

Research on Conceptual Model of Contaminant Transport From Septic-Tank Through Saturated And Unsaturated Sand Medium

Saad Abu-Alhail*; Wisam Sabeeh N. Alrekabi and Ammar A. Akish
*College of Engineering,
Department of Civil Engineering, University of Basrah, Basra city, 61028, Iraq
Corresponding Author*

Abstract:

This paper is provide a Conceptual Model of Contaminant Transport through Porous Media To predict the fate of contaminant transport in groundwater whereas Conceptual model can be used to predict all the known processes for transport and retardation of contaminant. firstly, the transport process was driven by advection and dispersion mechanics. secondly, the majority of retardations was investigated in the unsaturated zone. Organic carbon and nitrate nitrogen compounds could be retarded by biotransformation under aerobic and /or anoxic conditions. Phosphate could be adsorbed onto the soil minerals. E. coli could be filtered, adsorbed and decayed through the porous media. The available models in this paper are widely used to predict the fate of contaminants in either unsaturated or saturated zones. A comparison study between developed conceptual model and RT3Dv1.0 for phosphorus contaminants transport through soil after 1, 5 and 10 years of showed a good convergence in simulation results between them.

Key words: Septic tank; sand medium; Conceptual model; contaminant transport; and.

Introduction

A conceptual model for containment transport in unsaturated soil is proposed for process that takes place from time the containment water is discharged into a drainage field until it reaches the groundwater. The model consists of both contaminant transport and retardation processes.

Firstly, the contaminant transport process is described according to the geological and soil hydraulic properties, which could be used to predict the portable movement of wastewater.

Secondly; the containment retardation process is defined based on the geochemical and biological reactions.

The conceptual model is compared to available commercial models for estimating the fate and or migration of contaminant to select the most suitable model. There were many limitations on the existing models. A suitable model for microbial transport could not be achieved. The related governing equations for containment transport and retardation are reviewed to quantitatively describe the established model. Transport of containment can be described based on the processes of advection and dispersion. retardation of contaminates can be defined as the interactions between soil and contaminants.

Development of a conceptual model

A conceptual model of transport with retardation of containments associated with septic tank effluent is presented in figure (1). A septic tank is best suited to an area with a low groundwater table and moderately permeable soil. the exists residential areas which are outside the service of a centralized sewage treatment system that use septic tanks even though the geological conditions may not be suitable. the worse case concerns are those areas located in high ground water table with high soil permeability. the drainage field presented here contained unsaturated and saturated zones. The retardation mostly occurred in the unsaturated zone. The concentration of contaminants potentially reaching the ground water table depended on the unsaturated zone. Hence, the conceptual model focused mainly on the transport and retardation of contaminants in the saturated zone. the boundary of the system considered begins at the septic tank effluent drainage pipe and ends at the ground water table as shown in figure (1). Septic tank effluent percolates vertically in an unsaturated zone and the contaminants are carried by advection and dispersion. the effluent added into drainage field moves downwards due to gravitational force, whereas, groundwater moves upwards due to capillary forces. The flow presented here is under the influence of infiltration redistribution forces. groundwater normally contains low concentration of contaminants, and it is assumed that groundwater did not add any contaminant in the system. However, groundwater might dilute the concentration of contaminants. Dynamic Interaction between Soil and Contaminants in an unsaturated zone are complex. Thus, only dominate reactions are considered in order to simplify retardation are presented in table (1).

The assumptions made in developing the conceptual model are:

Soil was Homogeneous and Incompressible.

Soil had a mix of microbial cultures activated and acclimatized to contaminants. Septic tank effluent contained no hazardous chemicals, and hence there was no inhabitation of biological processes.

There was no rainfall and groundwater table was constant, so there was no smearing zone of contaminants,

Septic tank effluent was loaded into drainage field with a constant discharge rate and its characteristics did not vary significantly, and

All chemical interactions were fast enough to validate the chemical equilibrium assumption.

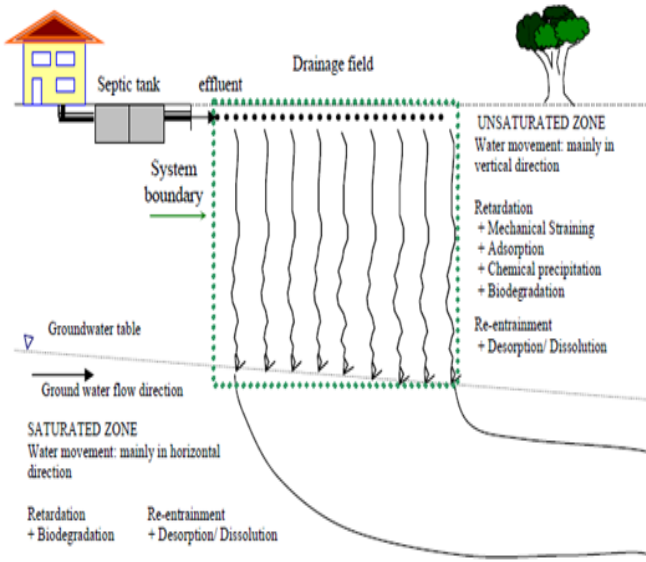


Figure 1: Conceptual Model

Table 1: Dominate reactions for retardation of contaminants in septic tank effluent.

| Contaminant | Physical reaction | Chemical reaction | Biological transformation |
|--------------------------|-------------------|-------------------|-------------------------------|
| Nitrate-nitrogen | - | - | Nitrification/Denitrification |
| Phosphate-phosphorus | - | Adsorption | - |
| Organic Carbon Compounds | - | - | Biodegradation |
| Microbes | Filtration | Adsorption | Cell decay |

