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Contaminated Water Bodies and Their Influence on Planted Areas.

تلوث الأجسام المائية و تأثيرها على المناطق المزروعة

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الملخص العربي: يعد تلوث الأجسام المائية مشكلة هائلة تحتاج إلى جهود عظيمة للتخلص منها. و نجد أن هذا التلوث ذو تأثير كبير على المناطق المزروعة المتواجدة بجوار هذه الأجسام المائية الملوثة. و في هذه الدراسة يتم توضيح تأثير هذه الأجسام المائية الملوثة على المناطق المزروعة وكيفية منع انتقال الملوثات إلى المناطق المزروعة خلال التربة. ذلك عن طريق استخدام الستائر اللوحية الخرسانية أو البلاستيكية بإنشائها في المكان المناسب و بالعمق المطلوب. و للقيام بهذه الدراسة يتم استخدام نموذج ثنائي الأبعاد. هذا النموذج يتم دراسته باستخدام نظرية العناصر المحددة. حيث يتم تطبيق معادلات هذه النظرية من خلال البرنامج المستخدم لحل و دراسة النموذج المستخدم. و كذلك يتم تطبيق المعادلات الخاصة بكيفية انتقال السوائل خلال حبيبات التربة و طرق انتقالها و هي (الالتصاق، الانتشار، الامتصاص). و قد اتضح من هذه الدراسة أن استخدام الحوائط اللوحية الخرسانية ذو تأثير فعال في إيقاف انتقال السوائل الملوثة من الأجسام المائية الملوثة إلى المناطق المزروعة. حيث تم دراسة هذه الحوائط اللوحية بالتفصيل لمعرفة أفضل مكان مناسب لإنشائها و كذلك أفضل عمق مؤثر لها. وذلك لتقليل وصول الملوث إلى المناطق المزروعة بأقصى درجة ممكنة.

ABSTRACT: The contamination of water bodies is a severe problem that needs affiliations to get rid of it. It has an influence on planted areas that exists near these contaminated water bodies. In this work an attempt is made to study the influence of contaminated water bodies on planted areas and how to prevent the transport of contaminated water to the planted areas through porous medium using sheet piles. Sheet piles with suitable depths and locations will be used. The model used in this work is a two dimensional model. This model is solved numerically using finite element method. The equations of contaminant transport by advection, diffusion, dispersion, and adsorption are discussed. It is found that sheet piles with suitable depth are effective in preventing contaminated water from reaching the planted areas.

1. Introduction

Due to the importance of surface water, Water bodies should be protected against all kinds of contaminations. Due to increasing of water bodies' contamination, it is important to study how to reduce such contamination. As the life needs of fresh water {agriculture, industries, domestic, etc.}, It is important to rationalize surface water from contamination. It is necessary to study the nature of porous medium which considered as the main part of study. It is also important to study the velocity of flow, the concentration of the contaminant and contamination resources that can be classified as follow:

i. *Natural resources*; there are sources that naturally found without human interference as acid rain and chloride rocks.

ii. *Artificial resources*; there are many artificial resources that caused by human activities.

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a) *Industrial resources*: pollution results from the manufacturing of several products such as production of textile, gas, oil, plastic,…etc

b) *Domestic sources*: pollution results from several activities at homes, infiltration from rapid mixing tanks in W.W.T.P and sewers of domestic waste water in water bodies,…..etc.

c) *Agricultural resources*: pollution results from the activity of agriculture and using several kinds of fertilizers.

A model should be applied To achieve a complete study of water body contamination and its influence on planted areas,. This model is either physical or numerical. This model represents the influence of contaminated water bodies on different types of porous medium. This helps in finding the best way to protect planted areas from contaminated water.

Several contaminants can be distributed through porous medium by advection, diffusion, dispersion and adsorption. The best way to study the distribution of contaminant is using three dimensional models. This model will provide detailed study of contaminant transport. This helps in finding the most suitable way to protect planted areas from contamination.

There are many possible solutions that can be performed to reduce the transport of contaminant from water body to planted areas as follow;

1-Performing impermeable media (sheet piles).

