Soil Protection from Lead Contaminant Using Sheet Pile or Isolation Methods

حماية التربة من ملوث الرصاص بأستخدام طريقة الألواح أو طريقة العزل

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الملخص

ان الملوثات التي تنتج من مختلف انواع المخلفات الزراعية والصناعية تعتبربعد ذلك هي المصدر لتلوث التربة . ملوث الرصاص (Pb) قد يسبب خطر يتعذر علاجه او اصلاحه عند دخوله الى السلسله الغذائية.هذا البحث يقدم تطبيق لنموذج عددي للتحقق من عملية أنتقال ملوث الرصاص (Pb) خلال طبقات التربة. تم أستخدام برنامجين حسابيين هما SEEP /W, CTRAN/W,معاً لتحليل أنتقال ملوث الرصاص .حيث تم أختبار سلوك أنتقال الملوث خلال طبقات التربة بدون أستخدام أي طريقة من طرق السيطرة على الملوث, وبعد ذلك بأستخدام طريقتين للسيطرة على الملوث هي طريقة الألواح (sheet pile) او طريقة العزل (isolation). تستخدم هذه الطرق للتقليل من تأثير أنتقال الملوث على البيئة . نتائج هذه الدراسة بينت أن طريقة الألواح (sheet pile) تعتبر الأكثر فعالية أقتصادياً والأكثر مرونةً في حماية التربة .

Abstract

The contaminants which result from different types of agricultural and industrial wastes are considered the source of soil pollution. Lead contaminants which may cause irreparable danger while entering the food chain. This research presents an application of numerical models in order to investigate the transport process of lead through soil layers. Two software products, SEEP/W and CTRAN/W, are used to analyze the lead contaminant transport. The behavior of lead transport through layered soil is tested without using a method of control and with the usage of two methods of control. These are sheet pile method or isolation method. They are used to minimize the impact on the environment. The study results show that the sheet pile method is considered to be the most economically effective and the most flexible method in protecting the soil.

I. Introduction

Soil is one of the most important and valuable resource of nature. Living on earth would be impossible without a healthy soil [1]. When the soil is contaminated due to high concentration of a heavy metal like lead (Pb) (because it is near from some types of industrial and municipal facilities, and adjacent to highways [2]), Many impacts can occur to the soil, human health and environment [3]. So, environmental study is very useful .This work uses two economical treatment methods to control or reduce the concentration of contaminants reaching to allowable percentage of lead,

a) Sheet pile method: by using steel barrier at different depths and locations [4] [5].
b) Isolation method: by using water isolation layers [6].

After that an economic comparison between the two methods is made.

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There are many numerical solution methods can be used to solve the equations of contaminant transport. Among these methods are; the Finite Differences (FDM), Finite Elements (FEM) and Boundary Elements (BEM). The FEM is an effective numerical technique because of its numerous applied fields such as groundwater flow, multiphase flow, and mass flow through pours medium.

SEEP/W is a finite element software product for analyzing groundwater seepage and excess pore-water pressure dissipation problems within porous materials such as soil and rock. It can model, in addition to traditional steady-state cases of seepage as a function of time and such processes as the infiltration of precipitation water through soil.

CTRAN/W is a finite element software product that can be used to model the movement of contaminants through porous materials. It utilizes the SEEP/W flow velocities to compute the movement of dissolved [7].

The dispersion–advection equation is the most effective method for representation of contaminant transport through unsaturated soil which is affected by the volumetric water content of the soil.

Furthermore, many contaminant transport problems may be simplified by using steady-state groundwater flow. In other cases, transient groundwater flow is required. SEEP/W can be used to generate a steady state or transient groundwater flow solution for CTRAN/W [8].

II. Numerical Model

This study uses both GEO – STUDIO 2004 software programs SEEP/W and CTRAN/W to simulate the study cases by choosing a heavy metal such as lead (Pb), as a contaminant that will transport through a region of model.

