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ARAŞTIRMA MAKALESİ /**RESEARCH ARTICLE**

EXPERIMENTAL STUDY OF GROUNDWATER CONTAMINANT TRANSPORT AND DETERMINATION OF LONGITUDINAL DISPERSIVITY

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ABSTRACT

Groundwater is the safest and most important source of available freshwater. However, it is threatened by pollution arising from various activities. In this study the contaminant transport in homogeneous medium is investigated by means of an experimental set-up designed for the hydrologic cycle available in Hydraulics Laboratory. The experiments are carried out in the physical aquifer chamber 2 m long, 1 m wide and 0.10 m high. The piezometer tubes and observation wells are placed at the bottom of the chamber longitudinally and transversally. NaCl solution which represents contaminant is injected from a well instantaneously, as a point source. Electrical Conductivity (EC) values of the water are measured by using probes placed in the observation wells. Measurements are taken at specific time interval. The NaCl concentrations of the samples are determined indirectly by converting these measured EC values to concentration values by means of the calibration curve generated at the beginning of the experiments. Consequently, the longitudinal dispersivity of the porous medium was determined by solving the one dimensional advective-dispersive equation.

Anahtar Kelimeler: Groundwater, Contamination transport, Longitudinal dispersivity

YERALTUSUYU KİRLİLİK TAŞINIM DENEYİ VE BOYUNA DİSPERSİVİTE DEĞERİNİN BELİRLENMESİ

ÖZ

Tatlı su kaymakları arasında yeraltısuyu en güvenilir ve en önemli kaynaktır. Ancak bu kaynaklar kirlilik tehdidiyle karşı karşıyadır. Bu çalışmada, Hidrolik laboratuarında mevcut olan Hidrolojik çevrim deney düzeneği kullanılarak homojen ortamda yeraltısuyu kirlilik taşınımı deneysel olarak incelenmiştir. Akiferin boyutları 2 m uzunluğunda, 1 m genişliğinde ve 0.10 m yüksekliğindedir. Piyezometre tüpleri ve gözlem kuyuları akiferde boyuna ve enine yönde yerleştirilmiştir. NaCl solüsyonu noktasal kirlilik kaynağı olacak şekilde bir kuyudan akifere verilmiştir. Suyun elektriksel iletkenlik değerleri gözlem kuyularından elektriksel iletkenlik probları kullanılarak ölçülmüştür. Ölçümler belirli aralıklarla gerçekleştirilmiştir. Ölçülen elektriksel iletkenlik değerleri deney başında çıkarılan kalibrasyon eğrisi yardımıyla NaCl konsantrasyonlarına dönüştürülmüştür. Sonuç olarak, gözenekli ortamın boyuna dispersivite değeri bir boyutlu adveksiyon-dispersiyon denklemi çözülerek elde edilmiştir.

Keyword. Yeraltısuyu, Kirlilik taşınımı, Boyuna dispersivite

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1. INTRODUCTION

Groundwater is the most important source of freshwater available in our planet. Nowadays it is mostly polluted because of the human activities. Therefore understanding the contamination process is really important in order to take required precautions. There are lots of investigations in the literature and some selected ones are mentioned above.

Huang et al. (1995) conducted laboratory tracer experiments to determine the dispersivity value. A channel 12.5 m long, 10 cm wide and 10 cm high was constructed for this purpose. Medium-textured sand was packed uniformly as practical as possible in the channel. NaCl solution of concentration C_0=6 g/l was injected into the sandy soil column and concentrations are estimated by electrical conductivity probes inserted at 100 cm intervals. According to experimental results, dispersivity values ranged from 0.1 to 5.0 cm.

Kim et al. (2002) investigated longitudinal dispersivity in a sandy aquifer at laboratory scale. The length, width and height of the model were 200, 50, and 150 cm, respectively. They estimated longitudinal dispersivities from the well-tracer tests as 9.5 and 13.5 cm, depending on the travel distance.

Aksoy and Guney (2010) investigated longitudinal, transversal and vertical dispersivities in homogeneous 3–5 mm sandy aquifer. The experiments were carried out in a channel 12-m long, 1.35-m wide and 0.60-m high which was built in the Hydraulics Laboratory of Civil Engineering Department in Dokuz Eylül University. NaCl was used as a tracer and conductivity values were measured at 220 measurement points. They obtained for α_x = 12 cm, α_y / α_x = 0.2 and $\alpha z / \alpha_x$ = 0.05.