2-Pumping wells.

3-Using chemicals to remove contaminants from water body.

4-Injection of surrounding soil.

Using any of the previous solutions depends on some factors. These factors should be studied to be able to select the most suitable method of protection, and these factors are as follow;

a) The cost of the proposed solution.

b) The nature of contaminants.

c) Velocity of flow.

d) Geometry of water body.

e) Type of porous medium.

f) Possible reactions.

One of the most effective ways used to control or restrict the transport of contaminant is using impermeable medium.

The chosen impermeable medium is sheet pile. There are two main types of sheet piles, steel sheet piles, concrete sheet piles and also plastic sheet piles. Sheet piles have several uses such as preventing contaminated water transport, stabilizing ground slopes, protecting beaches from erosion, controlling groundwater flow during excavation, and retaining lateral pressure from soil or water.

2.Mathematical Fundamental of Contaminant Transport.

2.1. *Hydrogeology in relation to other fields*

Hydrogeology is a branch of the earth sciences dealing with the flow of water through aquifers and other shallow porous media (typically less than 450 m or 1,500 ft below the land surface.) The very shallow flow of water in the subsurface (the upper 3 m or 10 ft) is pertinent to the fields of soil science, agriculture and civil engineering, as well as to hydrogeology.

The general flow of fluids (water, hydrocarbons, geothermal fluids, etc.) in deeper formations is also a concern of geologists, geophysicists and petroleum geologists. Groundwater is a slow-moving viscous fluid (with a Reynolds number less than unity). Many of the empirically derived laws of groundwater flow can be alternately derived in fluid mechanics from the special case of *Stoke's law.*

The mathematical relationships used to describe the flow of water through porous media are the diffusion and *Laplace equations*, which have applications in many diverse fields. Steady groundwater flow (Laplace equation) has been simulated using electrical, elastic and heat conduction analogies. Transient groundwater flow is analogous to the diffusion of heat in a solid. Therefore some solutions to hydrological problems have been adapted from heat transfer literature.

2.2. *Definitions and material properties.*

2.2.1. *Hydraulic head*; Hydraulic head Changes in hydraulic head (h) are the driving force which causes water to move from one place to another as shown in fig (1-1). It is composed of pressure head (ψ) and elevation head (z). The *head gradient* is the change in hydraulic head per length of flow path, and appears in *Darcy's law* as being proportional to the discharge.

(Aquifer)

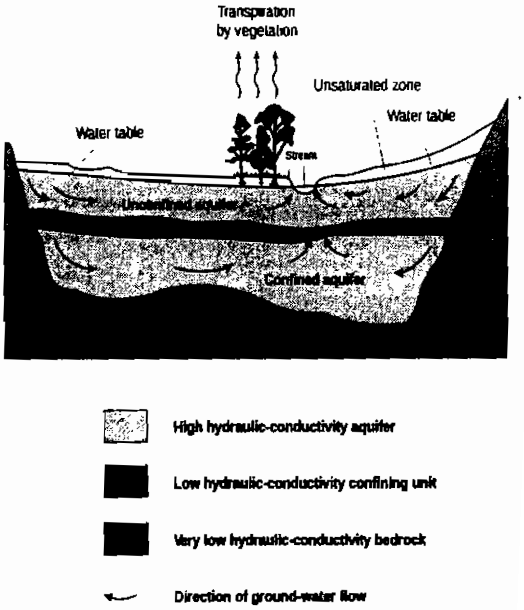

Figure (1-1) typical aquifer cross-section.

2.2.2. ***Porosity***; Porosity (n) is a directly measurable aquifer property. It is a fraction between 0 and 1 indicating the amount of pore space between soil particles or within a fractured rock. Permeability is an expression of the connectedness of the pores. For instance, an unfractured rock unit may have a high porosity (it has lots of holes between its constituent grains), but a low permeability (none of the pores are connected).

2.2.3. ***Water content***; Water content (θ) is also a directly measurable property. It is the fraction of the total rock which is filled with liquid water.