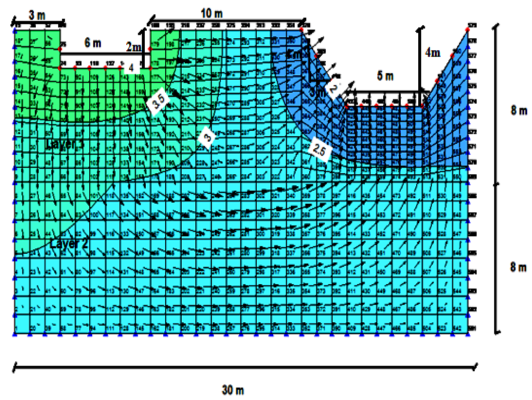
This region consists of two layers which have the same thickness (8.0m) for each and differ in the hydraulic conductivity and water content as shown in table 1.

Table1: Values of hydraulic function which are used in the model simulation.

No. of layer	**Hydraulic conductivity (m/sec)**	**Water content(m^3/m^3)**
Layer 1	**0.01**	**0.3**
Layer 2	**0.10**	**0.5**

The length of model is (30.0m) and the depth is (16.0m). The contaminated source is (6.0m) long and (2.0m) high. The protected area has a trapezoidal cross section. The cross section has a bottom width 5m and 4:3 side slope with(2.0m) deferent in head between two sides as shown in Fig.(1).

CTRAN/W advection – dispersion operation was the type of analysis. The time step sequence consists of 120 steps, (30 days each) and the period of study 3600 days (10 years).



(1) Model Dimensions

III. Results and Discussions

In order to model the contaminant migration in the soil, SEEP/W was firstly applied.

The flow is dependent on the hydraulic gradient and the hydraulic conductivity (coefficient of permeability). The Define part of the program SEEP/W includes the model dimensions shown in Fig. (1) and the soil hydraulic as reported in Table 1.The SEEP/W contour function allows one to graphically view the results by displaying velocity vectors that represent the flow direction.

A vector is drawn in each element, with the end point of the vector at the centre point of the element. The vector represents the average velocity within the element.

The seepage flow velocities computed from SEEP/W are then used by CTRAN/W for the contaminant transport analysis.

In the first step of this study no method of controlling is adopted. Different concentrations of lead (Pb) are thrown in contamination source side beginning from (0.05,0.03,0.015)gm/m³ and reaching to (0.012 gm/m³) over a period of (10 years) as shown in Fig.(2), Fig.(3), Fig.(4) and Fig.(5). The concentration rates at the four corners (1,2,3,4) shown in Figure 6 are illustrated for different concentration of the source in Figures.(7-10).

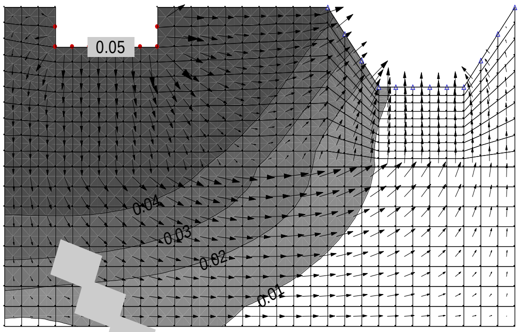


Fig. (2) Advection – dispersion analysis after (10 years) for concentration (0.05 gm/m³).

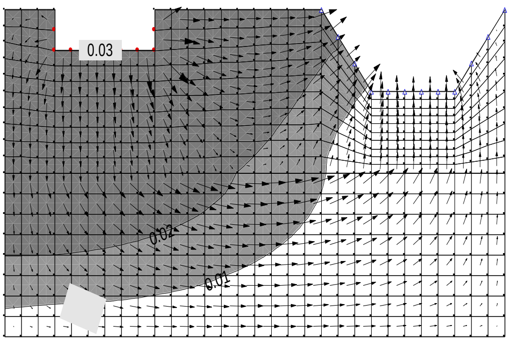


Fig.(3) Advection – dispersion analysis after (10 years) for concentration (0.03 gm/m³).

