Lead ~~Groundwater~~ Contamination of Groundwater in the Northeast of Buenos Aires Province, Argentina.

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Abstract The progressive increment of the water needs due to the expansion of the urbanization and industrialization in different regions in the Northeast of the Province of Buenos Aires, Argentina has produced an intense development of the groundwater resource.

The main objective of this work consists of the study of two sectors of different hydrogeologic features that have been contaminated by lead from industrial activities. We employ a method of characteristics combined with a mixed finite element procedure to simulate the plume evolution in time.

The result of this investigation is the application of an efficient tool for handling the hydric resources and evaluating the environmental impact from the transport of contaminants in groundwater.

Key words lead contamination; groundwater; Northeast of Buenos Aires Province, Argentina; shallow aquifer; numeric simulation

INTRODUCTION

The detailed description of the migration of pollutants is fundamental for the groundwater monitoring and it represents the base for the preservation of this groundwater resource. ~~One of the most~~An important problem~~s~~ is the increasing~~e of the~~ contamination ~~in~~ of ~~the~~ groundwater, which in turn, ~~that~~ leads to a decrease ~~of~~ in the ~~reserve~~ availability of good quality water. ~~In this sense~~Relvant to the study described heren, ~~the~~ contamination dramatically affects the regional behavior of the shallow groundwater system located in the n~~N~~ortheast of the Province of Buenos Aires, Argentina.

In this paper, we assess the variability in solute migration by ~~the use of~~augmenting historical data with ~~a,~~ groundwater ~~contamination~~ sampling for water quality analyses and hydrogeological investigations. Recent reports reveal contamination of soil and groundwater with heavy metals, and in particular, show a high lead concentration that can be toxic to living organisms. Lead can ~~because it can harm~~ damage ~~virtually every~~ human ~~system~~health, especially through disruption of the functions of thee brain, kidneys,~~ey~~ and reproductive system. The body accumulates lead in the blood, bones, and teeth, and soft tissue. Lead is absorbed through ingestion, inhalation, or other exposures.

There are many sources of lead in our environment including paint, gasoline, water distribution systems, food, and various hobby supplies. The lead is transported to the environment by atmospheric deposition, and solid and liquid waste disposal. Groundwater receives lead contamination ~~from the~~by mobilization of lead either natural or enriched from anthropogenic activities in the soil and in some cases, mineral weathering~~the earth's crust~~. The Environmental Protection Agency (US~~. S.~~ EPA) current drinking water lead standard is 0.015 mg l^{-1} ~~of lead~~. The USEPA lead standard~~is value~~ is used in Argentina ~~like~~ as a tolerable limit for drinking water. ~~There are many sources of lead in our environment. These include lead in paint, gasoline, water distribution systems, food and lead used in hobby activities.~~

The transport of reactive solute in spatially variable soil systems~~-~~, and in particular, the effect of the spatial variable hydraulic properties on the solute transport ~~was~~ were studied by van der Zee et al (1987)~~ and they studied the effect of the spatial variable hydraulic properties on the solute transport~~.

Marzal et al. (1995) ~~has~~ presented a coupled transport-chemistry hydrogeochemical model, which can predict~~ and~~ the development of contamination plumes~~ with great concentration is shown~~.

The linear isotherm model ~~in conjunction~~combined with a convective-dispersive solute transport model ~~has~~ have been used frequently to describe the transport of material through porous media. Begovich & Jackson (1975) used a linear adsorption isotherm for lead. In the paper of Chen et al. (1992), adsorption of cadmium, copper, or lead in the presence ~~absence~~ or absence ~~presence~~ of the other two elements was studied at five concentration levels.

Adsorption of lead and other heavy metals by soils and the transport has been studied by many authors (e.g., Griffin & Au 1977; Farquhar et al.~~,~~ 1997~~; Griffin & Au, 1977~~).

In this paper, we describe two field experiments, which~~–~~were conducted in the shallow groundwater system in Northeast of Buenos Aires Province, Argentina during 1999, ~~with the purpose of studying the~~to investigate the transport of lead contaminated water through the saturated zone.~~ were carried out at the shallower groundwater system in Northeast of Buenos Aires Province, Argentina during 1999~~.