2.2.4. ***Hydraulic conductivity***; Hydraulic conductivity (K) and transmissivity (T) are indirect aquifer properties (they cannot be measured directly). T is the integration of K over the vertical thickness of the aquifer (b) T=Kb (when K is constant over the entire thickness). These properties measure the ability of the aquifer to transmit water.

2.2.5. *Specific storage and specific yield*; Specific storage (Ss) and its depth-integrated equivalent and storativity (S=Ssb), are indirect aquifer properties (they cannot be measured directly). They indicate the amount of groundwater released from storage due to a unit depressurization of a confined aquifer. They are fractions between 0 and 1. *Specific yield*; (Sy) is also a ratio between 0 and 1 (Sy ≤ porosity(n)) and indicates the amount of water released due to drainage from lowering the water table in an unconfined aquifer.

2.3. Darcy's Law

Darcy's law is a Constitutive equation (empirically derived by Henri Darcy, in 1856) that states the amount of groundwater discharging through a given portion of aquifer is proportional to the cross-sectional area of flow as shown in fig.(1-2), the hydraulic head gradient, and the hydraulic conductivity.

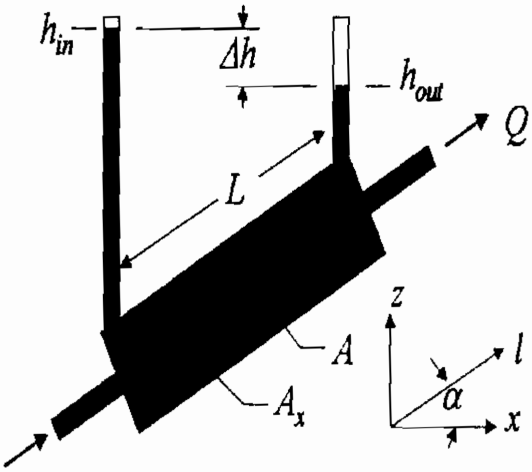

Figure (1-2) Geometry of Darcy's law

2.4. Contaminant transport properties

Often, it is interesting to know how the moving groundwater water will move dissolved contaminants around (the sub-field of contaminant hydrogeology). The contaminants can be man-made (e.g., Petroleum products, Nitrate or Chromium) or naturally occurring (e.g., Arsenic, Salinity). It is also needed to understand where the groundwater is flowing, based on the other hydrologic properties discussed above. There are additional aquifer properties which affect how dissolved contaminants move with groundwater.

2.5. Molecular Diffusion

Diffusion is a fundamental physical phenomenon, by which Einstein explained Brownian motion. It describes the random thermal movement of molecules and small particles in gases and liquids. It is an important phenomenon for small distances. It is also essential for the achievement of thermodynamic equilibrium. As the necessary time to cover a distance by diffusion is proportional to the square of the distance itself. it is ineffective for spreading a solute over macroscopic distances. The diffusion coefficient (D) is typically quite small. and its effect can often be considered negligible unless groundwater flow velocities are extremely low.(as they are in clay aquitards).

2.6. Retardation by adsorption

The retardation factor is another very important feature. It makes the motion of the contaminant to deviate from the average groundwater motion. It is unlike diffusion and dispersion which simply spread the contaminant.

The retardation factor changes its global average velocity so that it can be much slower than that of water. This resulting from a chemico-physical effect. This effect causes the adsorption to the soil which holds the contaminant back and does not allow it to progress until the quantity corresponding to In case of steady uniform flow in the x direction, this means that the the chemical adsorption equilibrium has been adsorbed. This effect is particularly important for less soluble contaminants which can move even hundreds or thousands times slower than water. The effect of this phenomenon makes only more soluble species cover long distances. The retardation factor depends on the chemical nature of both the contaminant and the aquifer.

2.7 Development of governing equation of solute transport.

Advective mass flux is the mass of solute transported advectively per unit area perpendicular to flow with the direction of Darcy velocity. Advective mass flux is (nCv). The dispersive mass flux; is the mass flux due to relative velocity components v_x^* & v_y^* The dispersive mass flux in X, Y direction is (nCv_x^*), (nCv_y^*). This means the total mass flux is sum of advective, and dispersive mass flux.