2. EXPERIMENTAL METHODS

2.1 Experimental Set-Up and Measument Technique

The container of the hydrologic cycle set-up available in the Hydraulics Laboratory of Civil Engineering Department in Dokuz Eylül University is used to investigate the contaminant transport. The physical aquifer chamber is 2 m long, 1 m wide and 0.10 m high.

The homogeneous porous medium constituted with medium texture sand has a thickness of 10 cm. Two reservoirs with adjustable level reservoirs are located at upstream and downstream part of the chamber. Plan view and longitudinal section of the chamber are shown in Figures 1 and 2. The groundwater levels were measured by 20 piezometer tubes. 19 perforated tubes were located into the aquifer to measure the EC values. The hydraulic conductivity of the porous material was found as 4.9 cm/sec from application of the Darcy Law in the aquifer chamber.

NaCl solution was used as tracer to determine the concentration distribution in the aquifer chamber. The measurements were carried out at 19 points indicated in Figure 1. The electrical conductivities were read from the perforated tubes by using an EC probe. These conductivity values were converted to concentration values by means of the calibration curve generated prior to experiments. This calibration curve is given in Figure 3.

2.2 Tracer Experiment

In the aquifer the steady-state flow condition was generated by adjusting constant water levels at upstream and downstream reservoirs, with a level difference of 0.9 cm. The average linear velocity of groundwater flow was 0.0247 cm/s during experiment. Subsequently, NaCl solution was injected into the aquifer for 104 minutes with a concentration of 15 g/l through the injection point located on the chamber axis. The NaCl concentration in the injection point was continuously measured during the injection process.

EC measurements were taken from perforated tubes at specific time interval and they converted to concentration values by using the calibration curve.

3. RESULTS

During the previous experiments it was observed that the concentration distribution is almost symmetrical along the y direction. Therefore the values corresponding to the half of the chamber are considered. (the points on the lines 1,2 and 3). The maximum concentration was observed at point 1-3 which is located just in front of the injection well. It decreases along the longitudinal direction as expected. Figure 4 illustrates the variation of the concentration in the form of breakthrough curves at some measurement points in the longitudinal direction along the axis.