Using hydrogeologic data ~~of transmissivity~~ from ~~field~~ pumping tests, we ~~generated~~ constructed the hydraulic conductivity field, which was used ~~run~~ in a numerical model to obtain the groundwater flow field. The flow field was used ~~and employed it~~ to simulate ~~the~~ lead transport ~~evolution~~ through the saturated ~~porous media~~zone. The hydraulic conductivity ~~field~~ is affected by the heterogeneity of the aquifer.~~ and we~~ used The field hydraulic conductivity measurements were ~~the~~ kriged~~ing method~~ to generate ~~this~~ the spatial distribution of hydraulic conductivity ~~field from local measurements~~.

The advection-diffusion equation was used to describe~~ing~~ the spatially variable vertical lead transport ~~in vertical cross-sectional planes of the aquifer is discretized employing a method of characteristics combined with~~ using a mixed finite element ~~procedure~~model, which provides an efficient way to eliminate spurious numerical oscillations and handle the convective term in the equation.

MODEL

Hydrogeological characteristics of the areas study

The shallow groundwater system includes the Puelche, Pampeano, and Postpampeano ~~following~~ hydrogeologic units.~~: Puelche, Pampeano and Postpampeano~~.

~~The Pampeano and Postpampeano units are outcrops in two differents geographic environment.~~ The Pampeano unit is located in high plains and the Postpampeano unit is in low plains. ~~Both~~ Each unit includes the water table, and ~~its~~ the associated groundwater is directly ~~related~~ affected by ~~to~~ processes originating~~ed~~ in the surface (infiltration and contamination). ~~They~~ Each unit overlies the Puelche unit, ~~that~~ which is the main aquifer of the northeast ~~of the~~ Buenos Aires province. In the study area, the Puelche unit is located at a depth of about 40 m with thickness up to 20 m and it is composed by fine to medium sand.

The Pampeano unit is composed of silty sediments, in part clayey and sandy with calcareous materials. The unit ~~has~~ is locally anisotropic~~y~~, ~~causing~~ which affects production and associated ~~different~~ abstraction~~productive levels~~ rates. ~~Its~~ it's the Pampeano unit is ~~thickness is of~~ about 40 m thick having ~~with~~ a regional transmissivity of 100 m^2 ~~-~~day^{-1}. The Postpampeano unit is composed of silty clay, clay, and clayey silt ~~. It~~ and varies in thickness ~~varies between~~ from 3 ~~and~~ to 7 m with a hydraulic conductivity of 0.01 m ~~-~~day^{-1}. The shallow groundwater systems (Puelche, Pampeano, and Postpampeano) are hydraulically connected ~~interrelated~~ and constitute a “multilayer aquifer”.

~~Regional studies in non-contaminated areas define a~~The grounddwater lead concentration in non contaminated areas in the region are about ~~of~~ 0.003 mg l^{-1} ~~in~~

~~groundwater~~ of the Pampeano and Postpampeano units (GALINDO ET AL.~~,~~ 1999). The highest ~~values of the~~ lead concentrations (0,10 mg-l^{-1}) ~~appear~~ were in ~~the~~ shallow groundwater of~~–~~ industrial areas. ~~We choose~~For this study, two field sites in these industrial areas were chosen to simulate the evolution of plume of lead contamination, one ~~of them situated~~ in the Pampeano unit and the other in Postpampeano unit ~~to simulate the evolution of plume of lead contamination~~.

Solute transport equations

The transport equation for lead was dervied from ~~Applying~~ the law of conservation of mass applied to a differential volume element in the porous medium ~~derives the transport equation for lead~~. ~~Equation (1) states that~~ T~~t~~he accumulation of the contaminant is exclusively caused by the convective-dispersive transport and can be written as:

$$\varphi \frac{\partial C(x,t)}{\partial t} + \nabla(D \nabla C(x,t)) - q_w \cdot \nabla C(x,t) = 0 \quad x \in \Omega$$ (**Error! Unknown switch argument.**)

(Please check equation error) where $C(x,t)$ denote the mass concentration of the contaminant at $\boldsymbol{x}$ location, $\boldsymbol{q_w}$ the flux velocity vector, Ω the two-dimensional porous domain, $\varnothing$ the porosity and $\boldsymbol{D}$ the dispersion tensor. To fully define the system ~~in~~ mathematical~~ terms~~ly, initial and boundary conditions must be specified. The initial condition is defined~~,~~ by specifying the total concentrations of the solute at time zero ~~time~~ throughout the transport domain. The flow satisfies the Darcy's law and under the incompressibility assumption, we have that

$$\nabla q_w = 0 \tag{2}$$

The modeling technique is based on a discrete representation of the porous medium. The stationary velocity field is computed using a hybridized mixed finite method and small variations in groundwater flow directions were found.

