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Comparison of Soil Saturated Hydraulic Conductivity under Inverse Auger Hole and Shallow Well Pump Methods

Motalleb Byzedi[1], Maaroof Siosemarde[*2]

Dept. of Water Engineering, Sanandaj Branch, Islamic Azad University, Sanandaj, Iran
Dept. of Water Engineering, Mahabad Branch, Islamic Azad University, Mahabad, Iran

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ABSTRACT

Hydraulic conductivity is one of the most important soil hydrodynamic Characteristics that is required to evaluate of groundwater flow and drainage studies and calculate of subsurface drainage spacing. The main objective of this study was to compare the saturated hydraulic conductivity measured using Inversed Auger Hole and Shallow Well Pump in Test Methods and also Determine the relationship between hydraulic conductivity obtained from these two methods are based on mathematical models (Linear, logarithmic, inverse, quadratic, cubic, compound, power, S, growth and exponential) have been compared. Shallow Well Pump in Test Method due to practical constraints, is less used. The measuring of hydraulic conductivity in Inversed Auger Hole method carrying out with a shorter period of time compared to Shallow Well Pump in Test Method. This method is currently the most commonly used methods. In this research, 30 wells were drilled at area of 2000 hectares of Saghez region to determine the saturated hydraulic conductivity. Inversed Auger Hole method was conducted for three consecutive times and then carried out Shallow Well Pump in Test Method. Results showed that mean saturated hydraulic conductivity of Inversed Auger Hole method was 87% greater than the Shallow Well Pump in Test Method. Also, the results showed that cubic model to estimation of saturated hydraulic conductivity of Shallow Well Pump in Test Method based on Inversed Auger Hole method was the best model with 0.863 correlation coefficient and 0.256 Root mean square error (RMSE). It was found that the inverse model was the worst model.

KEYWORDS: ***hydraulic conductivity, Inversed Auger Hole and Shallow Well Pump in Test Method***

I. INTRODUCTION

The saturated hydraulic conductivity of soil is a measurement parameter of the soil's ability to transmit water when submitted to a hydraulic gradient that is defined by Darcy's law. [1&2]. Saturated hydraulic conductivity of soil is difficult to measure and can be highly variable, Field observations show that the hydraulic properties of soils vary significantly with spatial location even within a given soil type [3&4]. Variability in the hydraulic properties of soil units has been studied by several researchers [3, 5&6].

Methodsfor determining hydraulic conductivity generally are divided into two categories (field and laboratory methods). Based on the measurement of water flow below the water table or above be done, methods for determining hydraulic conductivity will be different. Inversed Auger Hole (IAH) and Shallow Well Pump in Test (SWPT), including methods to measure hydraulic conductivity above the water table. SWPT method to practical limitations, are less frequently used. The IAH method for measuring hydraulic conductivity coefficient can be done with less time than the SWPT method. Despite the high accuracy of the SWPT method, the disadvantage of this technique is the high operating costs. The main objective of this study was to compare the saturated hydraulic conductivity measured using Inversed Auger Hole and Shallow Well Pump in Test Methods and also Determine the relationship between hydraulic conductivity obtained from these two methods are based on mathematical models (Linear, logarithmic, inverse, quadratic, cubic, compound, power, S, growth and exponential) have been compared.

Oosterbaan and Nijland (1994) concluded that the hydraulic conductivity values in Inversed Auger Hole Method are lower than the Shallow Well Pump in Test Method [7]. Gribb et al. (2004) compared Auger Hole and falling head methods in order to determine saturated hydraulic conductivity and concluded that the Auger Hole method contained higher values [8]. Carpena et al. (2002) concluded that the coefficient of variation in laboratory methods is higher than the field methods, Field methods because more soil volume, the more heterogeneous, thus, the standard deviation and coefficient of variation less [9]. Li et al. (2009) concluded that the saturated hydraulic conductivity in field methods is higher than the laboratory methods [10].

In areas where groundwater levels are low, methods such as Guelph permeameter, Inversed Auger Hole and Shallow Well Pump in Test Methods are used [11-15], among these methods; SWPT method has a high accuracy. Based this approach, is to maintain a constant water level in the hole and to measure the influencing water content from hole around. The disadvantages of

*** Corresponding Author:** Maaroof Siosemarde, Dept. of Water Engineering, Mahabad Branch, Islamic Azad University, Mahabad, Iran

this technique is the high operating costs and time consuming. The measuring of hydraulic conductivity in Inversed Auger Hole method caring out with a shorter period of time compared to Shallow Well Pump in Test Method. Haidarpoor and Mohammadzada (2006) compared Inversed Auger Hole and SWPT methods and concluded that the Inversed Auger Hole method estimated saturated hydraulic conductivity 56% higher than SWPT method [11]. Also research Moetamedi et al. (2012) showed that Inversed Auger Hole method estimated saturated hydraulic conductivity 44% higher than SWPT method and the best relationship between saturated hydraulic conductivity concluding by these methods was a linear equation [16].