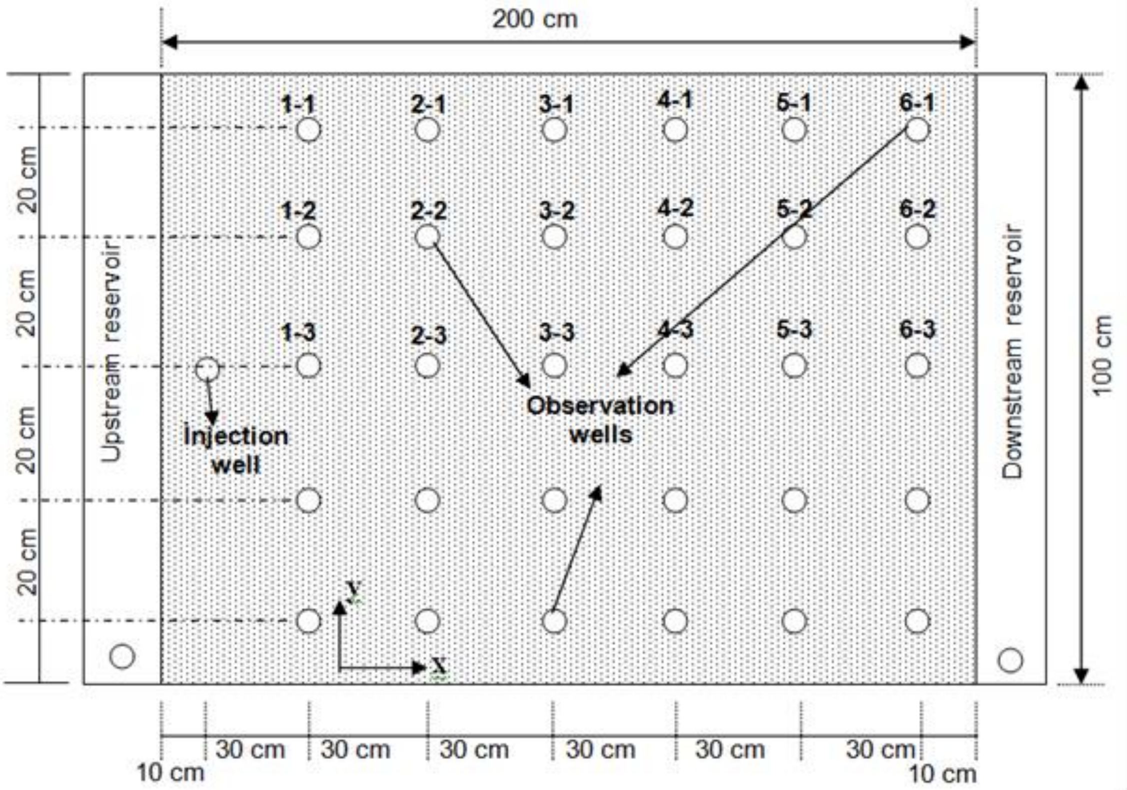

Figure 1. Plan view of the experimental set-up with location and number of the wells

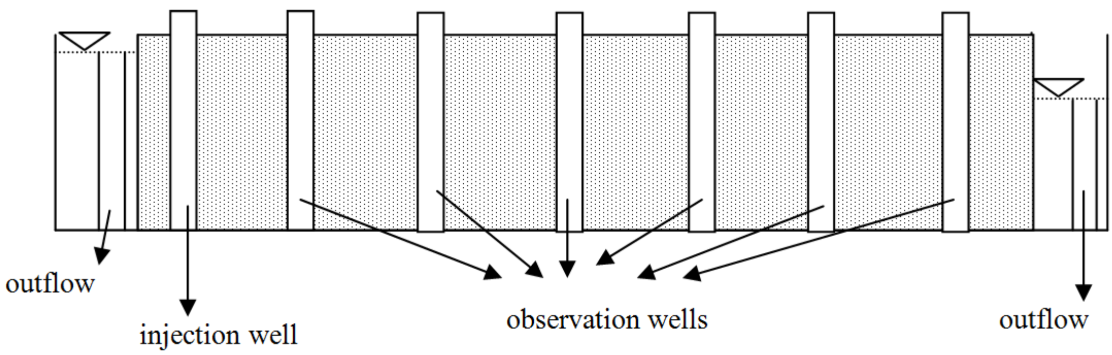

Figure 2. Longitudinal section of the experimental set-up

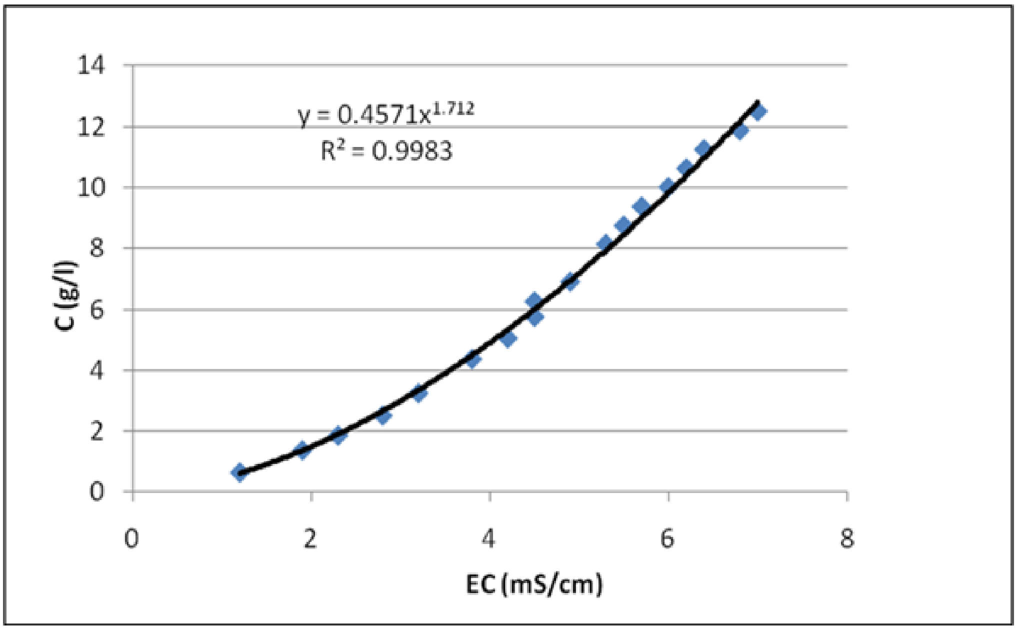

Figure 3. Calibration curve (Concentration versus electrical conductivity)