The transport equation is solved numerically by combining a method of characteristics with a mixed finite element procedure, (DOUGLAS ~~ET AL,~~ET AL. 1982; DOUGLAS ~~ET AL,~~ET AL. 1994), which is used to eliminate the nonsymmetry in the operators due to advection.

Lead Adsorption

The heterogeneous characteristic of the porous medium and the sorption in soil influence the solute transport~~ of heavy metals~~. When chemical species are dissolved in groundwater they may ~~undergo~~ adsorb~~ption~~ on the surface of porous media, which can be modelled by either linear or nonlinear isotherms. The simplest and most widely used of the equilibrium sorption isotherms is ~~that given by a linear relationship~~a linear isotherm. That is, it is assumed that the amount of the solute adsorbed by the soil matrix and the concentration of the solute in the soil solution are related linearly. Taking adsorption into account, the mass balance equation becomes

$$\frac{\partial(\varphi C(x,t)+\rho S(x,t))}{\partial t} + \nabla(D \nabla C(x,t)) - q_w \nabla C(x,t) = f(x,t) \quad x \in \Omega \qquad (3)$$

In equation (3) ρ denotes the bulk density of the soil and S is the adsorbed concentration. In this study we consider a linear adsorption isotherm of the form

$$S(x,t) = k_d\, C(x,t) \qquad (4)$$

where k_d is an empirical distribution coefficient and it is a measure of retention of solute by the soil matrix.

RESULTS

Aplication examples

The model ~~has been applied to~~used to simulate lead transport ~~problems~~ in two hydrogeological different ~~sectors~~settings: the Pampeano and Postpampeano units. In each unit~~, where~~, however, lead concentrations greater than 0.05 mg l^{-1} have been recorded for ~~the~~ water sampled from wells, indicating~~es~~ the existence of contamination ~~with measured major concentrations greater than 0.05 mg l^{-1}~~. We analyzed the lead concentration variations ~~evolution~~ in two 10 x 5 m ~~transversal~~ sections of the saturated zone for each unit~~ respectively~~. ~~It is considered an~~ The initial condition ~~of~~ for the lead contamination ~~of~~ was C_0=0.05 mgl^{-1} ~~attributed to a point~~ at the top of each section (depth z=0 m) located at x=3 m in the horizontal direction. In all the simulations the following parameters were use: Δx=1 m, Δz=0.25 m, Δt=1 day, k_d=0.2536 mmolkg^{-1} (HOUNG & LEE~~,~~ 1998) and the calculations were obtained for a 5-m depth of a saturated soil profile. For the Pampeano unit, ~~the~~ the hydraulic conductivity ~~is considered~~ranged from 1 to 10 m day^{-1} with a porosity (φ) = 0.2, and for the Pospampeano unit, the hydraulic conductivity ranged from 0.01 to 0.1 m day^{-1} with ~~it is used~~ φ = 0.4~~, with a hydraulic conductivity from 0.01 to 0.1 mday^{-1}~~.

In the first case, the ~~maximum~~ concentration maximum migrates at~~ a~~ 1 m horizontally ~~distance of one meter~~ from the contaminated point after 30 days (Fig. 1), ~~but~~ and ~~it~~ the maximum concentration continues to move at the top of the saturated zone. After 60 days, ~~we can observe that this~~the concentration maximum also moves

~~also in~~ verticalLy ~~direction being located~~ 0.25 m below the initial depth of contamination ~~level~~ (Fig. 2). ~~In the Fig. 3~~ T~~t~~he temporal concentration profile development ~~in time~~ under the initial point of contaminat~~ion~~ ~~ed point as a~~ is shown as a function of the depth ~~is observed~~in Fig. 3.

In the medium of lower hydraulic conductivity, the Postpameano unit, ~~the maximum~~ the lead ~~of 0.05 mg l^{-1} almost doesn't~~ doesn't migrate appreciably, ~~since~~ mainly due to the low groundwater velocity ~~makes that the contaminant continues concentrated at the initial point by different time's simulation~~ (Fig. 4). After 400 days ~~of migration~~, ~~it doesn't reaches to contaminant a distance greater that one meter~~ lead doesn't move more than 1 m (Fig. 5).