Transport models of soil contaminant

Most models could also support the transport of contaminant in either unsaturated or saturated soil conditions. The models developed for reactive containment transport in saturated soil conditions include CHEMTRAN the model of Kinzelbach et al. (1991), Ginn et al. (2002), MacQuarrie et al. (1990) and Zysset et al. (1994). CHEMTRAN was the most flexible model because the users could define any contaminant considered. However, the model did not provide any kinetic coefficients which made it inconvenient to use. The model of Kinzelbach et al. (1991) could be applied to transport of nitrogen Organic carbon compounds, and microbes. The model of Ginn et al. (2002) only mentioned the transport of microbes, whereas the model of MacQuarrie et al. (1990) could support the transport of organic carbon compounds and microbes. The model developed for reactive contaminant transport in unsaturated soil conditions include PRZM3, the model of Zanini et al. (1998) and Break et al. (1989), which can support the transport of pesticides phosphorus and microbes, respectively.

There is a need to develop a mathematical model using fundamental principles to predict contaminant transport through unsaturated porous media that incorporates the

transport and retardation of microbial actions.

3.1 Governing equations for contaminants transport.

The governing equation for multi-components transportation of contaminant in porous media under variable saturation conditions could be expressed in a general form as follows (Schnoor 1996).

Accumulation=dispersion-advection-sorption –reaction

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial z} \left(D_z \frac{\partial C}{\partial z} \right) - \frac{\partial}{\partial z} (q_z C) - \frac{\rho_B}{\Theta} \left[\frac{\partial C^*}{\partial t} \right] \pm \sum_{m=1}^n r_m \tag{1}$$

Where,

Θ=The Volumetric water content [L³L⁻³]

C*=The concentration of a considered constituent in sorbed Phase[M L⁻³]

DZ=the dispersion coefficient [L²T⁻¹]

rm=The physical chemical and biological reaction rate [ML³T⁻¹]

In accordance with mass balance concept, advection and dispersion terms are used to estimate the mass of contaminants that flow through a representative elementary volume (REV) of a porous medium. Sorption and other reactions define the source /sink terms (Schnoor 1996). This governing equation is in a form of a hyperbolic/parabolic partial differential equation (PDE) and consists of many idealized parameters such as Dz, qz and rm. Parameters Dz and qz can be determined using Richards equation and rm can be expressed as a function according to defined reactions. The details of these equations are given in the following sections.

Richard's equation

The non-linear flow velocity in the unsaturated zone was evaluated using either changing of pressure head or moisture content. Pressure head based Richard's equation was used to estimate the non-linear Darcy's velocity (Bear 1972, Bear and Verrujit 1987 and Huyakorn et al. 1984).

$$\frac{\partial}{\partial z} \left[K_{zz} K_{rw} \left(\frac{\partial \psi}{\partial z} + 1 \right) \right] = \phi \frac{\partial S_w}{\partial t} \dots \dots \dots \tag{2}$$

Where,

K_{zz}: The saturated hydraulic conductivity [L²T⁻¹]

K_{rw}: The relative permeability [unitless]

ψ: The pressure head [L]

φ: The porosity [unitless]

S_w: The degree of saturation [unitless]

Z: the depth in the vertical direction (positive upward) [L]

The specific moisture capacity (Mc) is ideally defined as the changing of volumetric content over the changing of pressure head ($\frac{\partial \Theta}{\partial \psi}$). The right hand side of equation (2) could be

rearranged as a function of Mc and $\frac{\partial \psi}{\partial t}$ as follows (Huyakorn et al. 1984):

$$\phi \frac{\partial S_w}{\partial t} = \phi \frac{\partial S_w}{\partial \psi} \frac{\partial \psi}{\partial t} \cong \frac{\partial \Theta}{\partial \psi} \frac{\partial \psi}{\partial t} = M_c \frac{\partial \psi}{\partial t} \tag{3}$$

Therefore Equation (2) could be rewritten as (Huyakorn et al. 1984):

$$\frac{\partial}{\partial z} \left[K_{zz} K_{rw} \left(\frac{\partial \psi}{\partial z} + 1 \right) \right] = M_c \frac{\partial \psi}{\partial t} \tag{4}$$

Where

Mc: the specific moisture capacity [L^{-1}]

The first term of equation (4) contained an unsaturated darcy's equation q_z . this was formulated as follows (the negative sign means a downward flow)(Huyakorn et al. 1984)

$$q_z = -K_{zz}K_{rw} \left(\frac{\partial}{\partial z} [\psi + 1] \right) \quad (5)$$

Where

q_z =Darcy's Velocity in vertical direction [$L T^{-1}$]

By interesting a series of tensiometer in different parts of a drainage field the profile of pressure head could be observed as shown in figure (2). the pore pressure under steady state flow of infiltration is negative pressure head in unsaturated soil layer is due to suction head zero pressure head occurred at the ground water table and the positive pressure head presented in the saturated soil layer is due to hydraulic head (gravitational head plus pore water

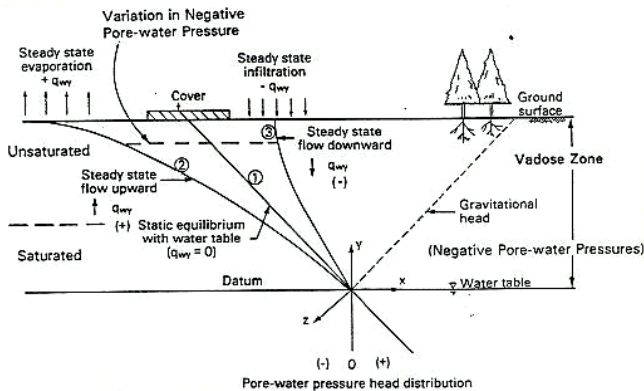


Figure 2: Profiles of pore pressure under a steady state flow of infiltration (adapted from Fredlune and Rahardjo 1940).