To develop a governing equation of solute transport, *Fick Law* of Diffusion is used as follow:

$$f = \ -nD_l \frac{\partial C}{\partial x} \text{........................} \quad \text{(Eq2-1)}$$

Where:

f solute mass flux(M/T)

n porosity of soil $(M^0L^0T^0)$

D_l Dispersion coefficient (L^2/T)

C the solute concentration as mass per unit volume of water $(M/L^3/L)$.

transport of solute in X direction due to advective flux and dispersive flux, while in the Y direction the transport due to dispersive flux only; thus

$$f_x = n\left(Cv_x + Cv_x^{\bullet}\right) \text{.................(Eq2-2)}$$

$$f_y = nCv_y^{\bullet} \text{...........................(Eq2-3)}$$

Where:

f_x The total solute mass flux in X direction (M/T);

f_y The total solute mass flux in Y direction (M/T);

v_x The average velocity in X direction (L/T);

v_y The average velocity in Y direction (L/T);

$v_x^{\bullet}$ The dispersive solute velocity in X direction (L/T) and;

$v_y^{\bullet}$ The dispersive solute velocity in Y direction (L/T).

Then Continuity law is used. The net outward flow mass per unit volume of the aquifer per unit time equals to the rate of solute concentration per the same unit volume; Thus

$$\frac{\partial f_x}{\partial x} + \frac{\partial f_y}{\partial y} = -n\frac{\partial C}{\partial t} \text{................(Eq2-4)}$$

The above equation takes the following form in one direction flow (X direction):

$$\frac{\partial}{\partial x}\left(nD_L\frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(nD_T\frac{\partial C}{\partial y}\right) - \frac{\partial}{\partial x}\left(nCV_x\right) = -n\frac{\partial C}{\partial t}$$

....(Eq2-5)

Where:

D_L Dispersion coefficient in longitudinal direction (L^2/T) and;

D_T Dispersion coefficient in transverse direction (L^2/T).

The generalization of governing equation of solute transport to two-dimensional flow can be expressed in the following form:

$$\frac{\partial}{\partial x}\left(nD_{11}\frac{\partial C}{\partial x} - nD_{12}\frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial y}\left(nD_{21}\frac{\partial C}{\partial x} - nD_{22}\frac{\partial C}{\partial y}\right)$$

$$-\frac{\partial}{\partial x}\left(nCV_x\right) - \frac{\partial}{\partial x}\left(nCV_y\right) = -n\frac{\partial C}{\partial t}$$

....(Eq2-6)

The above equation can be written in tensor form as;

$$\nabla\left(nD_{ij}\nabla C - nCV_i \right) = -n\frac{\partial C}{\partial t}$$

....(Eq2-7)

This equation is the basic transport of a non-reactive and non-radioactive substance. As there is no loss of mass due to adsorption or radioactive decay.

2.7.1. *Initial and Boundary Conditions.*

The differential equation of flow or solute transport did not have any information about shape of the flow domain " geometry of domain" .The equation needs initial and boundary conditions which describe initial state of the fluid. The importance of correctly determining the initial and boundary conditions to get a unique solution.

2.7.2. Initial Conditions.

Initial conditions describe the initial state of flow. In flow, model can express head of groundwater in mathematical form as following,

$\phi = f_{(x,y,z,t)}$ ....(Eq2-8)

Where:

$f_{(x,y,z,t)}$ the initial head of groundwater (L).

In solute transport model. It should be described the transient change of solute concentration in groundwater expressed in the following mathematical form:

$C = C_{o(x,y,z,t)}$ ....(Eq2-9)

Where:

$C_{o(x,y,z,t)}$ ....The initial solute concentration as mass per unit volume of water ($M/L^3/L$).

3. Finite Element Analysis.

There are many methods to solve the groundwater problem such as analytical solution which is the exact solution, but in many cases it is not available because of heterogeneity of domain and irregular in boundary. Recently the numerical solutions have increased development. It is approximate solution. There are many numerical solutions such as Finite Difference Method (FDM), Finite Element Method (FEM), Boundary Element Method (BEM), and Total Variation Diminishing (TVD) Method.