~~After observing the spatial variation of the maximum concentration, it can be seen that the flow system deflected the lead migration down and rightward in the two domains.~~

CONCLUSIONS

Model s~~S~~imulation of groundwater lead migration ~~results~~ demonstrate that the hydraulic conductivity and porosity ~~have an~~ are important ~~influence~~ controls ~~on the migration of lead~~ in the shallow groundwater system of the northeast of the Province of Buenos Aires, Argentina. The migration of lead in the Postpampeano unit is very slow and the movement is minimal~~um~~. The possibility that significant amounts of lead would ~~of reaching~~ reach the main ~~level~~ aquifer (Puelche), which underlies the Postpameano unit, ~~could be associated with the ocurrence of~~would only occur along macropore features like fractures or spatial heterogeneity of hydraulic conductivy, such as fine lenses of sand.

The migration of lead in the Pampeano unit is slow, but ~~a point of~~mobility is higher than in the Postpampeano unit and ~~contamination with persistance over~~ may in time ~~could be affected to the resources of drinkable~~ the potable groundwater supplies in the region.

The examples presented here illustrate that ~~the~~ solute transport ~~simulations~~ can be predicted for different ~~responses~~ hydrogeologic conditions ~~to an existing point of contamination~~ and ~~it~~ the predicted transport ~~can~~ may be used to plan different remediat~~l~~ion strategies.

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FIGURE CAPTIONS

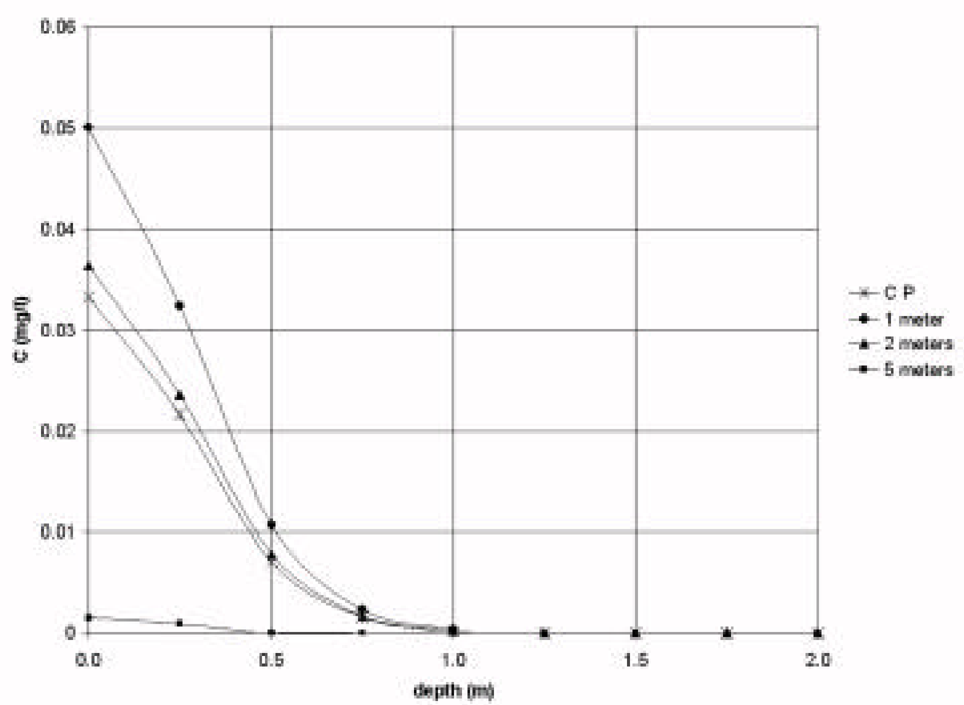

Fig. 1 Lead concentration profile at time t=30 days ~~in~~ at ~~different~~ several distances from the point of contaminat ion~~ed point~~ (C.P~~.):~~ .) in the Pampeano unit.