The dispersion D_z consisted of hydrodynamic dispersion and molecular diffusion and it could be obtained from Fick's law (Fetter 1992).

$$D_z = \omega v_i + D^* \quad (6)$$

Where: D^* :An effective molecular diffusion coefficient [$L^2 T^{-1}$]; ω : A coefficient relating to totuosity [unitless]; v_i :The average linear velocity in the vertical direction [$= \frac{q_z}{\theta}$] [$L T^{-1}$]

Tracer testing was the best way to estimate the dispersion coefficients. Tracers used included potassium bromide, sodium chloride tritium fluorescein and rhodamine WT dyes (Schnoor 1996). Scheidegger (1960) conducted laboratory and field scale tracer tests to estimate the dispersion and travel time of particles in soils. The resultssuggested that the dispersion relied on the depth and the pore size of soils. Deeper soil layers and smaller soil pores generated higher dispersion and longer travel times. Variables Mc and $K_{zz}K_{rw}$ presented in Richard's and Darcy's equations were estimated using the hydraulic properties equations.

Hydraulic Properties equations

The hydraulic properties equations used in this report included those of Haverkamp et al. (1977), Van Genuchten (1980) and saxton et al. (1986). the details of these equations were given as follow;

Haverkamp et al. 's equations (HV)

Haverkamp et al. (1977) fitted the properties of homogeneous soil in unsaturated conditions by the least square method. The equations were given as:

$$\Theta = \frac{\alpha(\Theta_s - \Theta_r)}{\alpha + |\psi|^\beta} + \Theta_r \quad (7)$$

$$K_{zz}K_{rw} = K_{zz} \left[\frac{A}{A + |\psi|^\gamma} \right] \quad (8)$$

Where: Θ_r :A residual moisture content [$L^3 L^{-3}$]; Θ_s : A saturated moisture content [$L^3 L^{-3}$]; A, α , γ , β :The curve fitting coefficient [unitless]

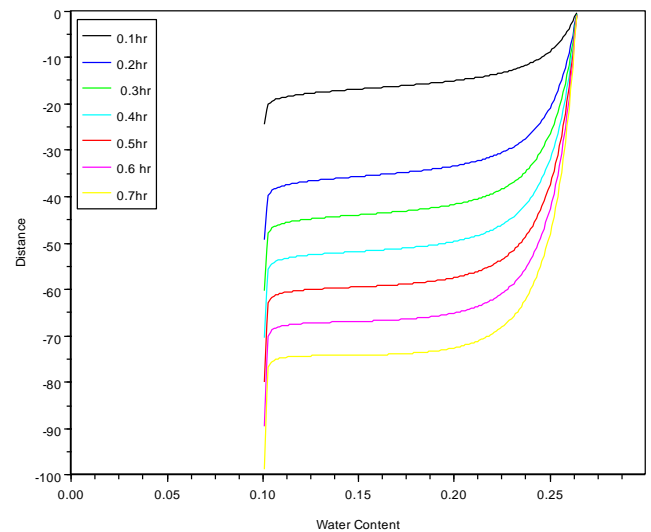


Figure 3: water retention curves fitted by HV equations (Haverkamp et al. 1977)

Variable Mc could be estimated by differentiating equation (7), yielding:

$$Mc = \frac{\alpha\beta(\Theta_s - \Theta_r)|\psi|^{\beta-1}}{(\alpha + |\psi|^\beta)^2} \quad (9)$$

Van Genuchten's equation (VG)

Van Genuchten (1980) derived the hydraulic properties equations based on the equation of Brooks and Coley (1964). the Hydraulic Properties equations were presented as follows:

$$\Theta = \frac{(\Theta_s - \Theta_r)}{(1 + \alpha|\psi|^p)^m} + \Theta_r \quad (10)$$

$$K_{rw} = \frac{[1 - (a|\psi|)^{p-1}[1 + (a|\psi|)^p]^{-m}]^2}{[1 + (a|\psi|)^p]^{\frac{m}{2}}} \quad (11)$$

Where,

a: The soil water retention function [L⁻¹]; m and p: the empirical parameters, (m=1-(1/p)) [unitless]; Variable Mc could be derived from VG equations (Equation (10)) as follows:

$$Mc = \frac{-a^p(p-1)(\Theta_s - \Theta_r)|\psi|^{p-1}}{(1 + (a|\psi|)^p)^{m+1}} \quad (12)$$

Saxton et al. 's equations

The hydraulic properties could be estimated from soil texture using a method generalized by Saxton et al. (1986). The textural class was assessed according to the USDA system. the water retention curve was fitted with linear regression and the formulations were presented in S. I. unit as follows

The applied tension 10 to 1500 kpa:

$$\psi = \Psi_e \left[\frac{\beta(\Theta - \Theta_r)}{(\Theta_s - \Theta_r)} \right]^H \quad (13)$$

By assuming $\Theta_r=0$, will give

$$\psi = J \Theta^G \quad (14)$$

Where,

Ψ : the soil water pressure [KPa]; Ψ_e : the air entry pressure [KPa]; Θ : The volumetric moisture content [cm³cm⁻³]; Θ_s : The Saturation volumetric moisture content [cm³cm⁻³]; Θ_r : The residual volumetric moisture content [cm³cm⁻³]; H: the statistical curve fitting value (From 44 Soil Samples and R²=0.99); (H=3.14-0.00222(%clay)²-3.484*10⁻⁵(%sand)²(%clay)); J: The statistical curve fitting value (From 44 Soil Samples and R²=0.99); (J=EXP(-4.396-0.0715(%clay)-4.88x10⁻⁴(%sand)²-4.285x10⁻⁵(%sand)²(%clay))100)

