Quality Management for Groundwater by Assessment of Aquifer Vulnerability to Contamination in Erbil City

2nd Conference on Environment and Sustainable Development 28-29-Oct-2015

Dr. Khalil I. Wali
College of Engineering, Salahaddin University, Erbil.
Email: Khalilwali2005@yahoo.com
Zina M. Alwan
College of Engineering, Salahaddin University, Erbil.

Abstract

Groundwater Protection begins with an assessment of the sensitivity of its environment. This study attempts to create a groundwater vulnerability map for Erbil city, Groundwater quality management can be effectively carried out by mapping for groundwater vulnerability to contamination. The purpose of this study is to evaluate the vulnerability of the aquifer to pollution in Erbil city, and to discover the groundwater vulnerable zones to pollution in the aquifer of the study area and to provide spatial analysis of the parameters and conditions under which groundwater may become polluted by using DRASTIC method within GIS environment. According to the DRASTIC model index, the results show that in the South-eastern part of the studied area, highly vulnerability to pollution due to the aquifer media consists of gravel and sand, it is also found that the most parameter effects on the calculation is the soil media. It found that when the soil is gravel, “the Impact of Vadose Zone” is composed of gravel and sand and “Hydraulic conductivity” is high. Most of the studied areas are found to be classified within the moderate level of vulnerability to contamination.

Keywords: Quality Management, Groundwater, Vulnerability, Contamination.

إدارة الجودة للمياه الجوفية من خلال تقييم حساسية طبقة المياه الجوفية للتلوث في مدينة أربيل

الخلاصة

ان حماية المياه الجوفية تبدأ بتقييم حساسية بيئتها. تحاول هذه الدراسة إنشاء خريطة توضح درجة الحصانة للمياه الجوفية في مدينة أربيل، وإدارة نوعية المياه الجوفية يمكن أن تنفذ فعليا من خلال رسم خرائط تبين أكثر الامكان تكون فيها المياه الجوفية عرضة للتلوث. ان الهدف من هذه الدراسة هو تقييم مدى تأثر المياه الجوفية للتلوث في مدينة أربيل، لمعرفة نطاق المياه الجوفية المعرض للتلوث ضمن الطبقة الحاملة للمياه الجوفية في منطقة الدراسة وتوفير التحليل المكاني للمعلمات والظروف التي قد تصبح ملوثة للمياه الجوفية باستخدام طريقة (DRASTIC) في بيئة نظم المعلومات الجغرافية (GIS). وفقا لمؤشر نموذج (DRASTIC)، فقد بينت النتائج أنه في الجزء الجنوبي الشرقي من منطقة الدراسة ذو مؤشر عالي للتلوث وذلك بسبب طبقة المياه الجوفية التي تتكون من الحصى والرمل، كما تبين أن أكثر عوامل مؤثرة على نتائج دراسة حساسية التلوث هو عامل التربة فعندما تكون التربة مكونة من الحصى

https://doi.org/10.30684/etj.34.4A.2
2412-0758/University of Technology-Iraq, Baghdad, Iraq

يكون مؤشر الحساسية أكبر وكذلك تأثير المنطقة المهواة (vadose zone) عندما تتكون من التربة والحصى، وعامل التوصيل الكهربائي تكون من الحصى والرمل فان مؤشر الحساسية يكون مرتفع. من ناحية اخرى فان معظم منطقة الدراسة تصنف ضمن المناطق ذات الحصانة المعتدلة للتلوث.

الكلمات المرشدة: مياه جوفية، ادارة نوعية، تلوث.

INTRODUCTION

Erbil City in the last decade witnessed rapid development in construction projects due to the increase in population in the city leading to increase in water consumption. Domestic wells represent 40% of water supply system in the city [١]. In general, groundwater is widely used for irrigation, industrial activities, drinking, and domestic purposes. Rapid growth of population, urbanization, industry-lization, and agriculture activities increase its exploitation, reduce availability, and enhance vulnerability to contaminate the quality of water.

Groundwater could be contaminated by disposal of urban and industrial wastes and agricultura chemicals. In urban areas, the disposal of wastewater, including human excreta in a septic tank is a common practice [2]. In some regions of study area nitrate and alkalinity concentration exceeding the Iraqi and WHO standards (2008), so in these regions domestic wells suffer of contamination. Under these conditions, groundwater resources need to be protected from any contamination source. The main objective of this work is to evaluate the most vulnerable areas of the study area that are vulnerable to the utilization and overall pollution owing to their geological setting and other human factors like groundwater draft, land use, land cover variations, depth to groundwater level, aquifer media, soil type, topography, hydraulic conductivity, ground water recharge etc. There are many factors which can be considered for the purpose of vulnerability [3]. Groundwater is vulnerable to pollution from human activities , and is very hard to remediate once polluted. “Vulnerability” is the degree to which human or environmental systems are likely to practice harm due to alarm or stress, and can be identified for a specified system; to properly manage and protect the resource, therefore, it is important to determine areas where groundwater may be more vulnerable to pollution [4]. Groundwater vulnerability maps have become a widely accepted tool in the land use planning process that takes into consideration features of groundwater protection from pollution. With the help of vulnerability maps, activities that are possibly dangerous to groundwater resources, such as waste disposal sites, sewage treatment plants, industrial plants, and commercial sites can be suitably located in areas of low contamination risk. At the same time, these maps help in delineating groundwater protection zones for wells and springs and help in putting into place groundwater monitoring, emergency, or restoration measures [5]. Groundwater vulnerability maps are aimed to show areas of greatest potential for groundwater pollution on the basis of hydrogeological and anthropogenic factors. DRASTIC method is widely used in groundwater vulnerability assessment. DRASTIC method depends on seven parameters they are: Depth to water, net Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone media, and hydraulic Conductivity of the aquifer. [6]. Groundwater vulnerability maps can be used to help define protective land-use zones over large geographic regions, or can be used as a preliminary screening tool for site selection [7]. Vulnerability maps have been created for a multiple purposes. For example, they provide a measure of the probability of contamination, assist in ensuring that protection schemes are not unnecessarily restrictive for human economic activity, help in the choice of engineering, preventative measures, and enable major developments, which have a significant probable to pollute, to be located in areas of relatively low vulnerability and therefore, of relatively low risk from a groundwater perspective [8].

