# *NUMERICAL SIMULATION OF METAL TRANSPORT FROM POLLUTED DRAIN*

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## ABSTRACT

Polluted drains are considered one of the most important hazardous elements for the surrounded environment. Seepage from polluted drains may contain different kinds of pollutants out of which heavy metals may be the most dangerous ones. Using polluted water for irrigation makes the problem more complex. The main objective of the current research is to predict the heavy metal impact around a polluted drain by simulating metals percolating to the adjacent land where water is used for irrigation and fish farming. Numerical model Hydrus-2D is applied to simulate the movement of five main heavy metals (Cu, Pb and Zn, Cd, and Ni) percolating from the polluted drain. Furthermore, the effect of including an adjacent minor drain parallel to the polluted drain was investigated as a potential remedy to protect agricultural lands along the polluted drain. Soil types and model setup were chosen corresponding to the severely polluted Bahr El Baqar drain in northeastern Egypt. Results of heavy metals prediction of 20, 50 years showed that the effect of downward infiltration is larger than the effect of seepage from the drain. Results showed also that a small deep ditch excavated adjacent to the polluted drain at small distance interval (10m) will reduce seepage from the drain. However, its effects on reduction of pollution from downward infiltration are limited. The study showed that using fresh water for irrigation of polluted soil during a reasonable time is an effective methodology for reducing soil pollution.

**Keywords**: Pollution, heavy Metals, modeling, drainage, soil pollutants.
*Received 13 March 2015.Accepted 2, August 2015*
*Presented in IWTC 18th*

## 1 INTRODUCTION

Due to water scarcity, many countries especially in arid and semiarid regions are forced to use marginal water for irrigation. The effect of using low quality water in irrigation maybe, however dangerous for environmental and human health. Polluted drains are considered a big threat for the surrounded environment (Azeem et al. (2007), Hamed et al. (2011)). Seepage and polluted water used for irrigation or fish farming are dangerous factors affecting environment and agriculture and eventually human health.

One of the most polluted drains in Egypt is Bahr ElBaqar drain (Abdel-Shafy & Aly 2002). It receives and carries industrial and domestic wastewater from Cairo (about 3 BCM/year) into Lake Manzala through the densely populated Eastern Delta area. During the last decades, areas located on both sides of the drain have used the drain water for irrigation and fish farming. As a result, Bahr El Baqar has received considerable concern by many scientists. Ali et al. (1993) and Abdel-Azeem et al. (2007) studied the effect of prolonged use of drain water for irrigation on the total heavy metals content of southern Port-Said city soils. They found that using such kind of water will cause high concentration of heavy metals in soil and plant roots and shoots. Abdel-Azeem et al. (2007) collected 25 soil and 30 water samples from cultivated soil and drain of Bahr El-Baqar. The study area is almost the same as the study area of the current study. Soil heavy metals content (Zn, Pb, Cd, Co, Mn and Cu), were determined. They concluded that total levels of heavy metals showed a trend relationship between metal concentration in soil and long term of irrigation assuming that there is a continuous deposition of heavy metals on the soils due the continuous use of Bahr El-Baqar drain in watering soil for many years in which both living and non-living components of ecosystem are hazardly affected.

Water quality, chemical composition, and hazardous effects on Lake Manzala water and living organisms caused by Bahr ElBaqar drain water was studied by several investigators like Rashed and Holmes (1984), Khalil (1985) and Ezzat (1989). Special attention has been paid to the effect of environmental pollution from microbiological and toxicological points of view (Zaki1994 ).

Numerical modeling is inexpensive, fast, and labor saving tool for simulating pollution seepage and infiltration from polluted drain. Oswald et al. (2003) studied the transport of zinc and copper in soil during a long-term phytoremediation. Numerical modeling with Hydrus-1D was applied especially for the zinc movement. The vertical movement downwards was illustrated and the relative importance of the processes involved and the impact of a planned remediation strategy.

Sayad et al. (2008) assessed the applicability of Hydrus model for simulating the mobility of Cd, Cu,Pb, and Zn under two common crop plants with different rooting systems,wheat (Triticumaestivum) with fibrous roots, and safflower (Carthamustinctorious) with taproot in the arid soils of Isfahan, Iran. The results showed that Hydrus could well predict Cd, Cu, and Pb uptake by wheat and Cd uptake by safflower.

The current study aims at quantifying the above effects of including a small drain beside the major polluted drain and investigates changes in soil quality using clean fresh water on polluted soils. Quantification of pollution transport was made using Hydrus (Simunek et al. 2006) simulations to test the results achieved by Hamed et al. (2011). Thus, the study investigated movement of five main heavy metals from a typical polluted drain and from soil surface through downward infiltration. The main purpose of the simulation was to test the most hazardous condition, seepage from the polluted drain or downward infiltration from polluted irrigation water used from the drain. Moreover, a small drain parallel to the polluted drain was introduced as a potential remedy to decrease pollution problem investigated in field in previous studies. Finally, the study also investigated the efficiency of using fresh water for irrigation or fish farming on the pollution reduction after long time of using polluted water.

Hamed et al. 2013 collected water and soil samples monthly from five sites for one year. Four sites located in Manzala Lake and one site located in Bahr Elbaqar drain. The site in the drain is located exactly in the study area of the current research. Samples were analyzed in order to calculate the concentration of five main heavy metals (Zn, Pb, Cd, Mn, and Cu). Table (1) shows the results for the drain site.

**Table 1 The values of heavy metals in drain water for one year. (From Hamed et al 2013)**

| Sites | Concentration in mg/liter | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Year 2008 | | | | Year 2009 | | | | | | | | |
| | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | Jul. | Aug. | Sep. | Oct. | Nov. |
| Cu | 0.151 | 0.022 | 0.204 | 0.245 | 0.062 | 0.005 | 0.045 | 0.106 | 0.083 | 0.014 | 0.012 | 0.008 | 0.011 |
| Pb | 0.749 | 0.235 | 0.273 | 0.195 | 0.088 | 0.030 | 0.287 | 0.041 | 0.033 | 0.053 | 0.009 | 0.031 | 0.066 |
| Zn | 0.139 | 0.549 | 2.066 | 1.438 | 0.431 | 0.333 | 0.688 | 0.031 | 0.095 | 0.199 | 0.024 | 0.028 | 0.051 |
| Cd | 0.069 | 0.061 | 0.017 | 0.062 | 0.101 | 0.199 | 0.032 | 0.128 | 0.001 | 0.025 | 0.021 | 0.016 | 0.016 |
| Mn | 2.573 | 3.935 | 0.084 | 0.065 | 0.281 | 0.56 | 0.278 | 0.519 | 0.064 | 0.010 | 0.011 | 0.125 | 0.816 |