The applied tension ψ_e to 10 kpa.

$$\Psi = 10.0 \frac{(\Theta - \Theta_{10})(10.0 - \Psi_e)}{(\Theta_s - \Theta_{10})} \quad (15)$$

Where; Θ_{10} : The volumetric moisture content at 10kpa

$$\left(= \exp \left(\frac{[2.302 - \ln J]}{G} \right) \right) [cm^3 cm^{-3}]$$

$\Psi_e = 100(-0.108 + 0.341\Theta_s)$;

And; $\Theta_s = 0.332 - 7.251 \times 10^{-4}(\%Sand) + 0.1276(\log(\%clay))$

The applied tension 0.0 Kpa to ψ_e .

$\Theta = \Theta_s$

Variables K_{zz} and K_{rw} were estimated as follows:

$$K_{zz} K_{rw} = 2.778 \times 10^{-6} \left\{ \text{EXP} \left[(12.012 - 0.0755(\%sand) + [-3.8950 + 0.03671(\%sand) - 0.1103(\%clay) + 8.7546] \right) \right. \right. \\ \left. \left. * 10^{-4}(\text{Clay})^2 \right] \left(\frac{1}{\Theta} \right) \right\} \quad (17)$$

Where,

$K_{zz} K_{rw}$: The unsaturated hydraulic conductivity [m s⁻¹]

Kunze et al. 's equation

Kunze et al. (1968) established a relative permeability function based on poiseuille's equation. the coefficient of relative permeability was obtained from the relationship between the matrix suction and volumetric moisture content. the equation was given as follows:

$$K_{rw}(\Theta)_i = \frac{(K_{zz})_{mea} T_s^2 \rho_w g \Theta_s^p}{(K_{zz})_{cal} 2\mu_w N^2} \sum_{j=1}^m \left\{ (2j+1 - 2i)(|\psi|_j)^{-2} \right\} \quad i = 1, 2, \dots, m \quad (18)$$

Where

$K_{rw}(\Theta)_i$: Calculated Coefficient of permeability for a specified volumetric moisture content, $(\Theta)_i$, corresponding to the i th interval [unitless]; i : Interval on the water retention curve [unitless]. j : Counter number from 1 to m [unitless]. $(K_{zz})_{mea}$: measured saturated coefficient of permeability [L T⁻¹]. $(K_{zz})_{cal}$: calculated coefficient of permeability [L T⁻¹]. T_s : Surface tension of water [M L⁻¹T²]. ρ_w : Water density [M L⁻³]. g : Gravitational acceleration [L T⁻²]. μ_w : Absolute viscosity of water [M L⁻¹T⁻¹]. P : A Constant which accounts for the interaction of pores of various sizes usually assumed to be 2.0 (Green and Corey 1971 cited in Fredlune and Rahardjo 1940) [unitless]. m : Total number of intervals between the saturation and residual Volumetric water content [unitless]; N : Total number of intervals Computed between saturation and residual volumetric water content $\left(N = \frac{m\Theta_s}{(\Theta_s - \Theta_r)} \right)$ [unitless].

Soil Contaminant reactions

The governing equations for contaminant retardations were defined as follows:

Nitrogen and organic carbon compounds

The total rate of organic carbon compounds (substrate) utilization, r_s was a combination of the substrate utilization rate due to aerobic and nitrate respiration (Widdowson et al. 1988).

$$r_s = r_{SO} + r_{SN} \quad (19)$$

Where

r_s , r_{SO} and r_{SN} : The total substrate Utilization, Substrate utilization under aerobic respiration and substrate utilization under nitrate respiration, respectively [T⁻¹]

Using a modified Monod's equation, the substrate utilization rates could be derived as follows (Widdowson et al. 1988):

$$r_{SO} = \frac{\mu_0}{Y_0} \left[\frac{C_S}{K_{SO} + C_S} \right] \left[\frac{C_O}{K_O + C_O} \right] \left[\frac{C_A}{K_{AO} + C_A} \right] \quad (20a)$$

$$r_{SN} = \frac{\mu_N}{Y_N} \left[\frac{C_S}{K_{SN} + C_S} \right] \left[\frac{C_N}{K_N + C_N} \right] \left[\frac{C_A}{K_{AN} + C_A} \right] I [C_O] \quad (20a)$$

Where

μ_0 and μ_N : The maximum specific growth rate for aerobic and denitrifying bacteria respectively [T⁻¹].

Y_0 and Y_N : A heterotrophic yield coefficient for aerobic and denitrifying bacteria, respectively [unitless].

C_s, C_o and C_A : The concentration in aqueous of organic carbon oxygen and ammonia, respectively [$M L^{-3}$].

K_{S0}, K_O and K_{A0} : Half concentration of substrate Oxygen and ammonia nitrogen under Aerobic respiration respectively [$M L^{-3}$].

K_{SN}, K_N and K_{AN} : Half concentration of substrate nitrate and ammonia nitrogen under nitrate respiration respectively [$M L^{-3}$].

$I [C_o]$: The inhibition factor $I [C_o] = \left[1 + \frac{C_o}{K_c} \right]^{-1}$ [unitless].

K_c : The coefficient of inhibition [$M L^{-3}$].