The FEM is effective numerical technique because of its numerous applied field such as groundwater flow, multiphase flow, and mass flow through porous medium. It is flexible in simulation and introduce accurate.

3.1.Basic concepts of Finite Element Method

The FEM based on dividing the domain to small elements (finite element) by a grid then convert governing equation to an integral equation and apply over elements. The domain is assemblage of finite element, which connected to each other in 2D at nodes and edges, and in 3D at nodes, edges, and surfaces. Appling boundary conditions after assemblage the domain, then do a numerical integration to solve for unknown parameters.

4. Description of the problem.

-Due to the great importance of studying the environmental problems.

-In the following there will be a study of contaminated water bodies and their influence on planted areas by using GEO slope (SEEP/W) programme.

-Various cases of this influence will be studied and how to reduce it as possible using numerical methods of finite elements and the equations of contamination transport through advection, diffusion, dispersion and adsorption.

4.1. Suggested Solution.

There are many ways to protect planted areas from contaminated water bodies. One of them is;

1-Using concrete or plastic sheet piles in suitable places with effective depths to prevent contaminated water from reaching planted areas.

In this part; Sheet piles are studied to choose the best location and depth of used sheet pile as shown in figure (1-3).

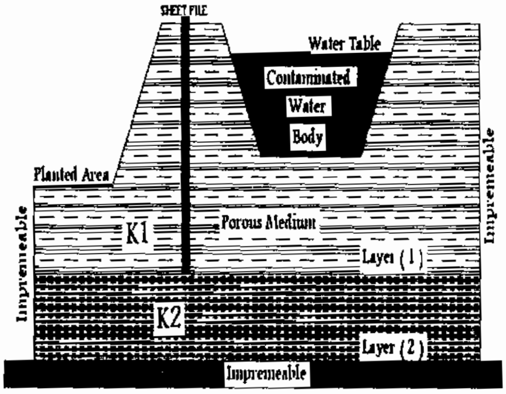

Figure (1-3) Model with Sheet Pile (Two Layers)

4.2. Studied Cases.

Case	1	2	3	4	5	6	7	8	9
K2 value	$1*10^{-7}$	$1*10^{-6}$	$1*10^{05}$	$1*10^{-4}$	$1*10^{-3}$	$1*10^{-2}$	0.1	1.0	10.0

- There are two main cases;

1-Model (1) consists of single layer of soil having conductivity (K_1= 0.1 m/sec) as shown in fig. (1-4).

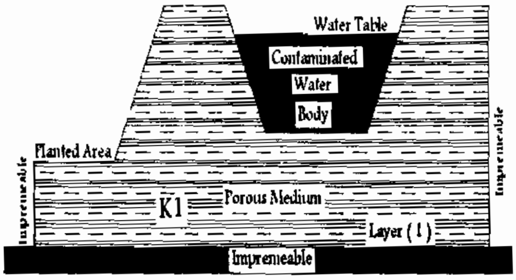

Figure (1-4) Model (Two Layers)

2-Model (2) consists of two layers of soil. The first layer has conductivity (K_1= 0.1 m/sec) and the second layer conductivity (K_2) as shown in fig. (1-5).

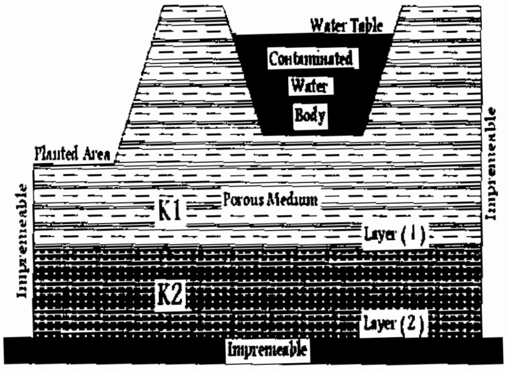

Figure (1-5) Model (Two Layers)

- (K_2) is variable and its values can be shown in table (1-1)

Table (1-1)

- To have a complete study, there is a study of the depth of the second layer and its influence on the flow of the contaminant that reaches the planted areas. And this study includes all previous cases and the different values of (K2) of the second layer at the same value of the first layer (K1). and these depths are shown in table (1-2).