Salem et al.(2012) in Hamed et al. (2011) conducted an integrated environmental assessment for areas located on both sides of Bahr ElBaqar along a 20 km reach upstream the Manzala Lake. Effects of seepage from the drain to the adjacent lands with different land uses were studied. Moreover, effects of using polluted water for irrigation were also investigated. Twenty four boreholes were dug in 8 horizontal sections for different locations at the study area. Every horizontal section has length of 120-160 m from the Bahr El Baqar drain side and contains three boreholes. Two soil samples were collected from each borehole at different depths. Results showed that the effect of using polluted water for irrigation or breeding fish is more dangerous than the effect of seepage from the polluted drain. Results showed that an existing minor drain parallel to the major polluted drain at relatively small distance (90-100m) may reduce the pollution transport to land located around the minor drain. However, the reduction may not be significant when polluted water from the major drain is widely used for irrigation or fish farming adjacent to the minor drain. The authors concluded that agricultural lands which have been irrigated with polluted water for long time (20 years) and changed to use fresh water for a shorter period of time (5 years), the improvement of soil quality is quite clear (Fig.1).

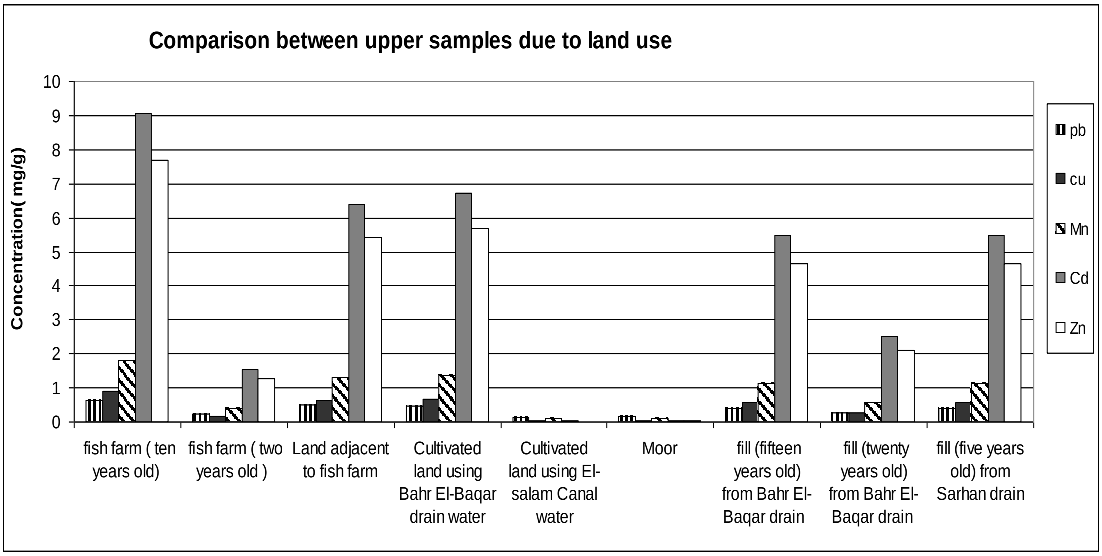


**Figure1. Mean heavy metals concentrations in upper soil samples for different land uses (From Salem,et al 2012)**

## 2 METHOD AND MATERIALS

## 2.1 Area Description

The study area chosen represented the last 20 km reach of Bahr ElBaqar drain before it spills its water into Lake Manzala. The same area was studied by Salem et al.(2012) in Hamed et al.(2011)

The study area is located within the service area of the national project El Salam Canal south of Port Said City (Fig. 2). Bahr El Baqar drain is used to collect and dispose the agricultural and industrial waste from industrial and municipal areas in Cairo. The drain's water depth is about 3.5 m while its free board is equal to about 0.5 m. The soil surrounding Bahr ElBaqar drain is classified as clayey soil with more than 55% clay, 30% silt, and 15% sand. The region is characterized by shallow water table (it is located 1.5 m below the soil surface) and the climate is characterized by high annual potential evapotranspiration and low annual rainfall. The agricultural lands are divided into canals and drains systems and the irrigation technique is flooding. Water comes from El-Salam main canal to distribute among group of branch canals. Each branch canal feeds some distributer canals where each distributer canal feeds a group of field canals. The lands are owned by farmers. Fish farms consist of small banks surrounding the area with two openings one for inlet and the other for exit. Water is pumped from the drain to the farms through the inlet. The main heavy metal pollutants in the drain water are Pb, Cu, Zn, Ni, and Cd. A small drain (Sarhan drain) is located 100 m to the east parallel to Bahr El Baqar drain. It collects the drainage water from the area nearby and spills it eventually to Bahr ElBaqar drain. Table (2) shows the values of drain water salinity and pH from September 2008 to November 2009 according to Hamed et al 2013.

**Table 2 : The values of water salinity(dS/m) and pH for the drain water for one year. (From Hamed et al 2013)**

| | Time | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2008 | | | | 2009 | | | | | | | | |
| | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | Jul. | Aug. | Sep. | Oct. | Nov. |
| EC dS/m | - | - | - | 3.31 | 4.2 | 4.57 | 4.24 | 3.54 | 4.53 | 5.33 | 4.04 | 4.26 | 4.25 |
| pH | 7.0 | 7.3 | 7.7 | 7.7 | 7.7 | 7.8 | 7.8 | 7.7 | 7.1 | 7.5 | 7.8 | 7.7 | 8.0 |

## 2.2 Theory

A multi-purposes finite element model, HYDRUS-2D/3D (Simunek et al.2008), for water flow and solute transport was used to investigate the influence of the geometric design of the minor drain adjacent to the main Bahr ElBaqar drain in order to reduce the pollutant transport from the main drain to the surrounding soil. The model was also used to investigate the downward infiltration of pollutants coming from polluted irrigation water or polluted water used for fish farming. The model can simulate water flow, solute transport, and heat movement in two and three dimensional variably saturated porous media. Furthermore, it has the ability to prescribe a variety of soil heterogeneities and