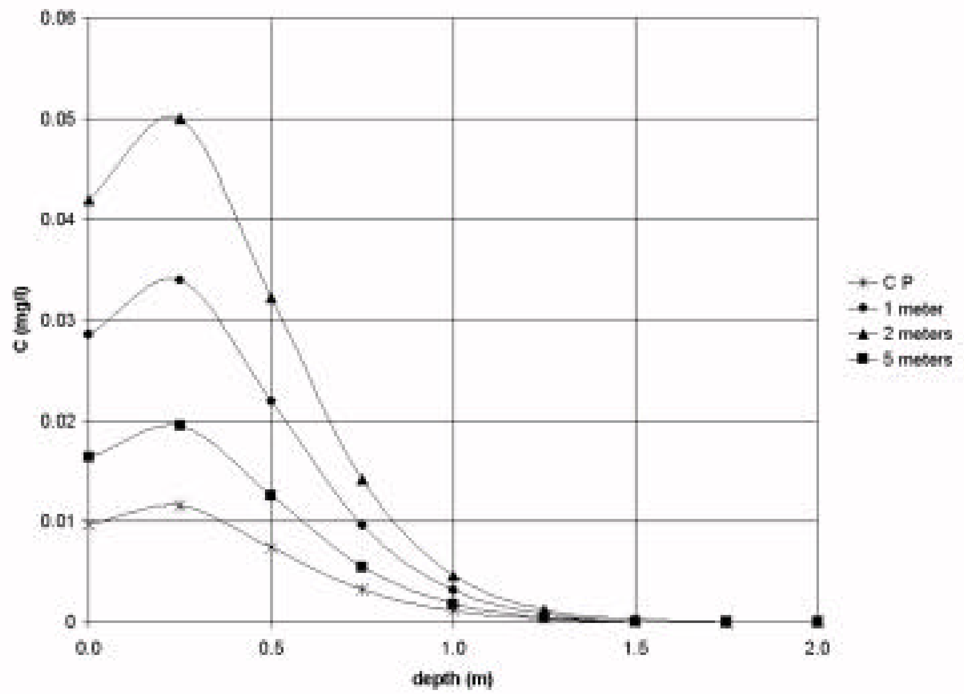

Fig. 2 Lead concentration profile at time t=60 days at several distances from the point of contamination (C.P.) in the Pampeano unit.~~Lead concentration profile at time t=60 days in different distance from the contaminated point (C.P.): Pampeano unit.~~

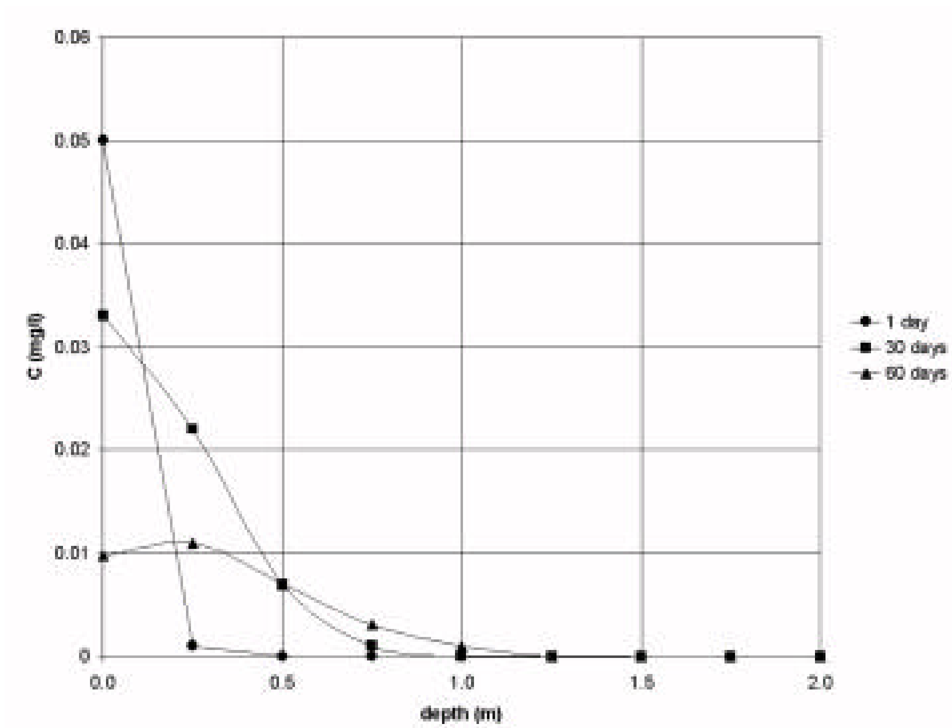

Fig. 3 Lead concentration profile at various times at the contaminated point for the Pampeano unit.