Sierra and Renault (1998) measured dissolved oxygen (DO) in soils. A Sample of which was classified as GleyicLuvisol. the concentration of DO relied upon soil moisture content soil temperature, and the rate of microbial respiration. DO decreased, when moisture content increased. It was observed that DO decreased from 1.19 to 0.56 mg/L after a heavy rainfall ($i=34$ mm and $t=24$ hrs). During summer, DO of the topsoil (0.2m below surface) was 2.5 times higher than in winter. A high population and activity of microbes was also found in summer. Evaporation increased during summer, and loss of moisture content induced an increase in DO. Average DO in all seasons at the depths of 0.2, 0.5, 0.75 and 1.5m (below the surface) were 0.84, 0.53, 0.23 and 0 mg/l respectively.

DO in the soil was actually relatively low $[C_o] < 0.5$ mg/l. The value of K_c was 0.01-0.05 mg/l, and the possible inhibition factor $I[C_o]$ was 0.091 (Widdowson et al. 1988). High DO was sometimes found in a low temperature area. DO at a Cambridge site was 6 mg/l and the average temperature was 120C. On this site, K_c was 1.0 mg/l which provide a $I [C_o]$ of 0.143 (MacQuarrie et al. 2001). DO in this research was assumed to be 0.2-2.0 mg/l according to Widdowson et al. (1988). This is one third of the Cambridge site. the K_c was assumed to be 0.1-0.2 and the inhibition to be 0.05-0.5. The inhibition was weighed on the K_c at 0.175 and the inhibition factor was 0.0802. The nitrate respiration was 8% of the total respiration.

The substrate and nitrate retardation could be arranged as follows (Widdowson et al. (1988)).

$$\frac{\partial C_S}{\partial t} = \frac{M_b r_s}{\Theta} \quad (21)$$

And

$$\frac{\partial C_N}{\partial t} = \frac{M_b r_N}{\Theta} \quad (22)$$

Where: M_b : Concentration of biomass per unit Volume of Porous media [$M L^{-3}$].

The production rate of biomass was not constant. The total biomass in the system could be assumed on the difference between its production and decay rate as follows (Widdowson et al. (1988)).

$$\frac{\partial M_b}{\partial t} = [(Y_S r_{S0} - K_0) + (Y_N r_{SN} - K_N I [C_o])] M_b \quad (23)$$

Where

K_0 and K_N : The microbial decay coefficient for aerobic, and nitrate respiration respectively [T^{-1}].

Phosphorus Compounds

Phosphorous adsorption was formulated as follows (Shah et al. 1975):

$$\rho_B \frac{\partial C_P^s}{\partial t} = K_t (C_P^w - C_P^{w*}) \quad (24)$$

Where

C_P^s : The concentration of adsorbed phosphours [$M M^{-1}$].

K_t : The overall Volumetric mass transfer coefficient [$L T^{-1}$].

C_P^{w*} : The concentration of phosphorus in liquid phase that is in equilibrium with the concentration of phosphorous in the solid phase [$M M^{-1}$].

$(C_P^w - C_P^{w*})$: A driving force for transferring phosphorus from liquid to solid phase [$M L^{-3}$].

The Langmuir isotherm equation was the best fit of phosphorous adsorption (SHAH et al. 1975). Variable C_P^{w*} presented in equation (24) was modified as follows (Schnoor 1996 and watts 1997):

$$C_P^{w*} = \frac{K_L K_M C_P^w}{1 + K_M C_P^w} \quad (25)$$

Where

K_L : The Coefficient (Langmuir rate constant) [unitless]. ;

K_M : The maximum phosphate adsorption capacity on soil [$L^3 M^{-1}$].

Fecal Coliforms

The overall reaction rates of microbial Kinetics were the summation of production, maintenance, decay, adsorption and desorption. The retardation equation was given as (Zysset et al. 1994):

$$n \frac{dC_b^f}{dt} = n v_y \eta K_\mu C_s C_b^f - n K_d C_b^f + \Theta K_C C_b^w - n K_S C_b^f \quad (26)$$

Where: n : The fraction of aqueous volume and biofilm in total volume (=Porosity) [unitless]. ; C_b^f : The concentration of adhering microbes [$M L^{-3}$]. ; C_b^w : The concentration of free Swimming Microbes [$M L^{-3}$]. ; C_s : The Concentration of limiting substrate in aqueous compartment [$M L^{-3}$]. ; v_y : The Stoichiometric Coefficient [$M N^{-1}$]. ; η : An effectiveness of biofilm [Unitless]. ; K_μ : Monod's Constant for substrate utilization in biomass [$L^3 M^{-1} T^{-1}$]. ; K_d : The constant decay rate [T^{-1}]. ; K_S and K_C : The constant desorption (detachment) and adsorption (attachment) rate respectively [T^{-1}]. The unit N is the quantity of microbes involved.

The equilibrium of immobile and mobile E. Coli was given as follows (Zysset et al. 1994 and stevik et al. 1999b):

$$C_b^w \rightarrow C_b^f \quad (27)$$

Equation (27) could be developed as a first order Kinetics equation as follows (Characklis et al. 1990).

$$\frac{\partial C_b^f}{\partial t} = K_B \theta C_b^w \quad (28)$$

Where; K_B : An overall rate constant of bacterial removal processes in biological filter systems (Including adsorption K_C and desorption rate, K_S) [T^{-1}].

Using the Initial Kinetic rate equation (28) was simplified as follows (Stevik et al. 1999b):

$$(C_b^w)_z = (C_b^w)_0 e^{-KBt} \quad (29)$$

Where

$(C_b^w)_0$: E. Coli Concentration in wastewater at the filter surface [NL⁻³]

$(C_b^w)_z$: E. Coli concentration at depth Z [NL⁻³]; t: time for wastewater flows down to depth z.