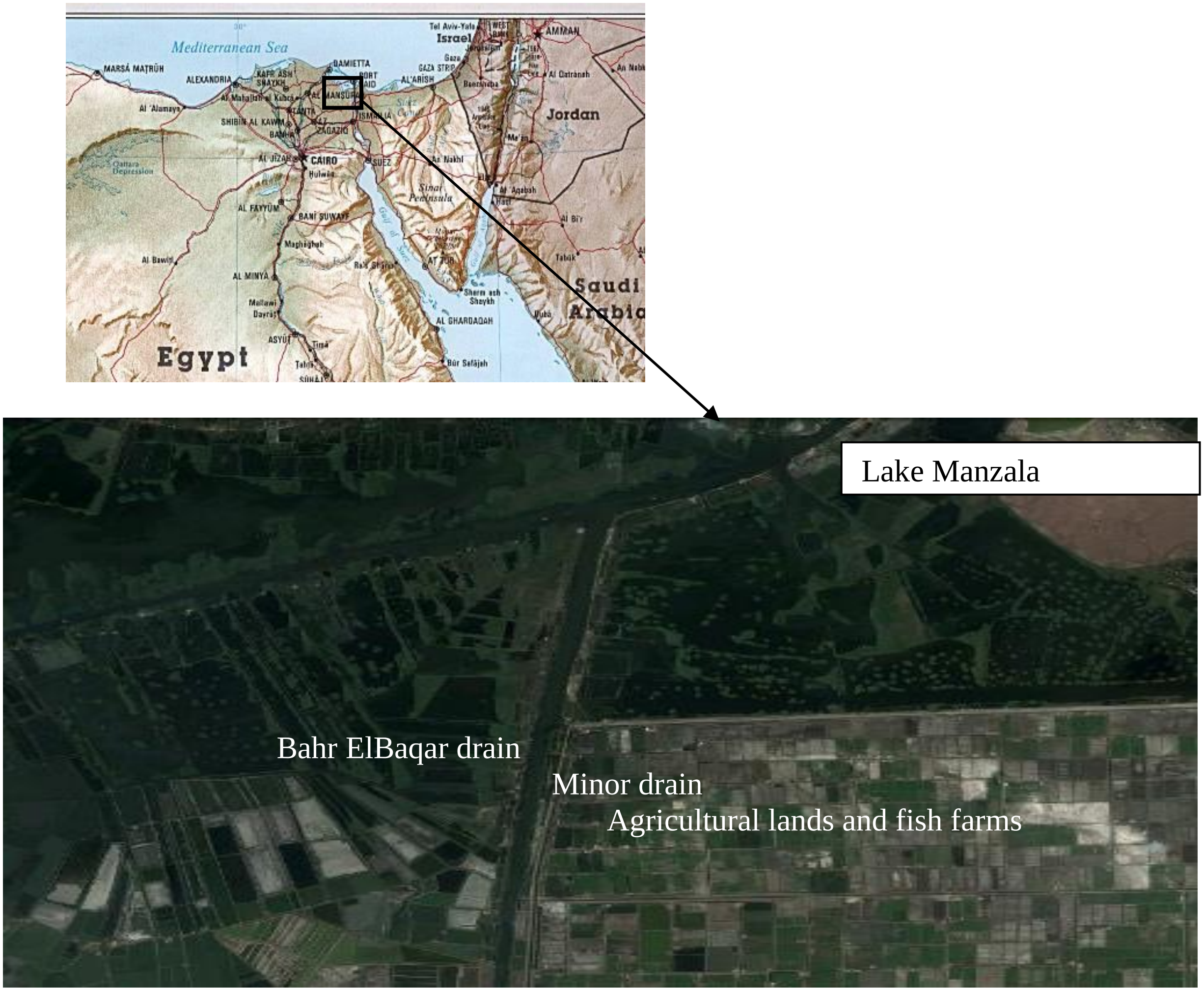


**Figure (2) Location of the study area**

Boundary conditions. HYDRUS code uses Galerkin finite element method (Celia et al. 1990) to numerically solve the modified form of Richards' equation (Richards, 1931) for water flow in isotropic variably saturated porous media. The modified form of Richards' equation in two dimensional vertical plans can be described as

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x}\left(K(h)\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial z}\left(K(h)\frac{\partial h}{\partial z} + K(h)\right) - S$$

Where θ is volumetric soil, water content ($L^3\ L^{-3}$), t is the time (T), K is the unsaturated hydraulic conductivity ($L\ T^{-1}$), h is the soil water pressure head (L), x and z are the horizontal and vertical coordinates respectively (z is positive downwards), and S is the sink term accounting for root water uptake ($T^{-1}$). On the other hand, the software uses the advection-dispersion equation (e.g., Hillel, 1998) to prescribe solute transport within the simulation domain and has the form

$$\frac{\partial \theta c}{\partial t} = \frac{\partial}{\partial x_i}\left(\theta D_{ij}\frac{\partial c}{\partial x_i}\right) - \frac{\partial q_i c}{\partial x_i}$$

Where c is the concentration of the solute in the liquid phase ($M\ L^{-3}$), the subscripts i and j indicate rather x or z, $D_{ij}$ is the dispersion coefficient ($L^2\ T^{-1}$), $q_i$ is the components of the flux density. The first term on the right hand side denotes to the solute flux due to dispersion while the other term represents the solute flux due to convection with flowing water. It is pertinent to mention that the above equation is used for simulating the movement of single non-reactive ion in homogeneous medium with the neglectation of plant solute extraction.

## 2.3 Flow Domain

In the present study, simulations were conducted to investigate the pollutant movement from the drain to the surrounding soil during a 20 and a 50 year time period. Although the drain contains many pollutants only the main pollutants Pb, Cu, Zn, Cd, and Ni were considered during this study. Usman (2008) demonstrated that Zn, Cd, and Ni pose more threats to the groundwater and plants than other heavy metals. The simulated domain for water flow and solute transport was complex and it was made large enough to avoid the effect of bottom and side boundaries. The total depth of the flow domain was assumed equal to 8 m while the width was assumed equal to 100 m. Unstructured triangular mesh with 2452 2D elements were used to spatially describe the transport domain. Mesh refinement was done closer to the drain perimeter and soil surface where rapid change in flux occurs. Figure 3 shows a schematic diagram of the simulation domain.