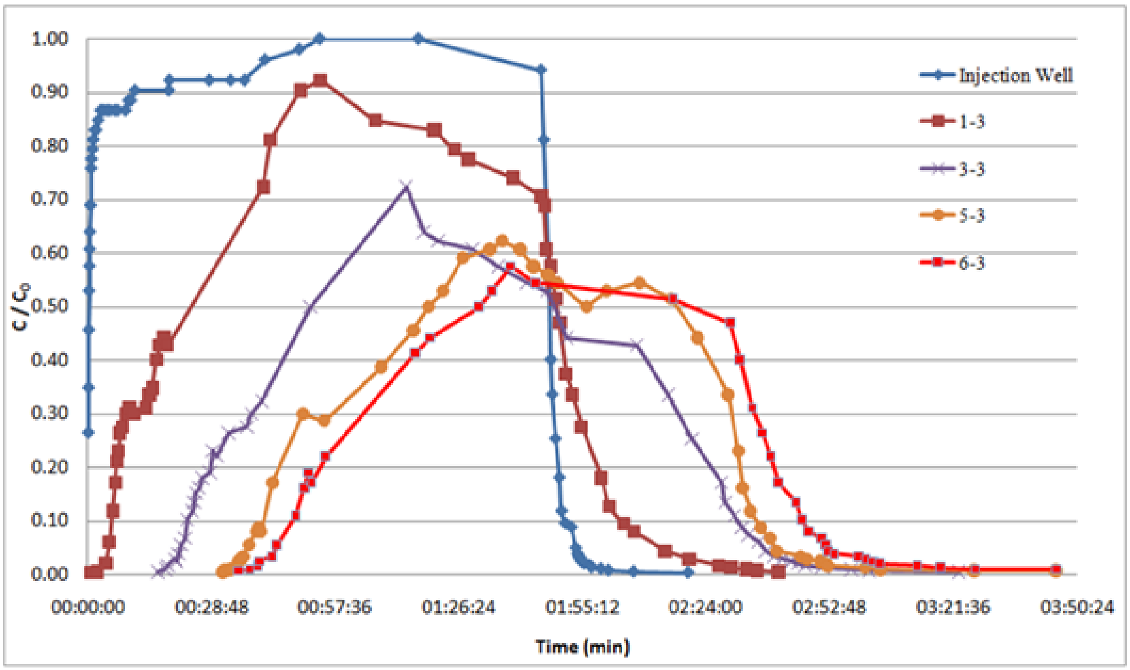

Figure 4. Breakthrough curves in longitudinal direction along the axis

Figure 5 illustrates the breakthrough curves in longitudinal direction for points 20 cm apart from the axis. Maximum concentration was observed at point 6-2 implying that the dispersion attains its highest value at the farthest point