Stevik et al. (1999a) has conducted column experiments to study the effects of physical and chemical properties of filter media on the the removal of E. Coli and their results are presented in figure (1), which had an overall kinetics rate constant, KB of 0. 105 hour⁻¹with initial concentration $(C_b^w)_0$ of 3. 4833x10⁸ cfu/100ml. the authors had defined the constant KB as overall E. Coli removal. This might not be correct because the columns were kept in dark and cool(temperature 7±1 OC) Conditions that certainly would have minimized the growth of E. Coli. Schnoor(1996) Reported the kinetic coefficient for decay of coliforms in ariver (Fresh water) was 0. 5-5day⁻¹.

Schijven et al. (2002) determined the kinetic coefficients of viruses in aquifers using two types of bacteriophages MS2 and PRD1. the applied dosages were 2. 5x10¹²and 2. 5x10¹³

cfu/100ml, respectively. the kinetics coefficients were calculated using data taken from six observation wells. The results are given in table (2)

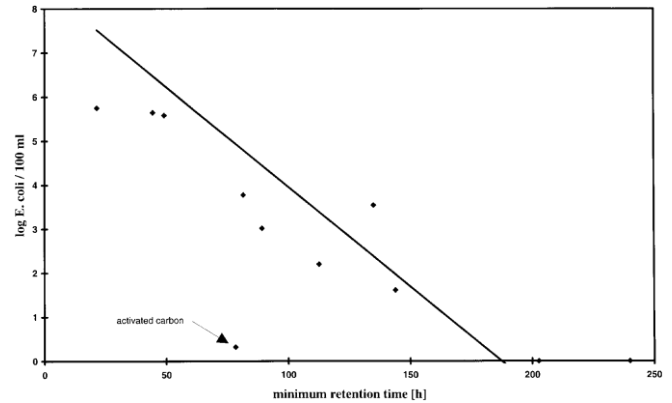


Figure 4: E. Coli Concentration of fecal coliforms (log-numbers) plotted against minimum wastewater retention time. (Steviket al. 1999b).

Table 2: Kinetics Coefficient of bacteriophages MS2 and PRD1 (Schijvenet al. 2002)

| Bacterio phage | ColumnI | | | ColumnII | | |
|----------------------|------------------------|------------------------|---------------------|------------------------|---------------------|---------------------|
| | X174 | PRD1 | MS2 | X174 | PRD1 | MS2 |
| One-sitemodel | | | | | | |
| Katt1 | 7.0 (6.3-7.8) | 2.0 (1.97-2.12) | 2.2 (2.1-2.4) | 10 (9.7-10.5) | 2.5 (2.2-2.8) | 2.5 (1.8-3.4) |
| Kdet1 | 0.0039 (0.0031-0.0050) | 0.085 (0.075-0.096) | 0.074 (0.050-0.11) | 0.046 (0.040-0.053) | 0.089 (0.081-0.098) | 0.14 (0.098-0.020) |
| μs1 | 0.012 | 0.47 (0.36-0.60) | 0.48 (0.40-0.58) | 0.53 (0.31-0.89) | 0.40 (0.33-0.47) | 0.48 (0.37-0.61) |
| α1 | 0.0023 | 0.0012 | 0.0010 | 0.0023 | 0.0011 | 0.00061 |
| r2 | - | 95% | 80% | 90% | 95% | 96% |
| λ | 5.3 | 1.8 | 2.0 | 9.3 | 2.1 | 2.0 |
| %μ1 | 0.2% | 2.5% | 4.1% | 0.1% | 2.1% | 4.2% |
| %S1 | 99.8% | 97.5% | 95.9% | 99.9% | 97.9% | 95.8% |
| Katt1/λ | 1.4 | 1.2 | 1.1 | 1.1 | 1.2 | 1.2 |
| -log10 (C/C0)/x | 1.4 | 0.48 | 0.55 | 1.2 | 0.26 | 0.25 |
| -log10 (C/C0)/t | 2.2 | 0.76 | 0.86 | 4.0 | 0.91 | 0.86 |
| Two-sitemodel | | | | | | |
| katt1 | 8.0 (7.0-9.2) | 1.9 (1.83-1.94) | 2.1 (1.8-2.4) | 9.5 (9.3-9.8) | 2.2 (2.0-2.3) | 2.1 (1.4-2.9) |
| kdet1 | 0.0028 (0.0018-0.0045) | 0.0045 (0.0036-0.0055) | 0.054 (0.045-0.065) | 0.0031 (0.0026-0.0037) | 0.017 (0.016-0.018) | 0.016 (0.011-0.023) |
| katt2 | 2.2 (1.4-3.7) | 0.47 (0.41-0.53) | 8.8 (6.5-12) | 0.72 (0.63-0.83) | 0.48 (0.44-0.53) | 0.63 (0.58-0.70) |
| kdet2 | 1.2 (2.3-4.1) | 1.1 (0.97-1.3) | 42 (29-61) | 0.96 (0.85-1.1) | 1.6 (1.5-1.8) | 1.4 (1.3-1.5) |
| μs1=μs2 | 0.012 | 0.064 (0.044-0.092) | 0.43 (0.39-0.47) | 0.012 | 0.065 (0.058-0.072) | 0.075 (0.060-0.094) |
| α1 | 0.0024 | 0.0011 | 0.00068 | 0.0022 | 0.00097 | 0.00051 |
| α2 | 0.00086 | 0.00027 | 0.0028 | 0.00016 | 0.00021 | 0.00016 |
| r2 | 83% | 98% | 96% | 91% | 98% | 97% |
| λ | 6.5 | 1.8 | 2.0 | 7.6 | 1.8 | 1.8 |
| %μ1 | 0.2% | 2.4% | 4.0% | 0.2% | 2.4% | 4.5% |