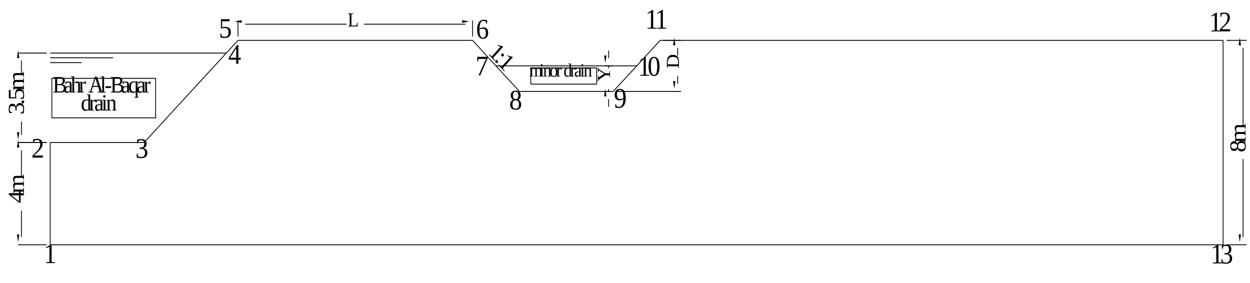


**Figure 3. Schematic diagram of the simulation domain**.

## 2.4 Initial and Boundary Conditions

As the groundwater table lies 1.5 m below soil surface, the water flow initial condition within the flow domain was assumed as a pressure head with its values linearly distributed with depth. Top pressure head value was set equal to -150 cm while the bottom pressure head was assigned equal to 650 cm. As HYDRUS-2D/3D requires assigning boundary conditions, water flow boundary conditions were assumed so as it typically described the condition of the study area. Table 3 shows the water flow boundary conditions used during the present work.

**Table 3. Water boundary conditions at the domain boundaries**

| Boundary | Boundary | Notes |
|---|---|---|
| 1-2 | Constant head | Constant pressure head was assumed equal to 650 cm at the lowest node with equilibrium from the lowest located nodal point |
| 2-3 | Constant head | Constant pressure head was assigned = 350 cm. |
| 3-4 | Constant head | Constant pressure head was assigned = 350 cm with equilibrium from the lowest located nodal point. |
| 4-5 | No flux | |
| 5-6 | Variable flux | The value of the flux was 48.7 cm $y^{-1}$ (i.e., 1.5 liter $d^{-1}$ per $m^2$). This amount is the net value of irrigation water that infiltrate through the soil surface after the evapotransipiration. |
| 6-7 | Seepage face | |
| 7-8 | Constant head | Constant pressure head was assigned = Y with equilibrium from the lowest located nodal point. |
| 8-9 | Constant head | Constant pressure head was assigned = Y. |
| 9-10 | Constant head | Constant pressure head was assigned = Y with equilibrium from the lowest located nodal point. |
| 10-11 | Seepage face | |
| 11-12 | Variable flux | The value of the flux was 48.7 cm $y^{-1}$. |
| 12-13 | Constant head | Constant pressure head was assigned = 650 cm at the lowest node with equilibrium from the lowest located nodal point. |
| 13-1 | Constant head | Constant pressure head was assumed to be 650 cm for all the bottom line 1-13 as the groundwater table lies 1.5 m below soil surface |

Solute transport boundary conditions were described using a third type Cauchy boundary condition along the wetted perimeter of Bahar Al-Baqar drain (i.e., edges 2-3-4) as well as along soil surface (i.e., edges 5- 6 and 11-12) and the solute concentration was assumed equal to unity.

## 2.5 Soil Hydraulic Parameters and Solute Parameters

Numerical solution of water flow and solute transport equations required defining of soil hydraulic parameters as well as solute parameters. Soil hydraulic parameters were calculated using ROSETTA software package coupled with HYDRUS-2D/3D (Schaap et al. 2001). ROSETTA executes pedo-transfer functions that estimate van Genuchten's water retention parameters and the saturated hydraulic conductivity (van Genuchten 1980) from soil textural distribution and bulk density. Table 4 shows soil hydraulic parameters used in the present study.

**Table 4. Soil hydraulic parameters**

| $\theta_r$ | $\theta_s$ | $\alpha$ | n | $K_s$ (cm $y^{-1}$) | $l$ |
|---|---|---|---|---|---|
| 0.1038 | 0.5294 | 0.0183 | 1.3104 | 9245.45 | 0.5 |

$\theta_r$: residual water content, $\theta_s$: saturated water content, $K_s$: saturated hydraulic conductivity , α , n: empirical factors , $l$ : pore connectivity parameter

Solute parameters required for model implementation were longitudinal and transversal dispersivities ($\varepsilon_L$ and $\varepsilon_T$, respectively). The value of $\varepsilon_L$ is depended on the scale of measurements and it ranges from 0.5 cm (e.g., laboratory experiments) to greater than 1 m (e.g., groundwater flows within aquifers; Phogat et al. 2011). $\varepsilon_L$ was set equal to one-tenth of the profile depth (see e.g., Gelhar et al. 1985; Beven et al. 1993; Cote et al. 2001) while $\varepsilon_T$ was set equal to 0.1 $\varepsilon_L$ (Bear 1972). Solute reaction parameters (bonding energy coefficient, η, and adsorption isotherm coefficient, $K_d$) for the simulated heavy metals were assumed according to the results of Usman (2008). In his study, solute reaction parameters were estimated based on the data of batch experiments conducted for the soil type nearly similar to the soil type of the study area of the present work and Langmuir isotherm equation. On the other hand, Molecular diffusion was ignored during simulation. Table 5 shows the values of solute reaction parameters used in the simulation scenarios.

**Table 5. Solute reaction parameters**

| Heavy metal | η ($l$ $mmol^{-1}$) | $K_d$ ($l$ $kg^{-1}$) |
|---|---|---|
| Zn | 18.51 | 193.98 |
| Cd | 16.82 | 14.8 |
| Ni | 6.86 | 27.37 |
| Cu | 3.29 | 100.61 |
| Pb | 25.53 | 345.17 |

It is pertinent to note that although Galerkin finite element method was used to numerically solve the water flow equation, upstream weighting finite element method was used for solving the advection-dispersion equation in order to eliminate numerical oscillation.

## 2.6 Simulation Scenarios

Series of simulation scenarios were conducted including four variable factors; the distance between Bahr ElBaqar drain and the new minor drain (L), Water depth in the minor drain (Y), the total depth of the minor drain (D), and the simulation period (T). Table 6 shows the different scenarios used in the present work. It is worth mentioning that additional simulation scenarios were carried out without the suggested drain to investigate and compare its effect on the surrounding environment for simulation periods of 20 and 50 year.