Sheet pile depth variable: (at constant distance=7m)

Table (1-2)

- The stated study includes calculating the flow at planted areas in the following case: -

1-When, d2 (depth of the second layer) = d1(depth of the first layer).

Distance variable: (from water body at constant depth = 17m) from the contaminant resource.

Table (3-3)

5. Analysis of Charts

5.1. As shown in figure (1-5) , the relationship between The flow of contaminated water & the depth of sheet pile. Considering the permeability of the different layers soil. And also at different values of permeability of layer (2) at (d2 = d1).

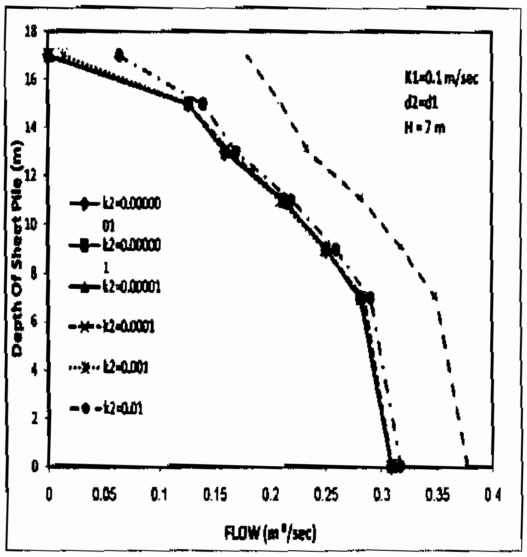

Figure (1-6) Flow change with depth at K2= $(1*10^{-7}, 1*10^{-6}, 1*10^{-5}, 1*10^{-4}, 1*10^{-3}, 1*10^{-2})$

1- At $K_2=1*10^{-7}$ &

$K_2=1*10^{-6}$ &

$K_2=1*10^{-5}$ &

$K_2=1*10^{-4}$ and

$K_2=1*10^{-3}$(m\sec)

(K_2value = permeability of second layer)

Case	1	2	3	4	5	6	7
Depth of sheet pile	5m	7m	9m	11m	13m	15m	17m

In these cases, the results of the flow versus depth of the sheet pile almost on the same way.

The flow equals almost Zero at depth of sheet pile equals 17m.

And also the second layer of soil can be considered as impermeable layer (conductivity K value =0.0).

2- At K_2=0.01 m/sec

In this case, the results becomes quite different from previous results.

The flow equals almost 0.06m3/sec at depth of sheet pile equals 17m.

case	1	2	3	4
Distace from water body	4m	6m	8m	10m

3- At K_2=0.1 m/sec

As the two layers have the same permeability (K_{value}), the flow equals almost 0.18 m3/sec at depth equals 17m.

In Sum:-

The flow of contaminated water increases with the increasing of the permeability (K_{value}) of the second layer of soil (Layer2) at the same depth of sheet pile and the same permeability K value of the first layer of soil (Layer1) .

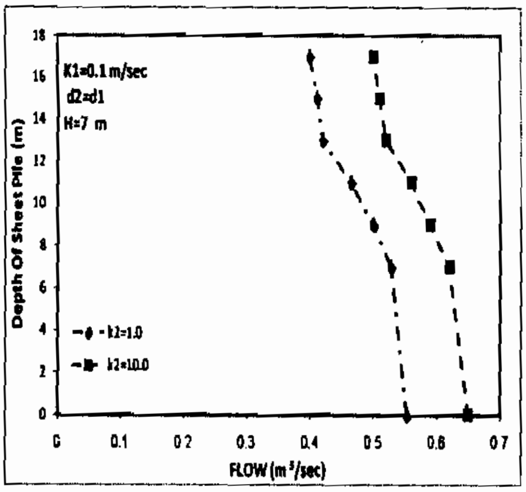

Figure (1-7) Flow change with depth at K_2=(1,10)

5.2. As shown in figure (1-7), the relationship between the flow of contaminated water and the depth of sheet piles. Considering the permeability of the different layers of soil. And also at different values of permeability of layer (2) at (d2 = d1).