| | | | | | | |
|-------------------|-------|-------|-------|-------|-------|-------|
| %s1 | 99.6% | 96.2% | 91.5% | 99.7% | 96.5% | 93.6% |
| %s2 | 0.2% | 1.4% | 4.4% | 0.1% | 1.0% | 1.9% |
| katt1/λ | 1.2 | 1.0 | 1.0 | 1.2 | 1.2 | 1.1 |
| log10 (C/C0)/x | 1.8 | 0.50 | 0.56 | 0.95 | 0.22 | 0.23 |
| log10 (C/C0)/t | 0.87 | 0.79 | 2.8 | 0.78 | 0.77 | 3.3 |

Comparison between Conceptual model and RT3D Model
 RT3D is a program for simulating reactive multi-species mass transport in three-dimensional groundwater aquifers. RT3Dv1.0 was first developed by P. T. Clement in 1997 for the Battelle Memorial Institute, Pacific Northwest National Laboratory, and was subsequently released into the public domain and quickly became an accepted standard for reactive transport modeling [Appelo 1994]. Unfortunately, the code was based on MT3Dv1.5 and did not include many of the new solver technology implemented in MT3DMS. As a result, the application of RT3D was always hampered by excessively slow run-times. RT3D 2.5 was released to the public domain in 2002, and now includes the same solver options as MT3DMS.

Exercise was undertaken to determine the rate of movement of contaminants from septic-tank so as to arrive at expected future concentrations of contaminants in the groundwater around Septic-tank. The study involved use of conceptual model, and phosphorus as contaminant. Equation, representing two dimensional mass transport of contaminants in porous media, was solved using finite difference method implemented in MatLab.

Simulation Data

The data used for simulation of phosphorus migration is shown in Table 3. Effective molecular diffusion coefficient was taken as 0.06 m²/year, and dispersivity was taken as 0.015 [Crooks et al 1984]. For the purpose of simulation the maximum phosphorus concentration has been taken as 10 mg/L with continuous addition of phosphorus at the bottom of septic tank, resulting in progressive increase of its concentration. Use of maximum concentration of phosphorus as 10mg/L, thus seems quite reasonable.

The groundwater level of Basra city is shown in figure (5). The results of simulations using RTD3 for phosphorus contaminants transport through soil after 1, 5 and 10 years of transportation predictions is shown in the figures 6, 7 and 8 while the results of simulations using developed conceptual model for phosphorus contaminants transport through soil after 1, 5 and 10 years of transportation predictions is shown in the figures 9, 10 and 11.

Table 3: The assumed aquifer parameters assigned for simulation [Soil Report 2014]

| Parameter | Value |
|--|--------------------------|
| Hydraulic conductivity K_{xy} | 60 m/d |
| Hydraulic conductivity K_z | 25 m/d |
| Total porosity | 0.25 % |
| Effective porosity | 0.22 % |
| Specific yield | 0.18 |
| γ_s : Average soil dry density | 1.78 Kg/m ³ |
| α_L : longitudinal dispersivity | 10 m |
| α_T : transverse dispersivity | 1.0 m |
| α_v : vertical dispersivity | 0.1 m |
| fluid viscosity for water | 0.001 kg. m/sec |
| g : gravitational acceleration | 9.81 m/sec ² |
| ρ_w : density of fresh water | 1000 kg. m ⁻³ |
| Source contaminant concentration | 10 mg/l |

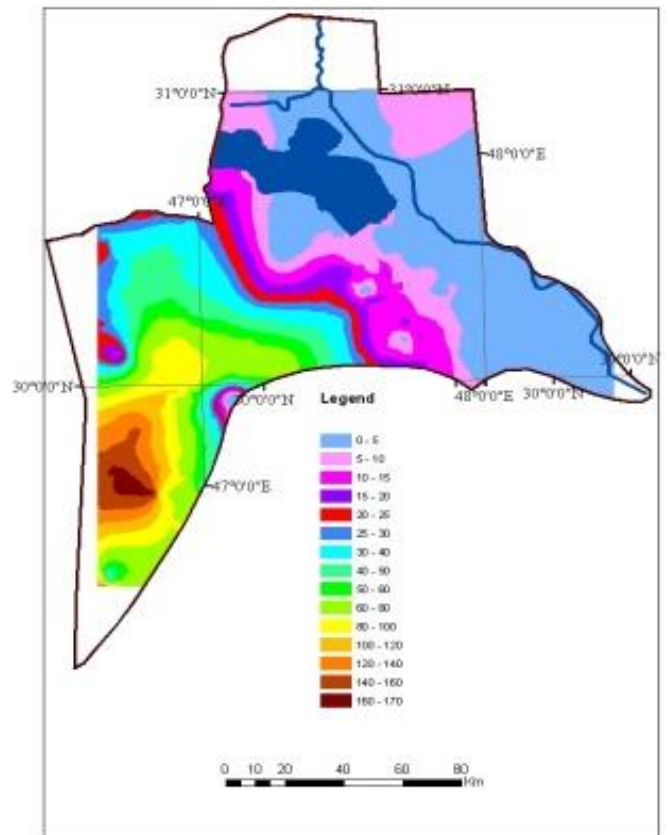


Figure 5: Groundwater level in Basra city (South of Iraq) [Naseer 2009]

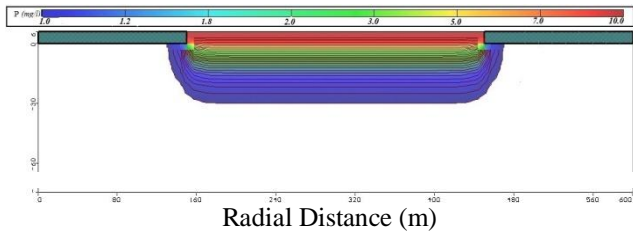


Figure 6: The profile of vertical phosphor transportation through the soil after 1-year.