**Table 6. Simulation scenarios**

| Scenario no. | L | D | Y | T |
|---|---|---|---|---|
| 1 | 10 | 2 | 0 | 20 |
| 2 | 10 | 2 | 1 | 20 |
| 3 | 10 | 4 | 0 | 20 |
| 4 | 10 | 4 | 2 | 20 |
| 5 | 10 | 2 | 0 | 50 |
| 6 | 10 | 2 | 1 | 50 |
| 7 | 10 | 4 | 0 | 50 |
| 8 | 10 | 4 | 2 | 50 |
| 9 | 20 | 2 | 0 | 20 |
| 10 | 20 | 2 | 1 | 20 |
| 11 | 20 | 4 | 0 | 20 |
| 12 | 20 | 4 | 2 | 20 |
| 13 | 20 | 2 | 0 | 50 |
| 14 | 20 | 2 | 1 | 50 |
| 15 | 20 | 4 | 0 | 50 |
| 16 | 20 | 4 | 2 | 50 |

## 3 RESULTS AND DISCUSSION

This section is divided into two mean parts. The first part, we will try to compare the model results with the available field results in Salem et al.(2012) in order to validate the model. The second part we will use the model results for comparison of three different aspects. The first one is the effect of downward infiltration of polluted water as compared with seepage effect from polluted drain on the soil adjacent to the drain. The second aspect is the effects of the minor drain parallel to the polluted major drain on the reduction of pollutants in soil. The results will be compared with the field results and conclusions achieved by Salem et al.(2012).

The initial concentrations of all heavy metals in soil were set to zero in the model and one in the polluted water. However, from Fig (1) in Salem et al.(2012) we find that moor land which represent the natural case of soil contains some heavy metals concentrations. Moreover, in land subjected to fill from the bottom of the Bahr Elbaqar drain we find that the soil contains high level of heavy metals concentrations. From personal contact to the authorities and land owners, we found that most of the lands located in both sides of the drain were subjected to fill from the drain in way or another. Consequently, it is more logic to use those high levels of heavy metals in case of fill land as an initial conditions for the heavy metals in soil. From Table (1) (Hamed et al 2013) the mean concentration values of Cu, Pb and Zn in drain water per year are 0.07,0.16 and 0.47 respectively. These values are considered the true initial values of the metals for the recent decades.

If we use the high levels of concentration of the fill soil as initial values in the soil the model will fit well with the results for pb and cu in both lands irrigated with polluted drain and lands of fish farms using polluted drain water. From Fig (1) if we subtract the mean value of cu concentration for fish farms and land using polluted drain water from mean value of cu in fill land we will get a value of 0.15. If we divide this value on the mean initial value which is 0.18 we will get the value of 83% which is the ratio of cu in soil divided on the initial value of cu in water. From Fig (4) at depth 1 m the mean value of cu is around 0.75. if we divide this value on the initial value of cu concentration in water we will get the ratio 75%.

From Fig (1) if we subtract the mean value of Pb concentration for fish farms and land using polluted drain water from mean value of Pb in fill land we will get a value of 0.25. If we divide this value on the mean initial value which is 0.749 we will get the value of 33% which is the ratio of cu in soil divided on the initial value of cu in water.

From Fig (4) at depth 1 m the mean value of Pb is around 36%. if we divide this value on the initial value of Pb concentration in water we will get the ratio 0.36.

Fig (5) compares a scenario of 50 years simulation of infiltration with polluted water with a scenario of infiltration of fresh water for 10 years after 50 years of infiltration with polluted water. If we compare the results of the concentrations of both of Zn and Cd for the model and the field results for lands cultivated with El salam canal (fresh water) after using polluted water in Fig (1), we will find a good match. The concentration of Zn in Fig (5) is around 0.12 while it is almost zero in fig (1). For Cd, the concentration in field experiment in fig (1) is around 0.1 while at depth 1 m from the surface in Fig (5), it is around 0.12. The figure confirms that a methodology of adding fresh water for irrigation or breeding fish for a certain time after many years of using polluted water may be viable. In spite of the low permeability of the soil, adding fresh water was a successful scenario for reduction pollution in a relatively not long time.

Fig.4 shows a comparison between the effect of seepage from the drain and the effect of downwards infiltration for 20 and 50 years simulations. The figure shows prediction of concentration of two main heavy metals Cu and Pb,. It shows that downward infiltration of polluted water is the dominant factor and more important than the seepage from the polluted drain which has limited effect. This is probably due to the low soil permeability and the extensive usage of polluted water for irrigation and fish farms (downward infiltration). The figure shows that seepage from the polluted drain through low permeable soil has a low environmental risk to the adjacent soil.

Fig. (6) shows the effect of the minor drain with different overall depths (scenario (1) D = 2 m, scenario (2) D = 4m) for 50 year simulation. In general, the figure shows that the effect of the minor drain for reducing pollution is limited. However, due to its near location to the polluted drain, it contributes to reduce pollution from seepage from the polluted drain especially in case of Cd and Ni. Reduction in pollution is higher for the deeper drain.

Fig. (7) studies the effect of the minor drain with different overall depths and no polluted water (drainage water coming from fresh irrigation water) ( Scenario (1) D = 2 m , Y=1m Scenario (2) D = 4m, Y= 2m) for 50 year simulation. These scenarios represent a minor drain with clean drainage water infiltrating in to polluted soils. As shown from the figures, the reduction in pollution is higher in this case especially in the part adjacent to the polluted drain. However, the effect is still limited to the area near to the minor drain. Again, reduction in pollution is higher for the deeper drain.

Fig. (8) shows the effect of distance between the minor and the polluted large drain (Scenario (7) (L = 10 m), Scenario (15) (L = 20 m). Since the seepage effect is not dominant here and has a limited transport distance, minor drain distance from the polluted drain has a negligible effect on the pollutants reduction especially in long distance (more than 20m). However, a minor drain located at 10 m distance from the polluted drain contributes to more seepage reduction. For a distance of 20 m, the effect of pollution reduction is only limited to the area near the minor drain at both its sides.