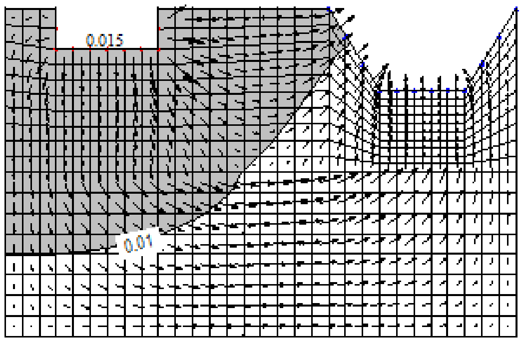


Fig. (4) Advection – dispersion analysis after (10years) for concentration (0.015 gm/m³).

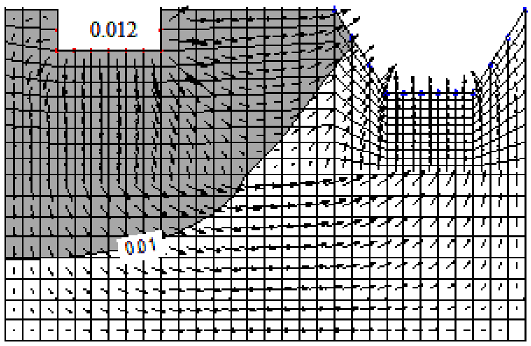


Fig. (5)Advection – dispersion analysis after (10years) for concentration (0.012gm/m³).

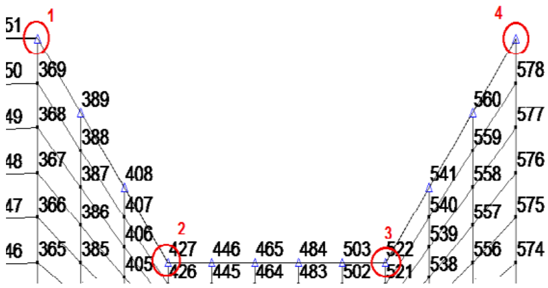


Fig. (6) Corner points of protected area (trapezoidal)

The results of lead ratio at the corner points of trapezoidal p (1, 2, 3, 4).

-In concentration (0.05 gm/m³) in source side were (p1=0.042, p2=0.014, p3=0.0011, p4=0.00008) gm/m³ as shown in fig. (7).

-In concentration (0.03 gm/m³) the result were (p1=0.025, p2=0.0084, p3=0.00062, p4=0.000051) gm/m³ as shown in fig.(8).

-In concentration (0.015 gm/m³) the result were (p1=0.012, p2=0.0042, p3=0.00031, p4=0.000025) gm/m³ as shown in fig. (9).

-In concentration (0.012 gm/m³) the result were (p1=0.01, p2=0.0034, p3=0.00025,
p4=0.00001) gm/m³ as shown in fig.(10) .
The results showed that (0.012 gm/m³) was the suitable concentration of lead that can be thrown in source side.

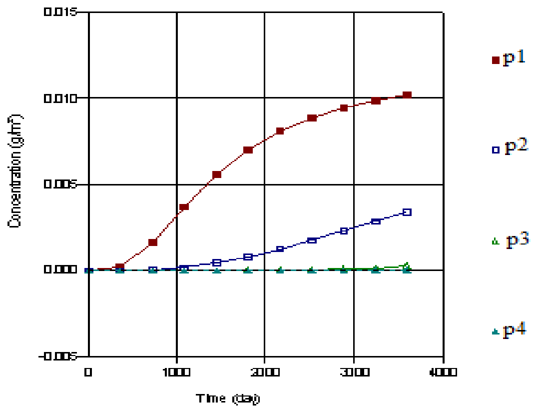


Fig. (7) Pb concentration with time at points (1, 2, 3, 4)at source concentration 0.05gm/m³.