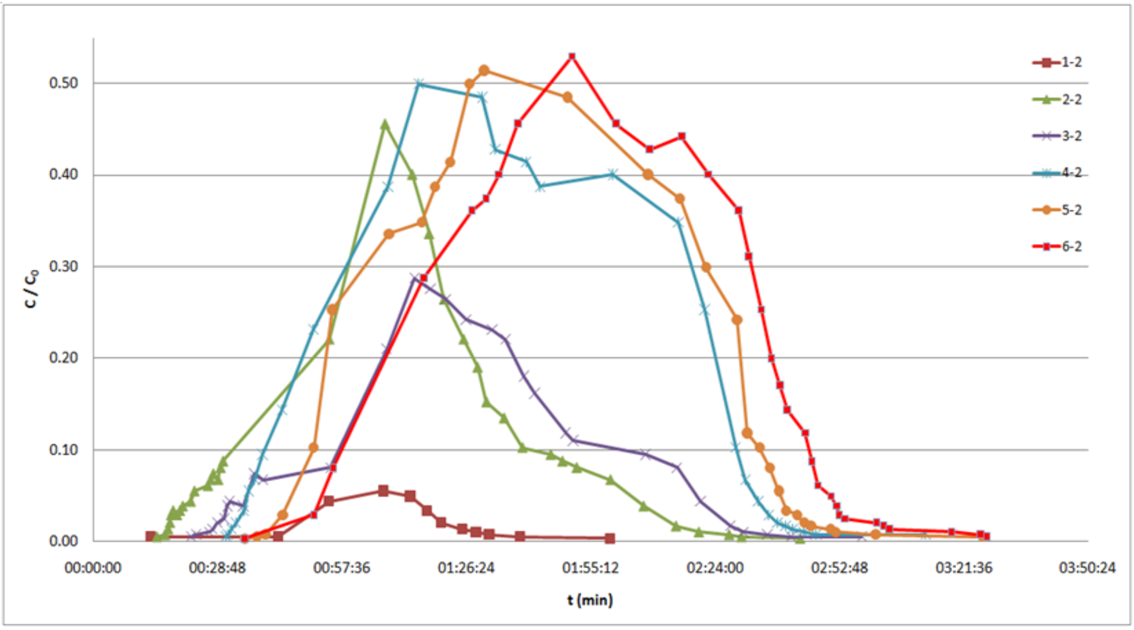

Figure 5. Breakthrough curves in longitudinal direction along the line 2-2

Figure 6 illustrate the breakthrough curves in the last transversal direction. Concentration values are higher at points close to the axis. The tracer arrives at points near the side much later and with small amplitude.

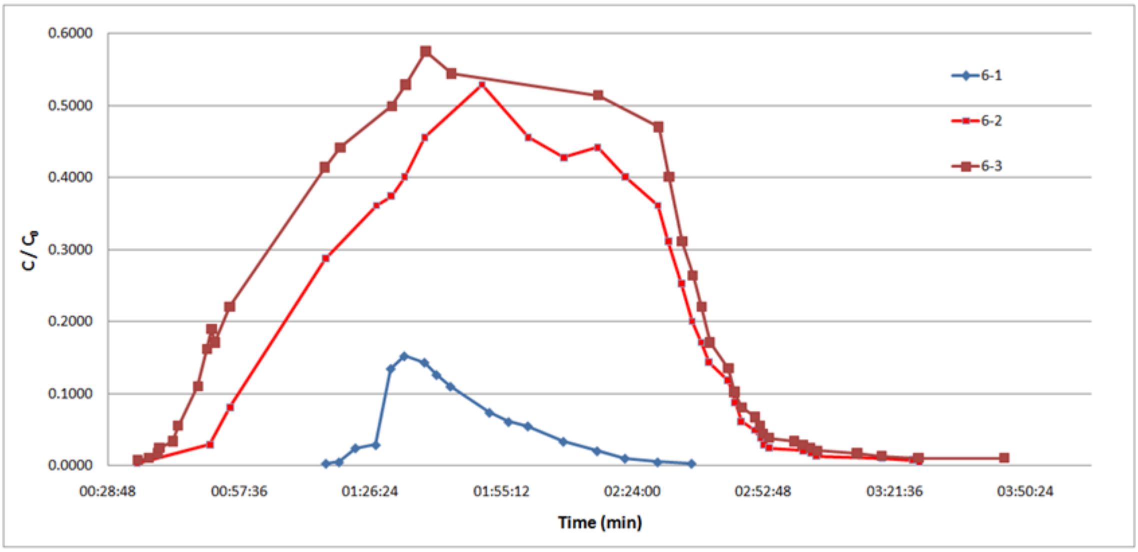

Figure 6 Breakthrough curves in transversal direction

The maximum concentrations and their arrival time to the points on the lines are given in Figure 7 and 8, respectively. The concentration values along the line 1-3 are higher than those along the line 1-2 especially nearest points to the injection well as expected. It is also seen that maximum values decrease along the line 1-3 but these values increase along the line 1-2.