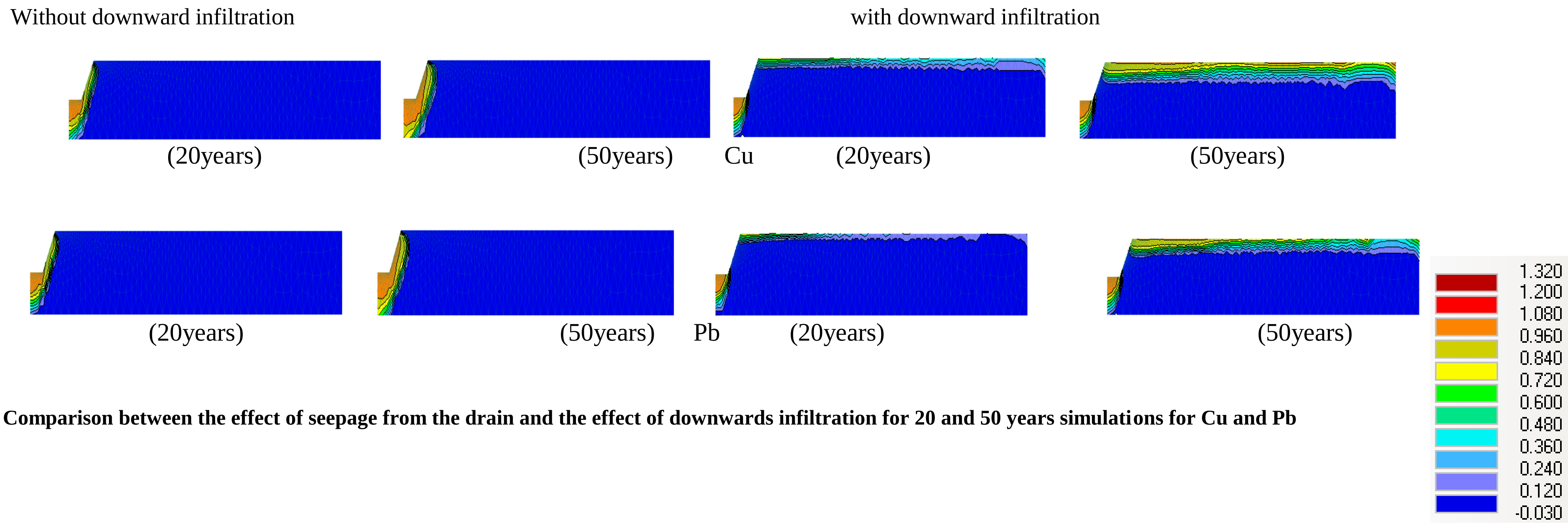


**Fig4. Comparison between the effect of seepage from the drain and the effect of downwards infiltration for 20 and 50 years simulations for Cu and Pb**

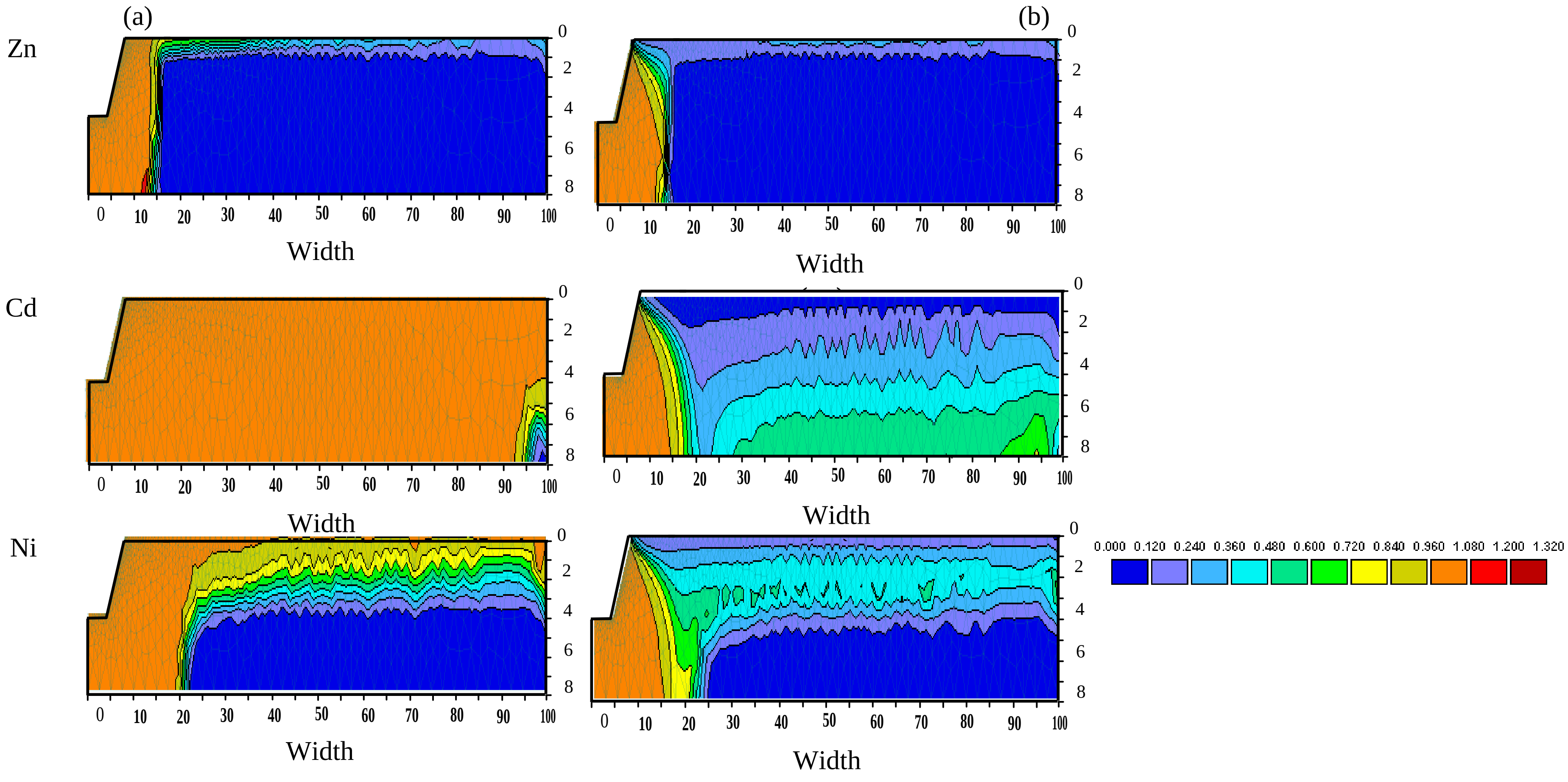


**Fig 5.Comparison between (a) 50 years of polluted downward infiltration and (b) 60 years ( 50 years of polluted downward infiltration and the next 10 years with fresh water downward infiltration)**