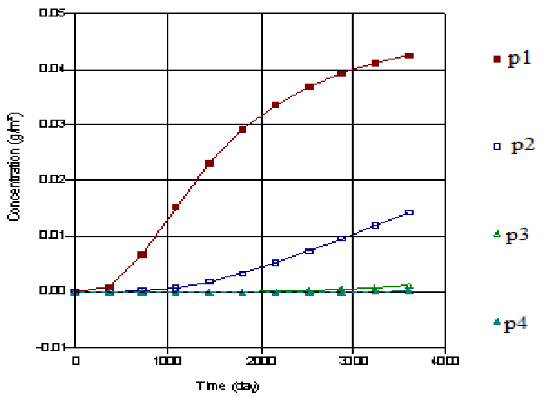


Fig.(8) Pb concentration with time at points (1,2, 3, 4)at source concentration 0.03gm/m³.

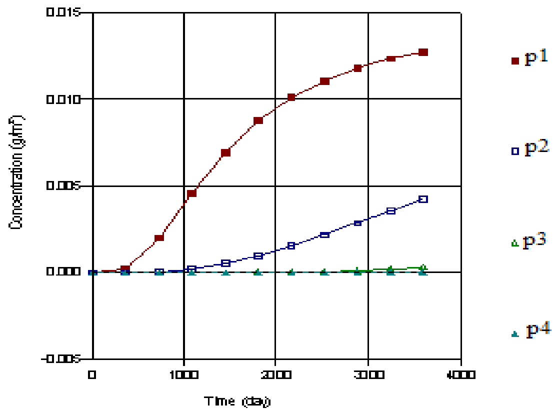


Fig. (9) Pb concentration with time at points (1, 2, 3, 4)at source concentration 0.015gm/m³.

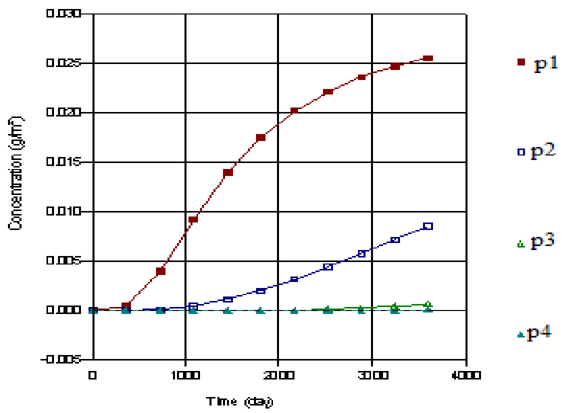


Fig. (10) Pb concentration with time at points (1,2, 3, 4)at source concentration0.012 gm/m³

In the second step of this study, using two economical contamination control methods are adopted, use; Steel sheet pile, use side Isolation

A. Steel sheet pile method.

In this case, a sheet pile is installed to different depths (2.0, 4.0, 4.75, 6.0, and 8.0) m at (1.0m) distance from source side over a period of (10 years), as shown in Fig. (11), Fig. (12), Fig. (13) and Fig. (14) and fig.(15).

To find the concentration consistent with the depth decline of the pile that gives allowable ratio of lead (0.01gm/m³) at the corner points of protected area side (trapezoidal).

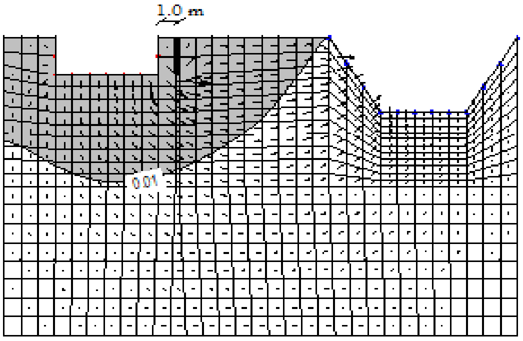


Fig. (11) Advection – dispersion analysis after (10 years) using sheet pile (2.0 m) in depth.