II. Materials and methods

In this study, research was conducted in the district, with an approximate area of 2,000 ha, at the Saghez region (Kurdistan Province, Iran). 30 holes with a depth of 2.5 m and 10 cm in diameter were drilled. Measuring of saturated hydraulic conductivity was conducted three times in Inversed Auger Hole method consecutively. Also saturated hydraulic conductivity was measured in SWPT method.

Data analysis of saturated hydraulic conductivity amounts of Inversed Auger Hole method (KIA, independent variable) and SWPT (KSWPT, dependent variable) method concluded using mathematical equations including Linear, Logarithmic, Inverse, Quadratic, Cubic, Power, Compound, S, Growth and Exponential equations as follows:

$$Y = aX + b \qquad (1)$$

$$Y = a\ln X + b \qquad (2)$$

$$Y = a\frac{1}{X} + b \qquad (3)$$

$$Y = aX^2 + bX + c \qquad (4)$$

$$Y = aX^3 + bX^2 + cX + d \qquad (5)$$

$$Y = bX^a \qquad (6)$$

$$Y = ba^X \qquad (7)$$

$$Y = e^{\frac{a}{X}+b} \qquad (8)$$

$$Y = e^{aX+b} \qquad (9)$$

$$Y = b.e^{a.X} \qquad (10)$$

In order to data analysis, the Correlation Coefficient (R), Root Mean Square Error (RMSE), Mean Bias Error (MBE),Mean Absolute Error (MAE) and Coefficient of Residual Mass (CRM) as follows:

$$RMSE = \left[\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}\right]^{1/2} \qquad (11)$$

$$MBE = \sum_{i=1}^{n}[(P_i - O_i)/n] \qquad (12)$$

$$MAE = \sum_{i=1}^{n}\left[|P_i - O_i|/n\right] \qquad (13)$$

$$CRM = \frac{\sum_{i=1}^{n}O_i - \sum_{i=1}^{n}P_i}{\sum_{i=1}^{n}O_i} \qquad (14)$$

Where, P_i, The saturated hydraulic conductivity amounts of Inversed Auger Hole method, O_i, The saturated hydraulic conductivity amounts of SWPT method, $\bar{O}$, mean of the saturated hydraulic conductivity amounts of SWPT method and n, number of samples.

III. Results

The results of the saturated hydraulic conductivity amounts measured by Inversed Auger Hole method and SWPT method at 30 stations is presented (Table1).

TABLE I. THE RESULTS OF THE SATURATED HYDRAULIC CONDUCTIVITY AMOUNTS MEASURED BY INVERSED AUGER HOLE METHOD (MEAN OF THREE REPLICATES) AND SWPT METHOD

Station	Saturated Hydraulic Conductivity				
	K_3	K_2	K_1	K_{IA}	K_{SWTM}
1	0.68	0.88	0.74	0.77	0.88
2	1.48	1.34	1.78	1.53	0.91
3	0.64	0.58	0.58	0.60	0.44

4	*0.58*	*0.91*	*0.77*	*0.75*	*0.95*
5	*0.92*	*0.83*	*1.01*	*0.92*	*0.54*
6	*1.78*	*2.18*	*1.77*	*1.91*	*1.11*
7	*0.72*	*0.55*	*0.62*	*0.63*	*0.51*
8	*1.44*	*1.11*	*1.12*	*1.22*	*0.34*
9	*0.62*	*0.55*	*0.68*	*0.62*	*0.11*
10	*1.05*	*0.93*	*1.11*	*1.03*	*0.71*
11	*2.11*	*1.73*	*1.88*	*1.91*	*0.53*
12	*0.76*	*0.92*	*0.88*	*0.85*	*0.44*
13	*1.72*	*1.32*	*1.24*	*1.43*	*0.52*
14	*1.95*	*2.22*	*2.11*	*2.09*	*1.41*
15	*2.11*	*1.91*	*1.82*	*1.95*	*0.79*
16	*0.58*	*0.62*	*0.89*	*0.70*	*0.18*
17	*0.68*	*0.95*	*0.92*	*0.85*	*0.42*
18	*1.01*	*1.05*	*1.15*	*1.07*	*0.52*
19	*2.68*	*1.98*	*2.02*	*2.23*	*1.44*
20	*1.84*	*2.34*	*2.01*	*2.06*	*1.32*
21	*2.71*	*3.12*	*2.92*	*2.92*	*1.85*
22	*1.24*	*1.15*	*1.32*	*1.24*	*0.61*
23	*1.18*	*1.12*	*1.52*	*1.27*	*0.31*
24	*2.52*	*2.34*	*1.95*	*2.27*	*1.52*
25	*0.88*	*0.72*	*0.88*	*0.83*	*0.21*
26	*2.88*	*2.72*	*2.92*	*2.84*	*1.12*
27	*2.91*	*3.01*	*2.85*	*2.92*	*2.01*
28	*1.12*	*1.22*	*1.08*	*1.14*	*0.28*
29	*2.52*	*2.54*	*2.71*	*2.59*	*1.31*
30	*0.89*	*0.78*	*0.81*	*0.83*	*0.25*