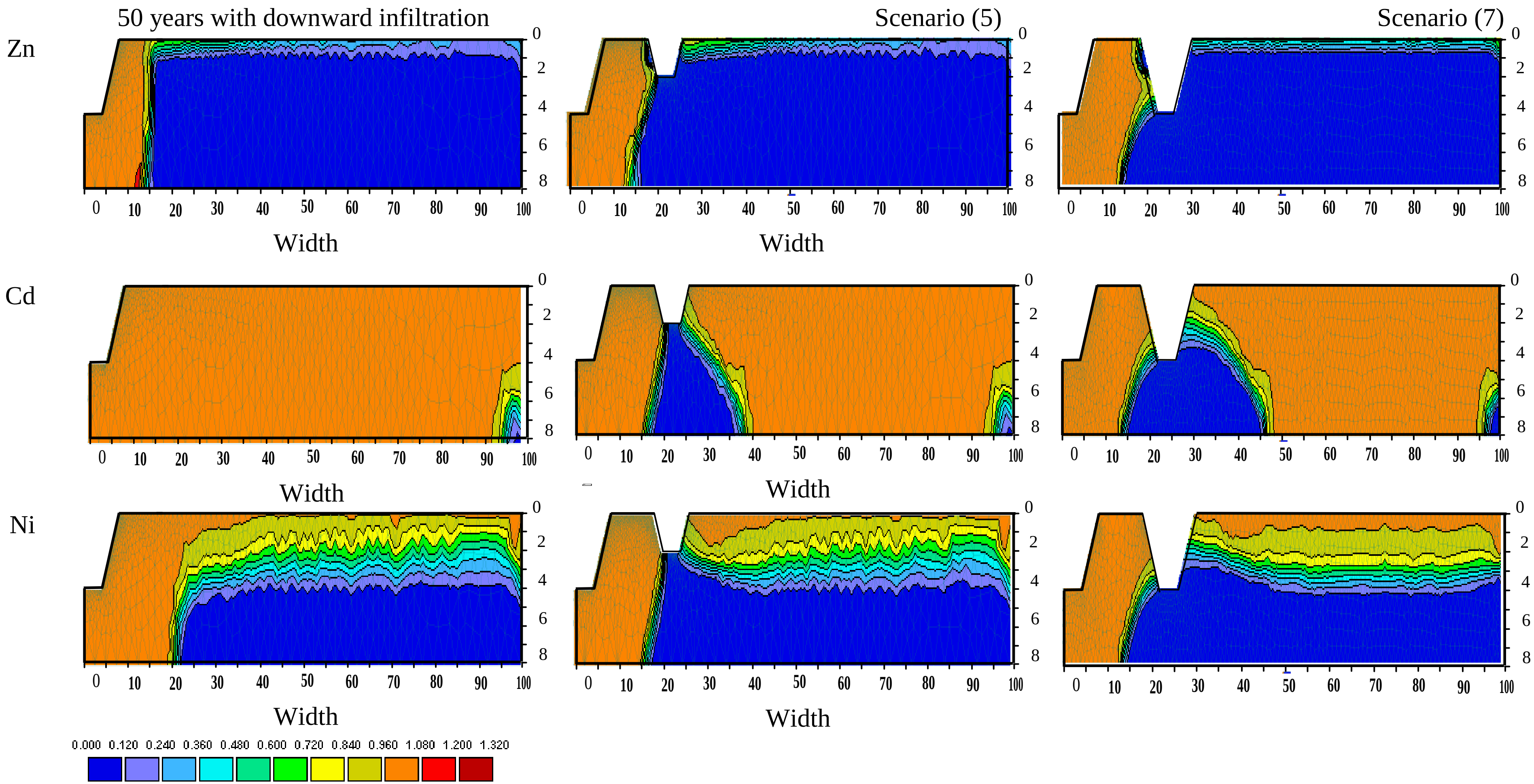


**Fig 6.Effect of 10 m distance minor drain with different overall depth ( Scenario (1) D = 2 m , Scenario (2) D = 4m) for 50 years simulation**

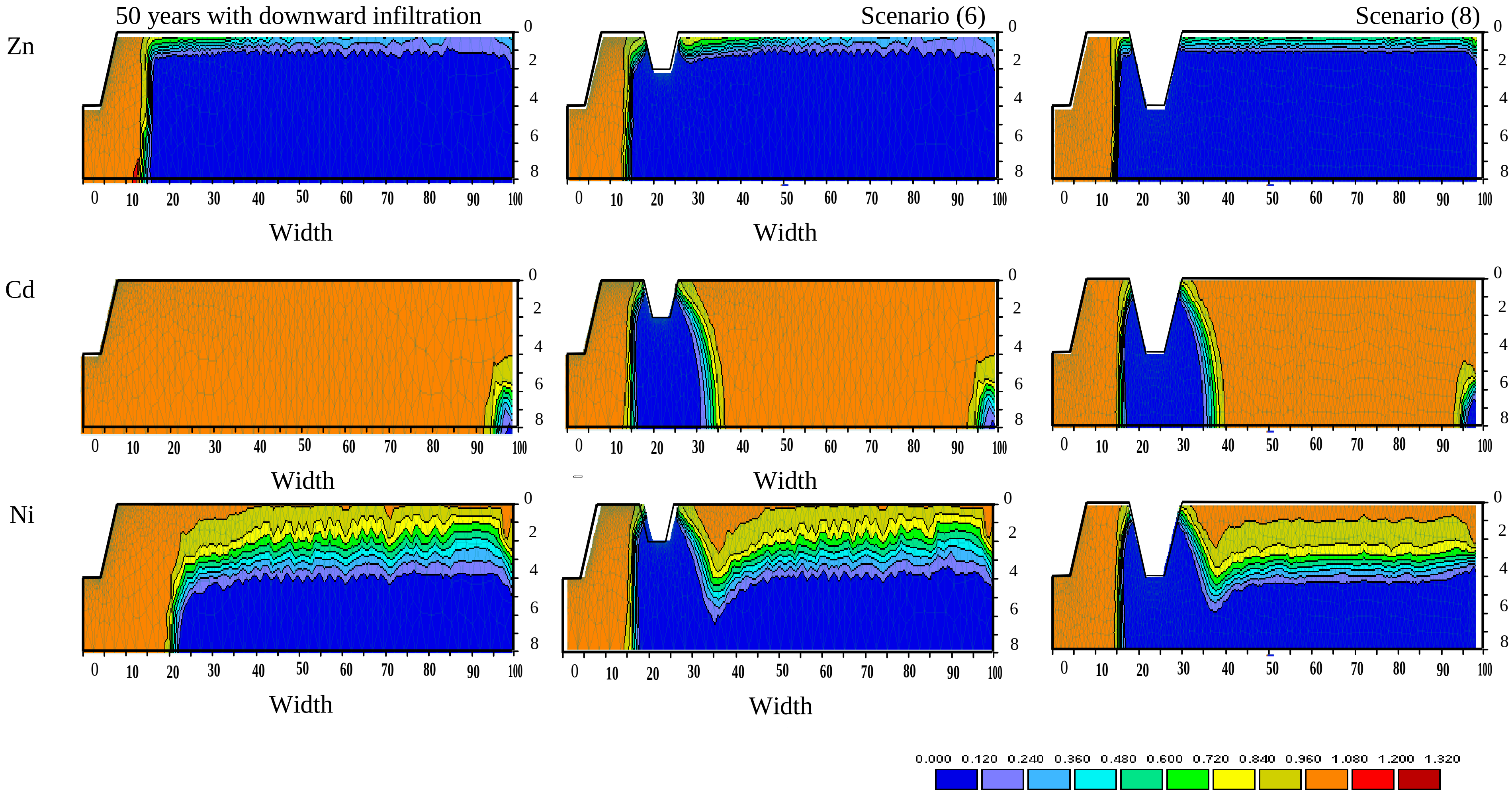


**Fig 7.Effect of 10 m distance minor drain with different overall depth and water inside ( Scenario (1) D = 2 m , Y=1m Scenario (2) D = 4m, Y= 2m) for 50 years simulation**