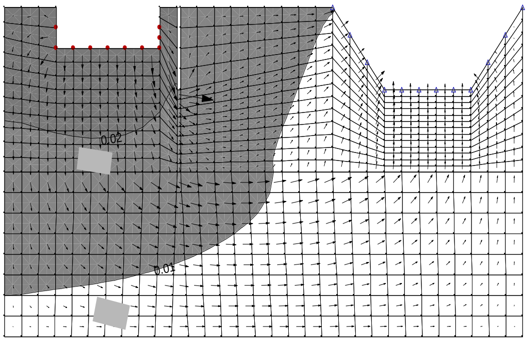


Fig. (12) Advection – dispersion analysis after (10 years) using sheet pile (4.0m) in depth.

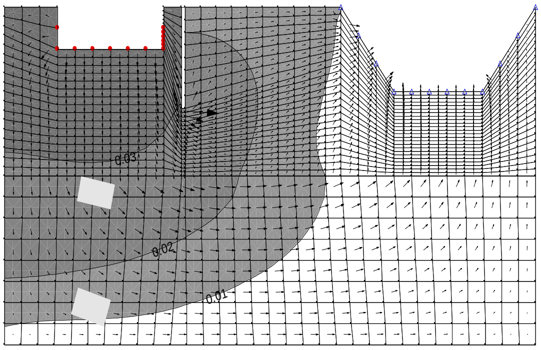


Fig. (13) Advection – dispersion analysis after (10 years) using sheet pile (4.75m) in depth.

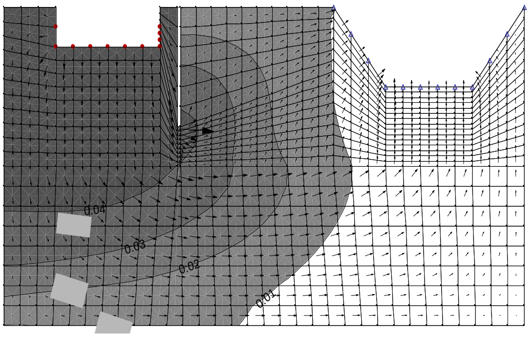


Fig. (14) Advection – dispersion analysis after (10 years) using sheet pile (6.0m) in depth.

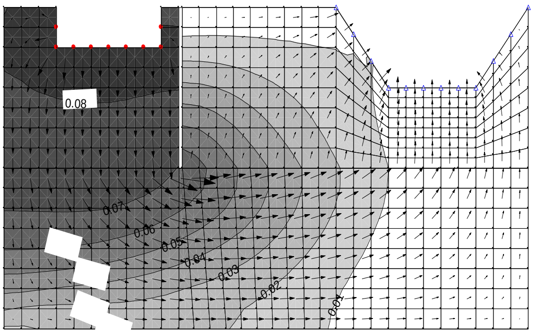


Fig. (15) Advection – dispersion analysis after (10 years) using sheet pile (8.0m) in depth.

The results of lead ratio at the corner points of trapezoidal p (1, 2, 3, 4).

-In concentration (0.013 gm/m³) and depth (2.0 m) at source side were (p1=0.01, p2=0.004, p3=0.00006, p4=0.000016) gm/m³ as shown in fig. (16).

-In concentration (0.022 gm/m³) and depth (4.0 m) the result were (p1=0.01, p2=0.0037 ,p3=0.00026,p4=0.000008) gm/m³ as shown in fig.(17).

-In concentration (0.031 g/m³) and depth (4.75 m) the result were (p1=0.01, p2=0.0045, p3=0.00034, p4=0.000009) gm/m³ as shown in fig.(18).

-In concentration (0.047 gm/m³) and depth (6.0 m) the result were (p1=0.01, p2=0.0058, p3=0.00047, p4=0.000019) gm/m³ as shown in fig.(19).