The results comparison saturated hydraulic conductivity measurements showed differences between Inversed Auger Hole and SWPT methods. Table 1 shows the saturated hydraulic conductivity amounts from Inversed Auger Hole method is greater than the SWPT method (Average 87%).

Data analysis of saturated hydraulic conductivity between of SWPT method (KSWTM, dependent variable) and Inversed Auger Hole method (KIA, independent variable) concluded using mathematical equations (Linear, Logarithmic, Inverse, Quadratic, Cubic, Power, Compound, S, Growth and Exponential) as follows table 2.

TABLE II. COEFFICIENTS OF STUDDIED MATHEMATICAL MODELS

Model	**Coefficients**			
	a	***b***	***c***	***d***
Linear	*0.582*	*-0.068*		
Logarithmic	*0.803*	*0.578*		
Inverse	*-0.884*	*1.556*		
Quadratic	*0.154*	*0.060*	*0.284*	
Cubic	*-0.197*	*1.196*	*-1.579*	*1.024*
Power	*2.135*	*0.204*		
Compound	*1.093*	*0.469*		
S	*-1.260*	*0.623*		
Growth	*0.758*	*-1.587*		
Exponential	*0.758*	*0.204*		

In order to data analysis the different statistics used included Correlation Coefficient (R), Root Mean Square Error (RMSE), Mean Bias Error (MBE), Mean Absolute Error (MAE)and Coefficient of Residual Mass (CRM) as follows table 3.

TABLE III. THE RESULTS OF DIFFERENT STATISTICS OF MATHEMATICAL EQUATIONS

Model	**Statistics**				
	R	***RMSE***	***MBE***	***MAE***	***CRM***
Linear	*0.845*	*0.271*	*0.000*	*0.227*	*0.000*
Logarithmic	*0.797*	*0.306*	*0.000*	*0.248*	*0.000*
Inverse	*0.717*	*0.353*	*0.000*	*0.290*	*-0.001*
Quadratic	*0.856*	*0.262*	*0.001*	*0.219*	*-0.002*
Cubic	*0.863*	*0.256*	*0.003*	*0.214*	*-0.003*
Power	*0.849*	*0.274*	*-0.051*	*0.226*	*0.065*
Compound	*0.847*	*0.279*	*-0.064*	*0.234*	*0.081*
S	*0.794*	*0.328*	*-0.082*	*0.265*	*0.105*
Growth	*0.849*	*0.274*	*-0.049*	*0.225*	*0.063*
Exponential	*0.849*	*0.274*	*-0.051*	*0.225*	*0.066*

The results presented inTable2indicate cubic model with the highest correlation coefficient (0.863) and lowest root mean square error (0.256) is the best model among the mathematical equations. Also the results indicate invers model with the lowest correlation coefficient (0.717) and highest root mean square error (0.353) is the worse model. The calculated cubic modeless follows:

$$Y = -0.197X^3 + 1.196X^2 - 1.579X + 1.024$$

Also, comparison of observed amounts (SWPT method) vs predicted amounts using cubic model is as follows figure 1.

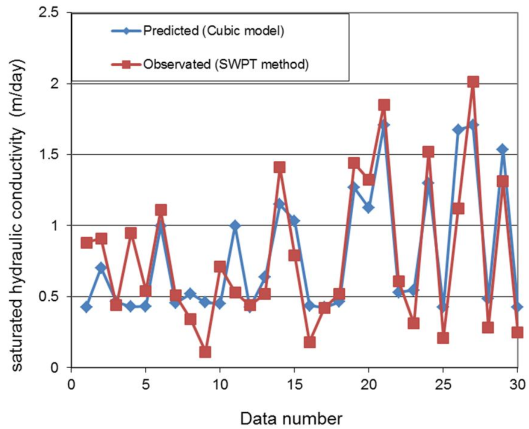

Figure 1. Comparison of observated amounts (SWPT method) vs predicted amounts using cubic model

IV. Discussion

The results showed the saturated hydraulic conductivity amounts from Inversed Auger Hole method is greater than the SWPT method (Average 87%). Also, it is concluded that the cubic model is the best and invers model is the worse model among the mathematical equations.

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