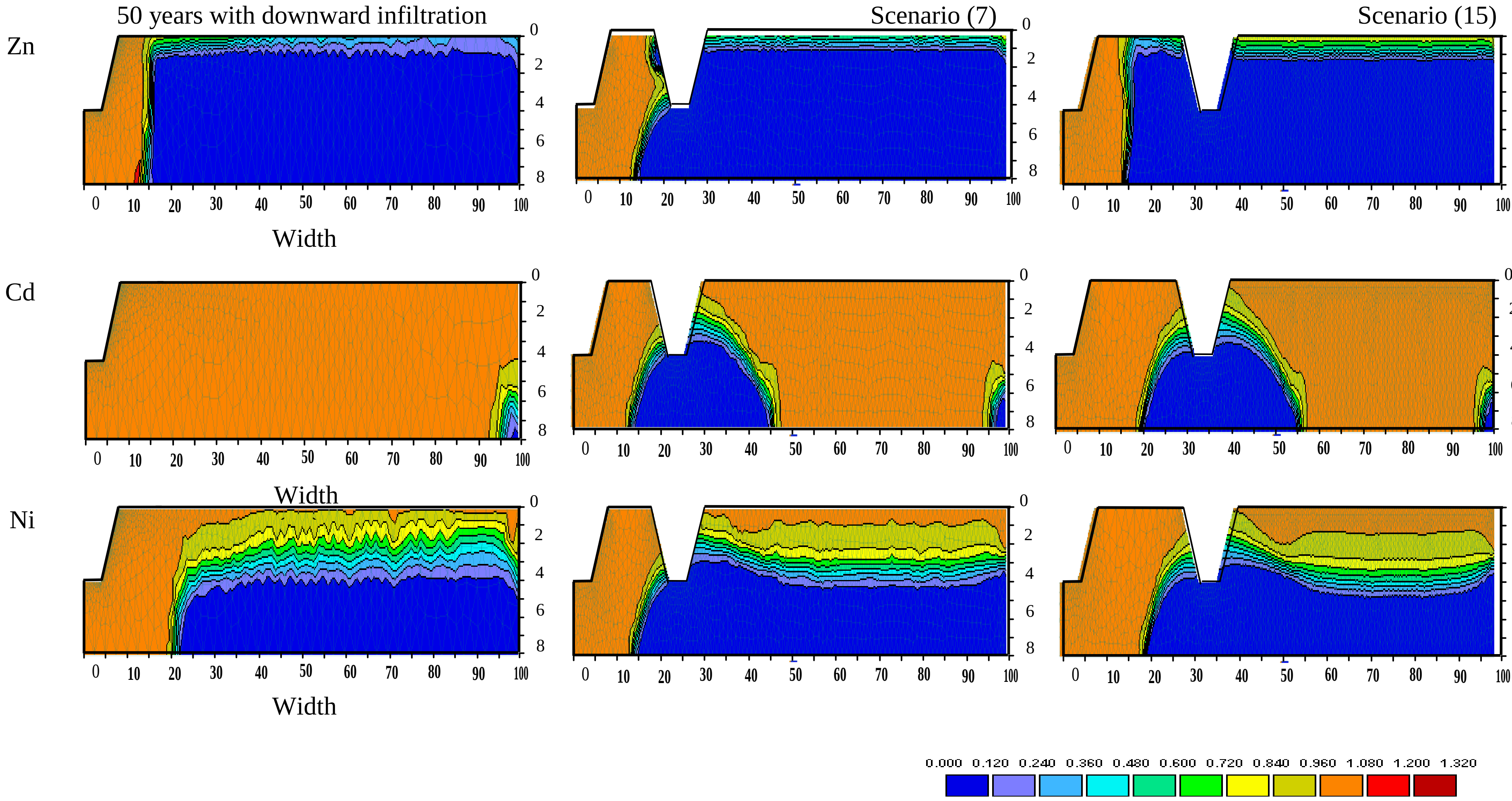


**Fig 8. Effect of distance between minor drain and the polluted drain (Scenario (7) (L = 10 m), Scenario (15) (L = 20 m)**

## 4 SUMMARY AND CONCULSION

Transport of five main heavy metals was simulated using a numerical model (Hydrus-2D). Downward infiltration and seepage from a heavily polluted drain was simulated using Hydrus model. The area is located in the end of polluted drain (Bahr El Baqar drain) northeast of Egypt. Possible future heavy metal impact on soil in the area were simulated. Comparison between the effect of downward infiltration from polluted irrigation water and seepage from the polluted drain was evaluated. Effects of a minor drain parallel to the polluted drain as a potential pollution reduction was studied. Also, using fresh water for irrigation on polluted soil was investigated.

In general, results confirm the results and recommendations achieved by previous field work done by Salem et al.(2012) in Hamed et al 2011. Results showed that the future heavy metals impacts on soil could be serious. Soil pollution will extend deeper if the use of polluted water for irrigation will be continued. The effect of downward infiltration of polluted irrigation/fish raising water is the dominant factor of the soil pollution. Pollution as a result of seepage coming from the polluted drain is limited due to the low soil permeability.

Creating a deeper minor drain parallel to the major polluted drain at close distance (10m) will contribute to reduce pollution coming from the polluted drain. However, its effect will be limited in case of using polluted water for irrigation or breeding fish.

An alternative to use clean freshwater reduces the pollution problem in the low permeability soil. However, cultivating crops and raising fish should be avoided until the soil has completely recovered from pollution which could take about 10 years.

Results show also a prediction of the heavy metals impacts.in the area after 20, 50 years of using polluted water for irrigation or raising fish. The results give warning to the local authorities in order to act rapidly to reduce or control the environmental pollution hazardous.

## 5 REFERENCES

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