1- At K2=1.0 and K_2=10.0 m/sec

In previous cases, the results of the flow versus depth of the sheet pile in a different way.

The flow doesn't equal Zero at depth of sheet pile equals 17m. And the second layer isn't considered as impermeable layer and contaminated water can pass through it.

2- At K_2=1.0 m/sec. In this case, the flow increases to be almost ($0.55m^3$/sec) at depth of sheet pile equals 17m.

3- At K_2=10.0 m/sec

In this case, the flow increases more to be almost ($0.65m^3$/sec) at the same depth (17m).

In Sum:-

The flow of contaminated water increases with the increasing of the permeability (K_{value}) of the second layer of soil (Layer2) at the same depth of sheet pile and the same permeability Kvalue of the first layer of soil (Layer1) .

5.3. As shown in figure (1-8), the relationship between the flow of contaminated water & the distance from water body at which the sheet pile is located considering the permeability of the different layers of soil constant depth of sheet pile=17m when (d2 = d1).

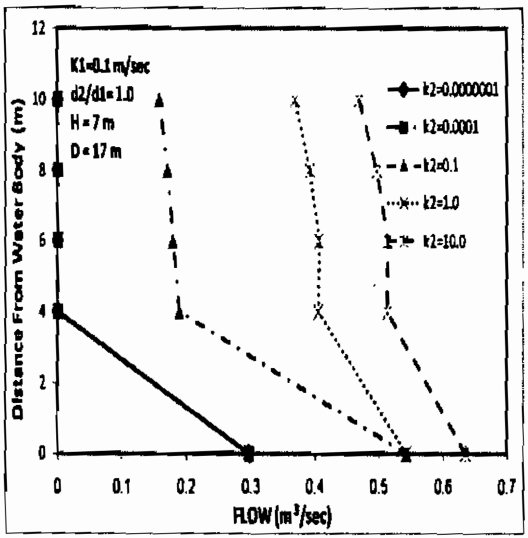

Figure (1-8) Flow change with distance at

K_2=($1*10^{-7}$,$1*10^{-4}$,0.1,1,10)

1- At K_2=$1*10^{-7}$ and K_2=$1*10^{-4}$ m/sec (K_{2value}=permeability of second layer)

In these cases, the results of the flow versus distance from water body at which the sheet pile located almost on the same way as the flow equals Zero at distances (4, 6, 8, 10) m when the depth of sheet pile equals 17m.

As shown, the depth of the sheet pile is deep enough to prevent the flow of contaminated water from contaminated water body to the planted area.

2- At K_2=0.1 m/sec

In this case, the flow increases when both layers have the same permeability at distances (4,6,8,10) m at constant depth of sheet pile (17m). It is found that the flow increases more with decreasing the distance. And the flow became maximum (0.19m^3/sec) at distance (4m).

3- At K_2=1.0 m/sec

In this case, As the second layer has permeability (K_{value}) more than the permeability of the first layer, the flow increases more at distances (4,6,8,10) m at constant depth of sheet pile (17m) and the flow is maximum (0.42 m3/sec) at distance (4m) and decreases with the increasing of distance .

4- At K_2=10.0 m/sec

In this case, the second layer has permeability (K_{value}) more than the permeability of the first layer. and the flow increases more at distances (4,6,8,10) m at constant depth of sheet pile (17m) and the **flow is** maximum (0.53 m^3/sec) at distance (4m) and decreases with increasing the distance .

<u>In Sum</u>, at (d2 = d1):-

The flow of contaminated water increases with the increasing of the permeability (K_{value}) of the second layer of soil (Layer2). And increases with the decreasing of the distance at which the sheet pile is located at the same depth of sheet pile (17m) & the same permeability K_{value} of the first layer of soil (Layer1).

