were prepared. The plots had been moldboard plowed and disked each time and thereafter. A pvc drainage pipe was installed in one meter depth of each plot to collect the leached water. The first plot was irrigated with pipe water as control plot, second plot with wastewater and thrd one added sludge of wastewater treatment plant. Fourth plot was irrigated by simulated solutions with waste streams in southern Tehran and fifth plot was added both, wastewater and sludge from wastewater treatment plant. Concentrations of Ni were determined in wastewater and sludge samples by atomic absorption Varian model 200. Five months after the cultivation of crops, sampling from the soils was performed, also after and during each irrigation period leached water from each plot was sampled and Ni was measured. Soil samples were taken from the topsoil to 100 cm depth. Overall 100 soil samples were taken from all plots in different depths. Nickel concentration in the soil samples were obtained by extraction Ni in 4 normal HNO3 extracts (70 ^{o} C) by atomic absorption spectrometry (Behbahninia *et al.*, 2009)

Results

The results showed that the concentration of nickel in the surface soil layers is more than dawn layers, Respectively , in fifth plot ,60; forth plot 58; third plot 52 and in second plot 9 and first one 6 mg/kg. As indicated in Fig. 1, the average maximum depth of 30 cm has been observed to move. Penetration depth is higher for the second and fourth plot. Fig. 2, 3, 4 and 5 show the results of modeling and experimental results. The most important consideration for the material transfer is transferring of material which has a high absorption coefficient is taking place slowly over time. Much of this material was absorbed to soil particles near the soil surface. This research should also considered, transfer of heavy metals into groundwater is so complicated because of organic matter percent of soil and percent calcium carbonate of soil and formation of salts and various complexes with different absorption coefficient. Therefore the absorption coefficient as an important parameter in determinant, Lack of precision in the choice of the coefficients, can be one of the reasons that the simulation results are not fully consistent with the experimental results. Increase of diffusion coefficient is caused faster transmission of material. On the other hand with increase diffusion coefficient, concentration distribution in the soil profile depth increases and the upper parts of the profiles decreases (Camobreco *et al.*, 1996). Sorption coefficients of the material depend on the type of material and soil type. And the coefficient is measurable only through testing for different materials and soils. Increasing the value of the dispersion coefficient, cause in faster transmission of materials. By increasing the value of this coefficient, concentration of material distributed increased in the depth of the soil profile and reduced on top of profile points. Based on the investigation, Reuse of wastewater, sewage, sludge should use basic management; several standards have been developed in this field that can be monitored to implement them. Analysis of heavy metals in waste sludge and effluent should be done in most treatment plants. Presence of heavy metals in leachate samples represents the transfer of metals to groundwater that it can be done through preferential pathways.

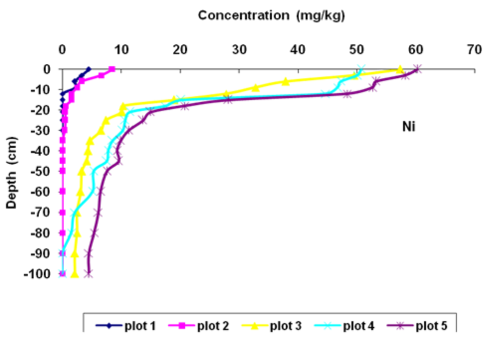

Fig. 1. The average concentration of Ni in different depth of plots.

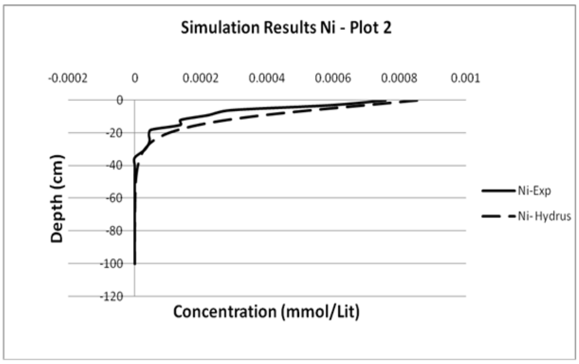

Fig. 2. Experimental and simulation results of Ni concentration in plot 2.

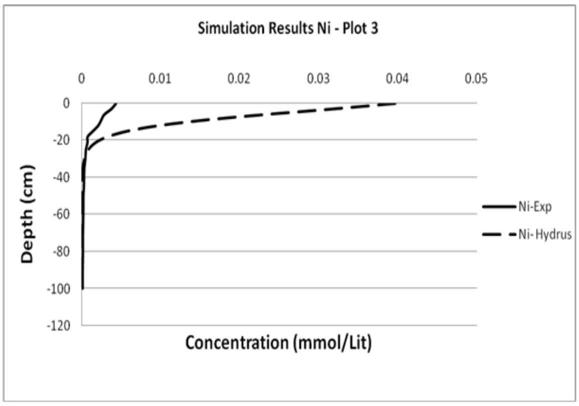

Fig. 3. Experimental and simulation results of Ni concentration in plot 3.

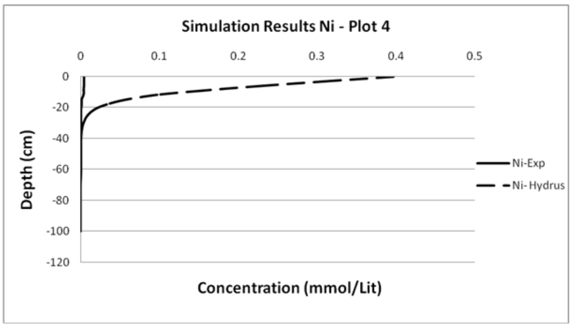

Fig. 4. Experimental and simulation results of Ni concentration in plot 4.

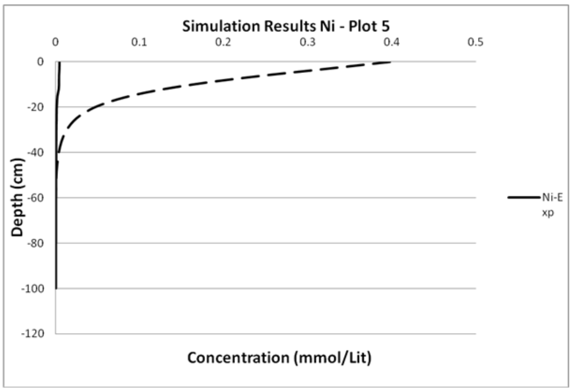

Fig. 5. Experimental and simulation results of Ni concentration in plot 5.

So continue with these resources of irrigation reduced groundwater quality, therefore knowledge of irrigation water quality and management of irrigation system in order to protect groundwater especially shallow groundwater can be particularly important.

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