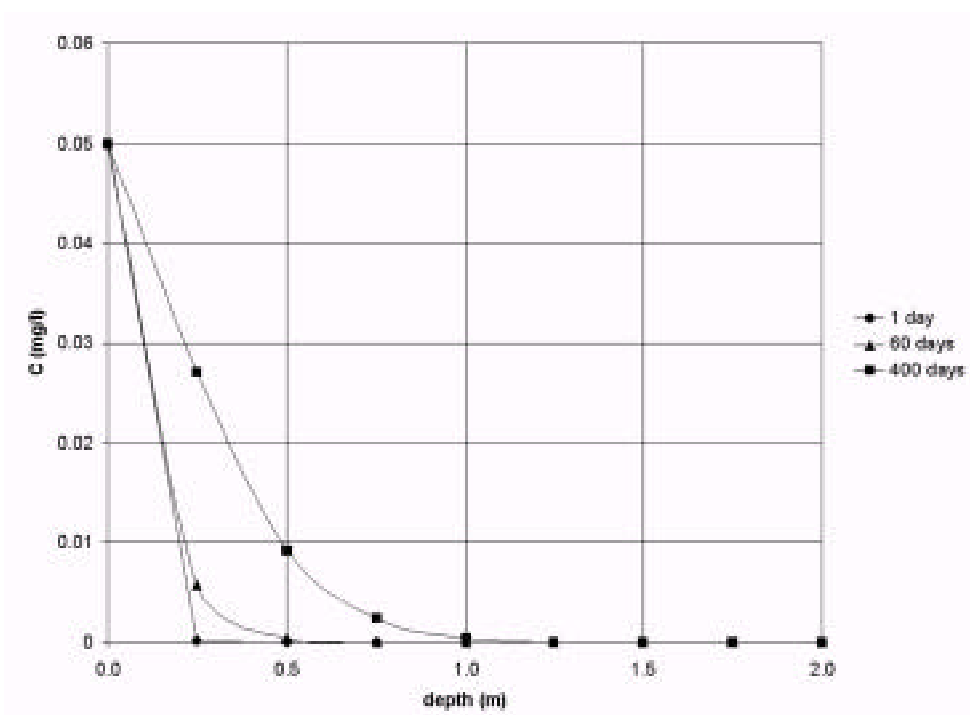

Fig. 4 Lead concentration profile at various times at the contaminated point for the~~:~~ Postpampeano unit.

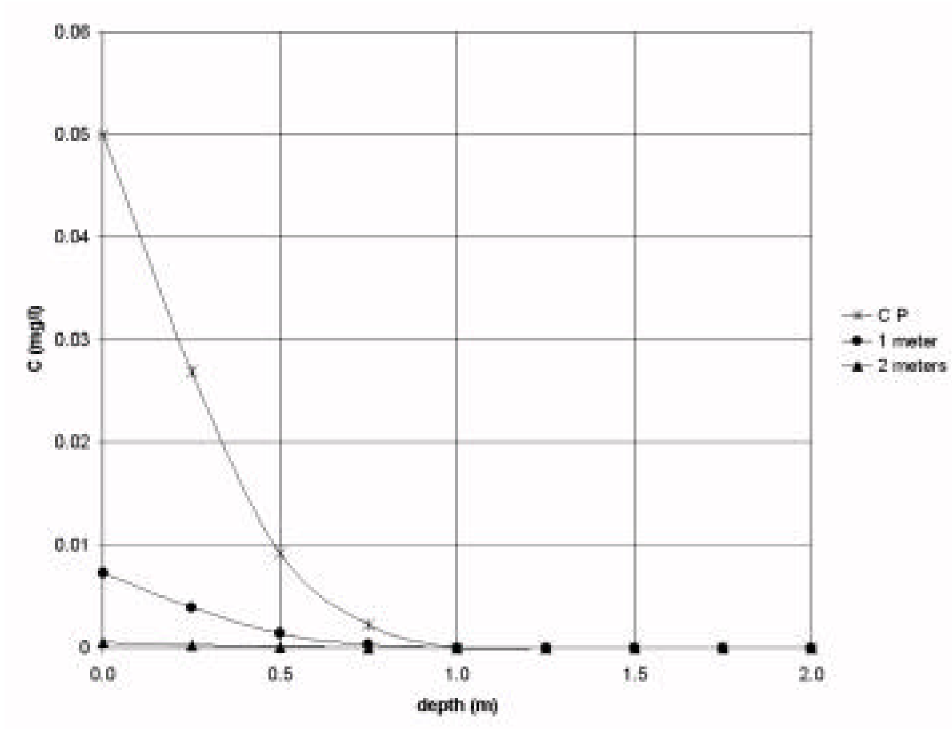

Fig. 5 Lead concentration profile at time t=400 days at two distances from the point of contamination (C.P.) in the ~~Lead concentration profile at time t=400 days in different distance from the contaminated point (C.P.)~~ Postpampeano unit.