-In concentration (0.081 gm/m³) and depth (8.0 m) the result were (p1=0.0072, p2=0.009, p3=0.00075, p4=0.000041) gm/m³ as shown in fig. (20).

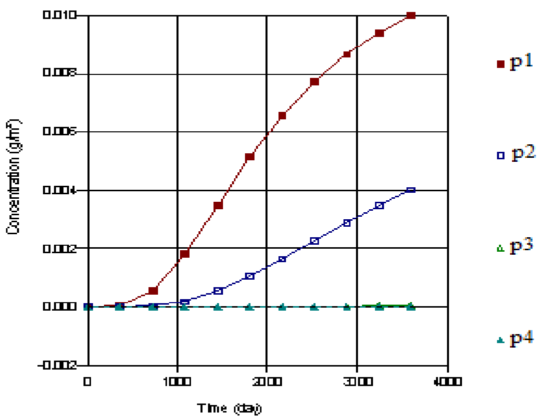


Fig .(16) Pb concentration with time at points (1, 2, 3, 4) at depth (2.0)m.

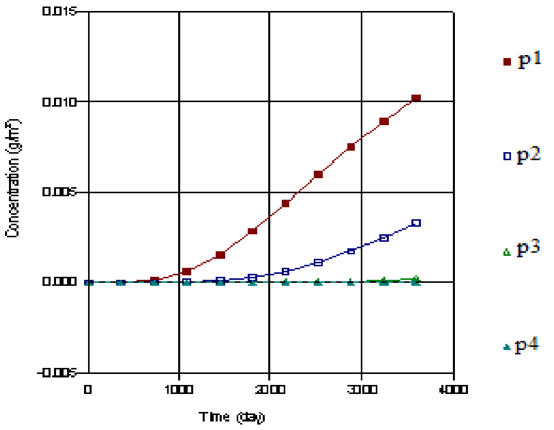


Fig. (17) Pb concentration with time at points (1, 2, 3, 4) at depth (4.0)m .

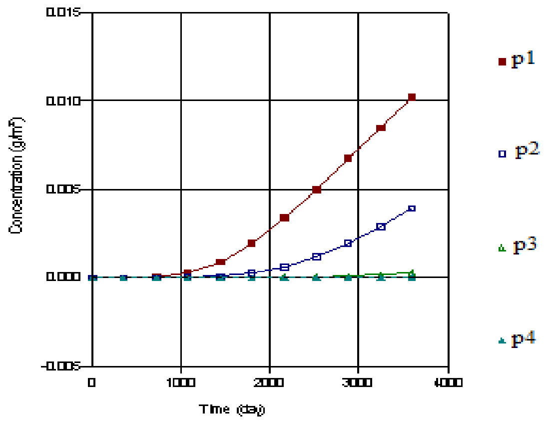


Fig. (18) Pb concentration with time at points (1, 2, 3, 4) at depth (4.75) m.

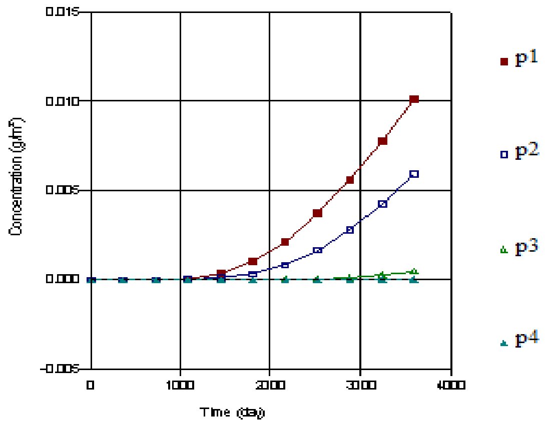


Fig. (19) Pb concentration with time at points (1, 2, 3, 4) at depth (6.0)m.