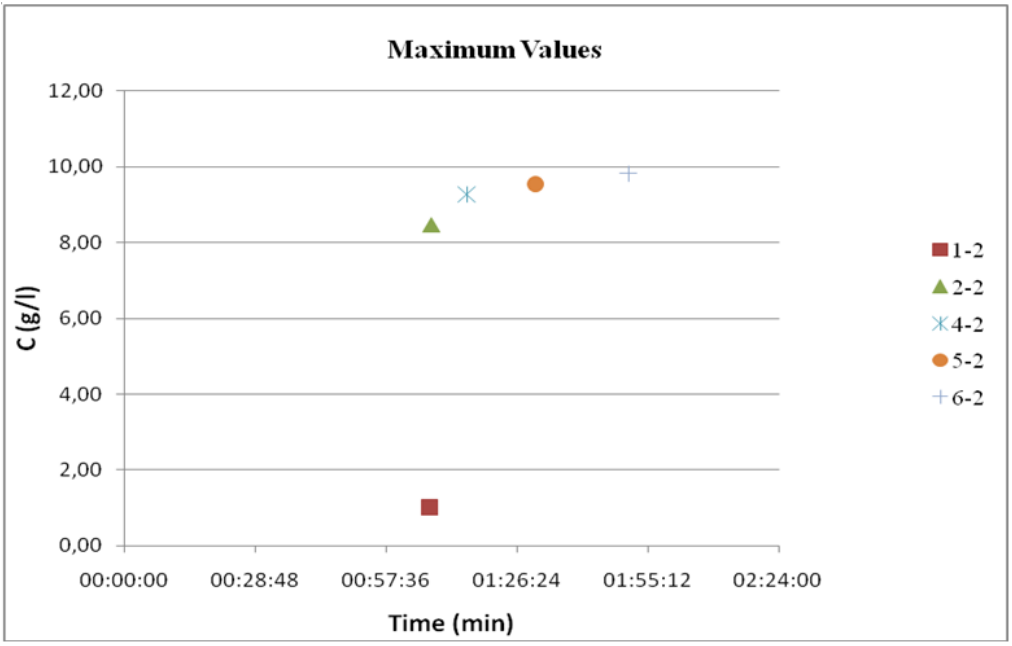

Figure 7. Maximum concentrations and their arrival time for the points on the line 1-2

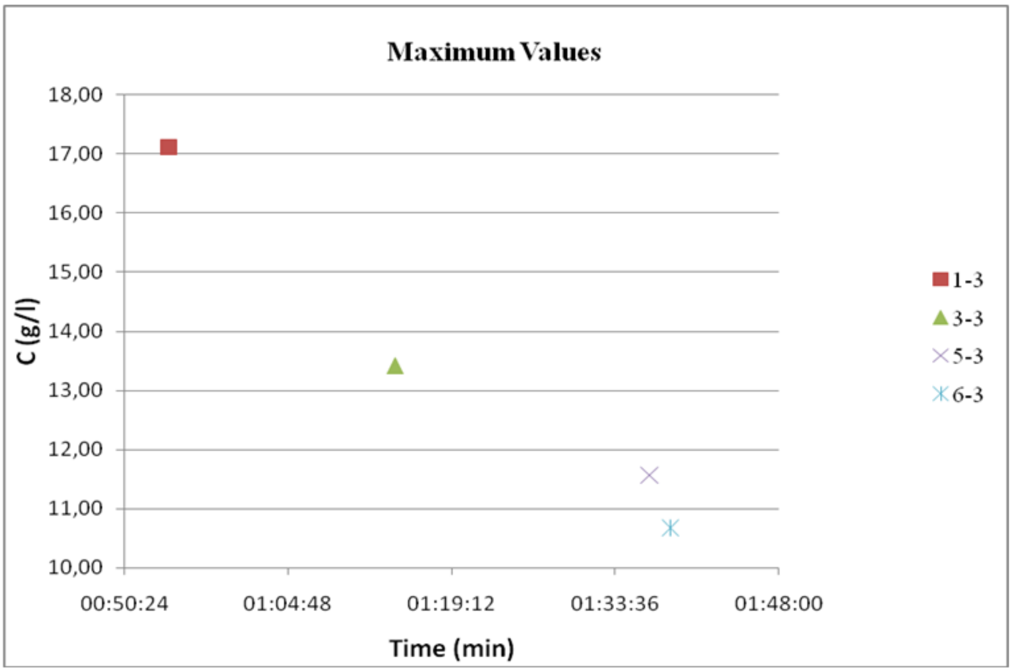

Figure 8. Maximum concentrations and their arrival time for the points on the line 1-3

Figure 9 illustrates the travel times of the contaminant along the axis. The contaminant arrived at downstream part of the chamber approximately 33 minutes after its injection.