It is concluded that, it's much better to locate sheet pile at further distances to prevent big quantities of flow from reaching planted areas.

And also in last three cases it's preferred to increase depth of sheet pile to decrease flow reaching planted areas.

6. CONCLUSIONS.

- Sheet Piles can be used as a very efficient solution to reduce contaminant transport from contaminated water bodies to planted areas.

- It is found that when the hydraulic conductivity of the second layer of soil increases from ($1*10^{-7}$m/sec) to (10m/sec) the flow from contaminated water body that reaches the planted areas increases.

- In this study different depths of sheet piles are applied at a fixed place. And it is found that when the depth of sheet piles increases, the flow of contaminated water reaches the planted areas decreases. Beside that when the hydraulic conductivity of the second layer of soil increases, the flow increases.

- **At (d_2=d_1),**

1- At ($D_{(depth\ of\ sheet\ piles)}$=7m) the flow of contaminated water that reaches planted area (Q) increases from(0.2825 to 0.53 m^3/sec) when the hydraulic conductivity of the second layer of soil increases from ($1*10^{-7}$ to 10 m/sec).

2- At ($D_{(depth\ of\ sheet\ piles)}$=9m) the flow of contaminated water that reaches planted area (Q) increases from(0.2513 to 0.50 m^3/sec).

3- At ($D_{(depth\ of\ sheet\ piles)}$=11m) the flow of contaminated water that reaches planted area (Q) increases from(0.213 to 0.465 m^3/sec).

4- At ($D_{(depth\ of\ sheet\ piles)}$=13m) the flow of contaminated water that reaches planted area (Q) increases from(0.16 to 0.42 m^3/sec).

5- At ($D_{(depth\ of\ sheet\ piles)}$=15m) the flow of contaminated water that reaches planted area (Q) increases from(0.127 to 0.412 m^3/sec).

6- At ($D_{(depth\ of\ sheet\ piles)}$=17m) the flow of contaminated water that reaches planted area (Q) increases from($1.612*10^{-6}$ to 0.4 m^3/sec).

- It is concluded that the flow decreases when the depth of sheet pile increases. And also it is found that the flow increases when the permeability of the second layer increases.
- In sum, It is better to increase the depth of sheet pile in cases of high permeability of the second layer as possible to reduce the flow of the contaminant.

- In this study sheet piles with fixed depth are located at different distances from contaminated water body (4,6,8,10m).
- **At (d_2=d_1),**

1- At $K_2=1*10^{-7}$ m/sec the flow (Q) decreases from (.0747 to $1.38*10^{-5}$ m^3/sec) when the distance from contaminated water body increases from (4 to 10m).

2- At $K_2=1*10^{-4}$ m/sec the flow (Q) decreases from (.0738 to $7.71*10^{-4}$ m^3/sec).

3- At K_2=0.1 m/sec the flow (Q) decreases from (.2268 to 0.177m^3/sec) when the distance from contaminated water body increases from (4 to 10m).

4- At K_2=1 m/sec the flow (Q) decreases from (.46 to 0.39 m^3/sec) .

5- At K_2=10 m/sec the flow (Q) decreases from (.554 to 0.478 m^3/sec).

- It is concluded, that when the sheet pile is located near of the water body, the flow of contaminant water reaches the planted areas increases. This happens due to the lateral pressure of contaminated water of the water body. And the flow reaches the planted areas decreases while the sheet pile is located far from the water body.
- It is also found that the flow of contaminated water reaches the planted areas increases with the increasing of the hydraulic conductivity of the second layer of soil. The problem of this increasing of flow can be solved with the increasing of the distance between water body and sheet pile but this solution is not considered very effective.

As it could be difficult to get the required distance between sheet pile and the water body. It is found that it would be more effective to increase the depth of sheet pile to be more effective in decreasing the flow from contaminated water body to planted areas.

- It is concluded that, to reduce the flow of contaminated water reaches the planted areas, sheet piles can be used with effective depth at effective locations to be able to reduce the flow as possible.

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