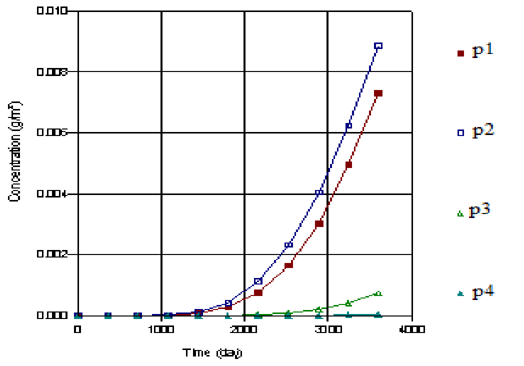


Fig. (20) Pb concentration with time at points (1, 2, 3, 4) at depth (8.0)m

B. Isolation method.

In this method using isolation from one side of trapezoidal over a period of (10 years), as shown in Fig.(21) is treated.to find the suitable concentration that can be thrown in source side to give the allowable ratio of lead (0.01gm/m³) at the corner points of protected area side (trapezoidal).

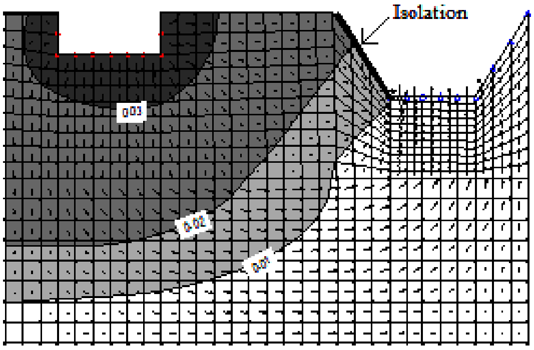


Fig. (21) Advection – dispersion analysis after (10 years) using isolation from one side.

The results of lead ratio at the corner points of trapezoidal p (1, 2, 3, 4) in concentration (0.031 gm/m³) in source side were (p1=0 , p2=0.01, p3=0.00083, p4=0.000093) gm/m³ as shown in fig.(22).

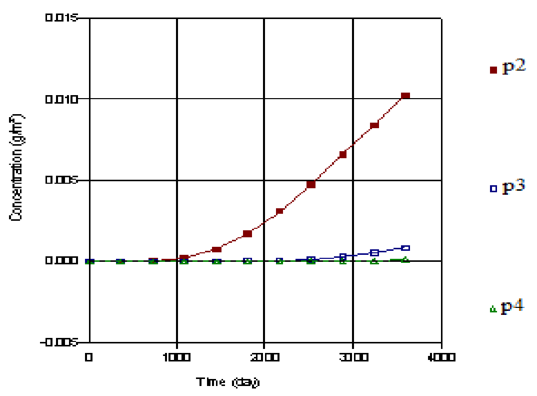


Fig. (22) Pb concentration with time at points (2, 3, 4).

III Economic comparison between two methods

A comparison between the two methods that give the same concentration (0.031gm/m³) of lead (Pb) in the source side. The sheet pile at depth (4.75m) based on the world price has been calculated as (196$) for (1.0 /m). The isolation method from one side in trapezoidal protected area by using non permeable concrete slab, with rate (1:1.5:3) and thickness (0.15m) after adding a compacted (0.15m) boulder layer, costs (300 $) for (1.0m) along (5.0m) slope side based on the world price.

Moreover, the steel sheet pile can be reused at another project.

V. Conclusions

Within material presented in this work the following conclusions can be made:

- The contaminant transport in the bottom layer of soil model is faster than the top layer because the bottom layer has a higher hydraulic conductivity and water content.
- Without using any method of controlling (0.012 gm/m³) was the suitable concentration of lead that can be allowed in the source side, which consider low ratio.
- Using steel sheet pile method with (4.75m) decline depth at(1.0m) distance from source contaminant or using isolation from one side of trapezoidal area give the same concentration of lead (pb) that can be thrown in the source side.
- Steel sheet pile method is more economic in cost than isolation method.

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