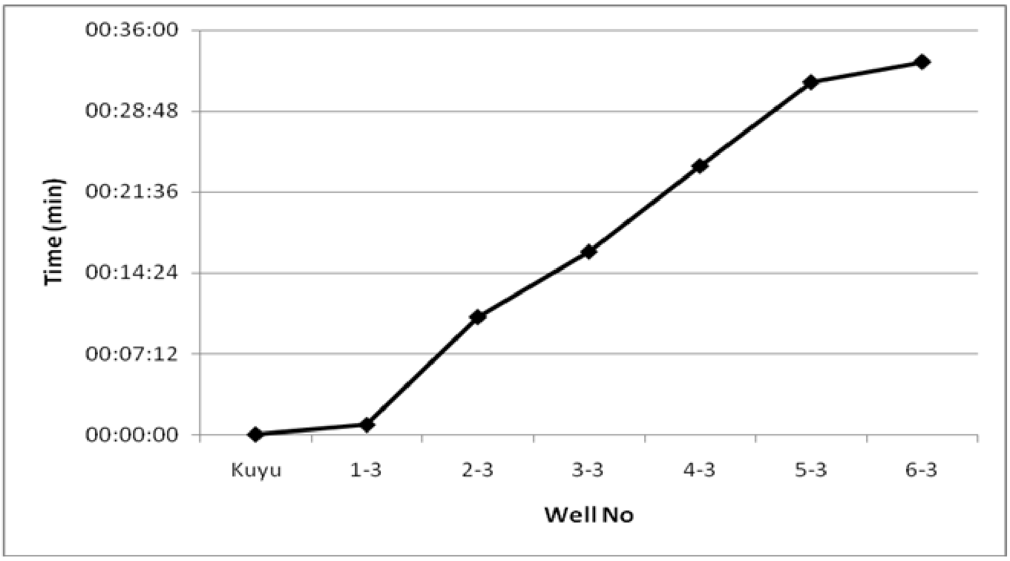

Figure 9. Travel times of the tracer along the axis (line 1-3)

The distribution of the concentration 55 minutes and 105 minutes after the injection are given in Figure 10 and 11, respectively.