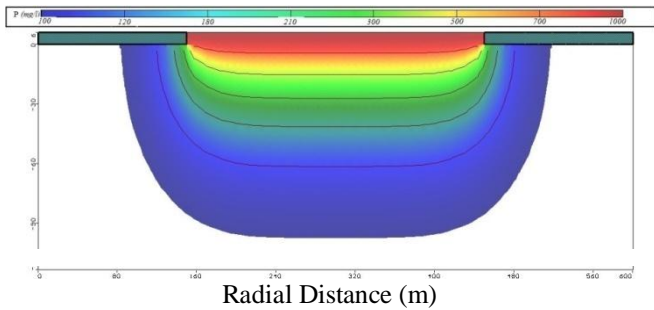


Figure 7: The profile of vertical phosphorus transportation through the soil after 5-year.

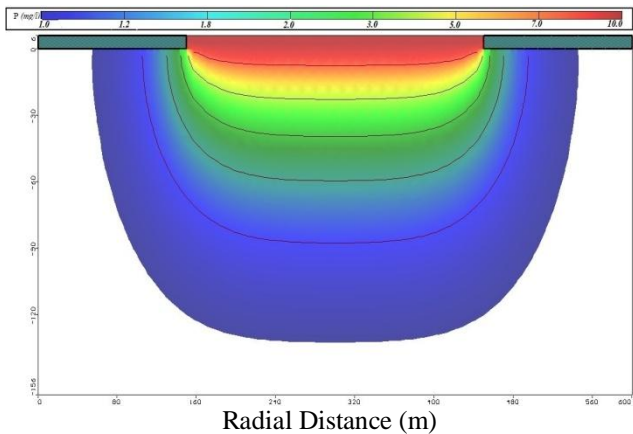


Figure 8: The profile of vertical phosphor transportation through the soil after 10-year.

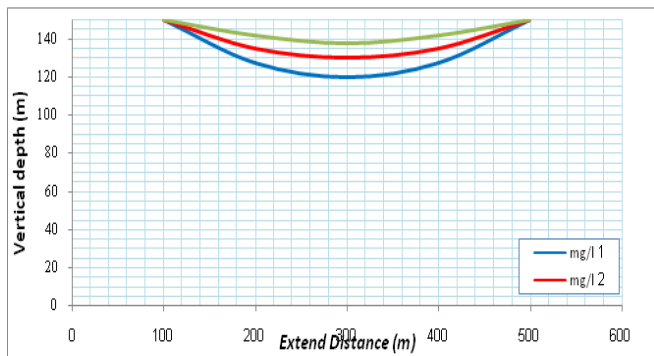


Figure 9: The mathematical solution for the line of (1 mg/l) concentration profile of vertical phosphor transportation through the soil after 1 year.

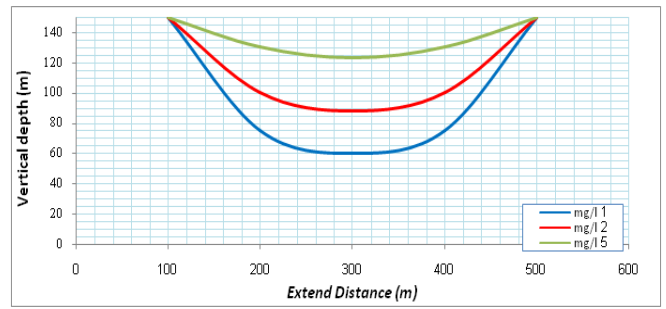


Figure 10: The mathematical solution for the line of (1 mg/l) concentration profile of vertical phosphor transportation through the soil after 5 years.

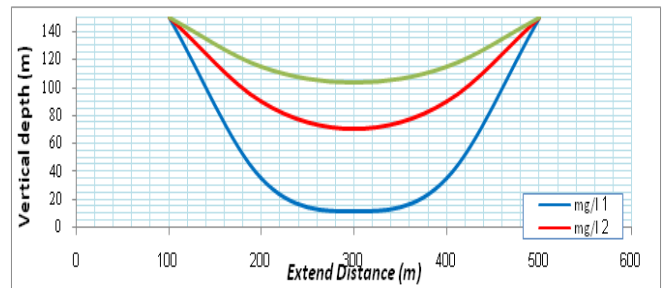


Figure 11: The mathematical solution for the line of (1 mg/l) concentration profile of vertical phosphor transportation through the soil after 10 years.

Conclusions

A Conceptual model is used to predict all the known processes for transport and retardation of contaminant. firstly, the transport process was driven by advection and dispersion mechanics. secondly the majority of retardations was investigated in the unsaturated zone. organic carbon and nitrate nitrogen compounds could be retarded by biotransformation under aerobic and /or anoxic conditions. Phosphate could be adsorbed onto the soil minerals. E. coli could be filtered, adsorbed and decayed through the porous media. The available models reviewed in this paper are widely used to predict the fate of contaminants in either unsaturated or saturated zones. A comparison study between developed conceptual model and RT3Dv1.0 for phosphorus contaminants transport through soil after 1, 5 and 10 years of showed a good convergence in simulation results between them.

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