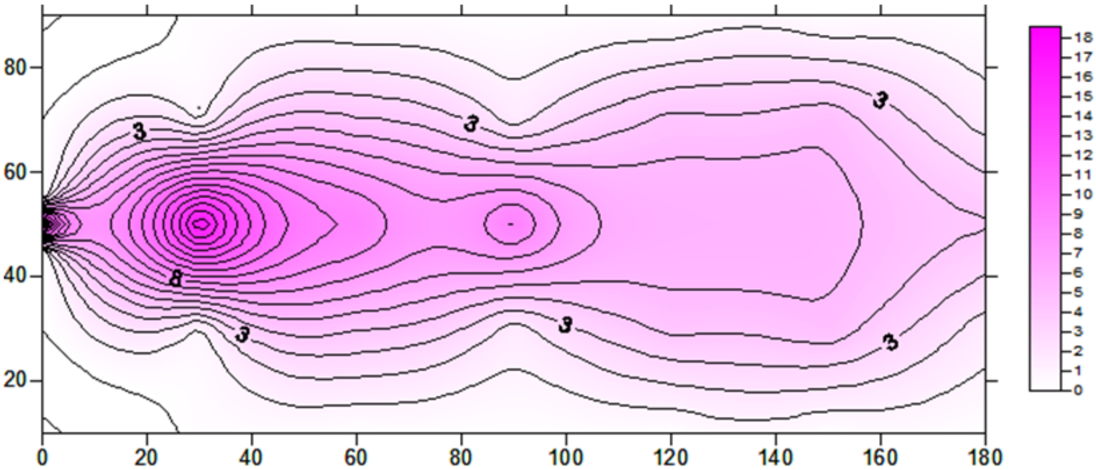

Figure 10. Concentration distribution 55 minutes after the injection

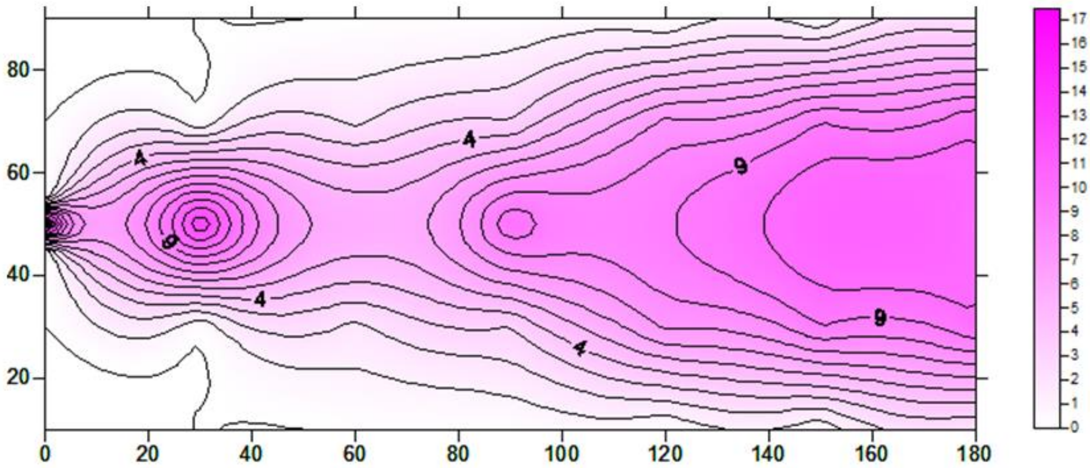

Figure 11. Concentration distribution 105 minutes after the injection

The leave times of the tracer are given in Figure 12 for longitudinal direction. The line is almost linear.

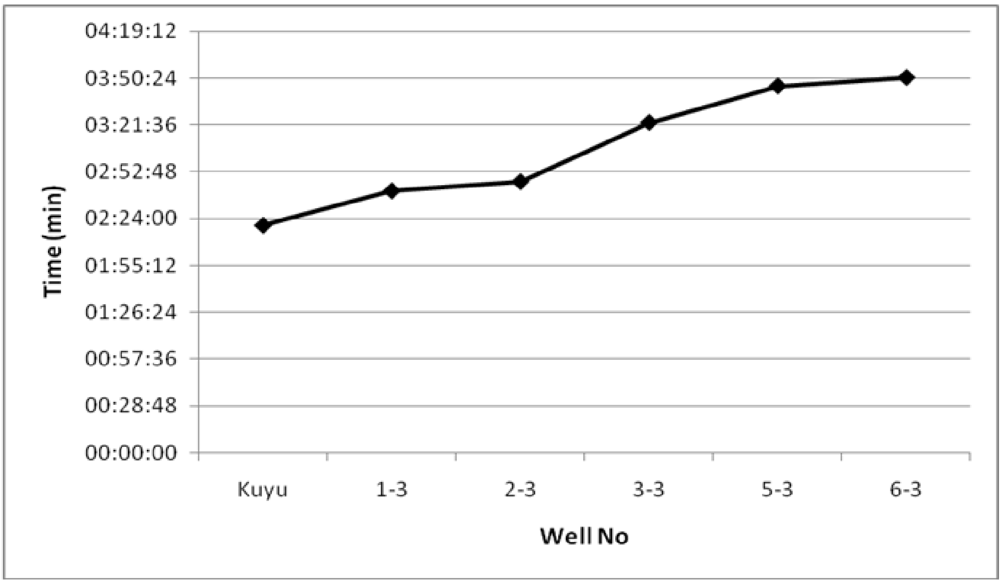

Figure 12. Leave times of the tracer

4. DETERMINATION OF THE LONGITUDINAL DISPERSIVITY

In one dimension, the advective-dispersive equation is given as (Bedient et al.1994):

$$D_X \frac{\partial^2 C}{\partial x^2} - v_X \frac{\partial C}{\partial x} = \frac{\partial C}{\partial t} \quad (1)$$

$$D_X = \alpha_X v_X$$

where D_x is the coefficient of hydrodynamic dispersion in longitudinal direction, v_x is the average seepage velocity, C is the concentration, α_x is the dispersivity in longitudinal direction.

The average longitudinal dispersivity value was computed as 9.29 cm by solving equation 1 with finite differences method.

5. CONCLUSION

In this study, the contaminant transport in a physical aquifer chamber was studied experimentally. NaCl solution with a concentration of 15 g/l was injected in the porous medium as a tracer. EC values of the water were measured at observation wells and then they converted to the concentration values by using the calibration curve. The duration of the experiment was approximately 225 minutes. Concentration distributions in the chamber versus time were obtained. These values were used to determine the dispersivity value of the porous medium. The dispersivity parameter was obtained as 9.29 cm by solving the advective-dispersive equation with finite differences method. This value is compatible with those given in the literature (Huang et al, 1995; Kim et al, 2004 and Aksoy and Guney, 2010).

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