Because municipal water supply wells have been constructed in a variety of hydrogeological settings and have a range of possibly significant contaminant sources, best professional judgment will be important in determining the susceptibility of each of the public water systems. The results of the vulnerability analysis will be summarized in a drinking water source valuation report to help the public water system in determining the major threats to their drinking water source and prioritize the protection strategies. Due to lack of information and data about groundwater protection within Erbil city, protection of domestic wells from contamination will consider an effective method to protect domestic wells quality to be suitable for future and sustainability. Assessment of groundwater vulnerability map in Erbil City will consider very important tool in order to manage groundwater quality in the study area. It will provide a very useful instrument for authority for future land use and planning for distribution of projects and industries in Erbil City.

Materials and Methods

Study area

The studied area is Erbil City which is the center of Erbil Governorate and capital of Iraqi Kurdistan Region. Its area is about 145 Km^2 and within its latitude (36°07'08"36°13'08") and longitude (43°57'06"-44°09'00"), while the population in Erbil City was 1,561,918 estimated for the year 2013 [9]. Erbil city is part of Erbil basin is divided into three sub-basins: Northern (Kapran), Central and Southern (Bashtapa) sub-basins. Erbil city lies on central sub-basin (Figure 1).

Data collection

Data are collected from 63 domestic well sections within Erbil City [10]. Almost necessary data sufficient to draw a vulnerability map are extracted from these domestic well sections. The data included: depth of water for each well within studied area, soil media, aquifer media, vadose zone (unsaturated zone) media and Hydraulic conductivity . Rainfall average data are obtained from [١1], which has been used to determine Net recharge for the study area. Most of data were collected in (2004-2014) it represents the latest wells drilled in the study region except well no. 61 and no. 62 they were drilled in 1993 and 1994 respectively because these districts within Erbil City depend on surface water (Ifraz project) as water supply so they consider the latest wells drilled in these districts.

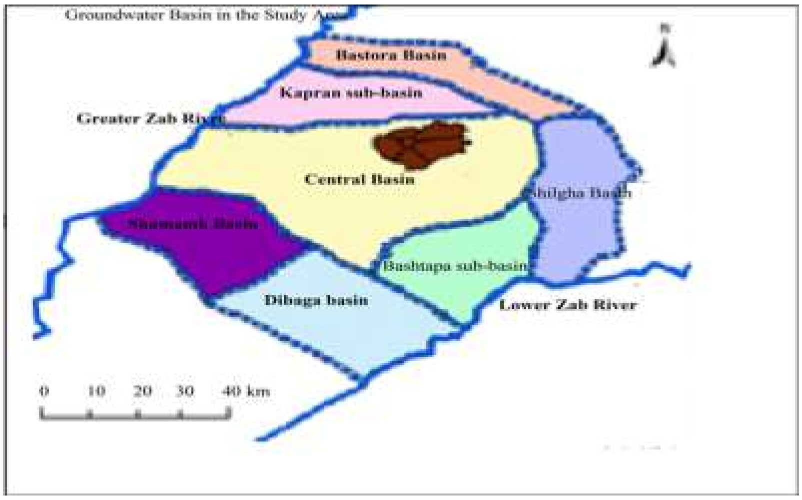

Figure (1). Groundwater sub-basin for Erbil plain [12]

Data Analysis

Vulnerability assessment includes evaluating likely travel times from the ground surface to the water table, or to the aquifer in the case of confined conditions. The greater the travel time, the more possible there is for pollutant attenuation. Extreme vulnerability is related with aquifers having a high density of open fractures and with shallow water tables, which offer little chance for pollutant attenuation [13]. Depth to water in the studied area varies between 26 m at well no.39 in the west to 128 m at well no.13 in the east as shown in Figure (2). The net recharge is calculated by two methods the first is: Method of Analysis of Rainfall-Recharge Relationships (R.R.R) and recharge value is 145 mm/year and the second is the Maximum Water Surplus method the recharge value of this method is 197.9 mm/year. In order to compute the Net Recharge, the average value has been used in studying the area and its value is 171.5 mm/year. Aquifer media for studying area are classified into two zones that mean this aquifer consists of sand, gravel and clay or silt clay. Soil media in Erbil City composed of clay, silt clay, sand, and gravel. The topography or slope for Erbil City ranging between (0 and 2.9 %). Vadose zone in Erbil City has been classified into four zones depending on the data collected and analyzed of the unsaturated zone in the studied area. Hydraulic Conductivity in the study area has a minimum value is 12.96 m/day and maximum value is 368.675m/day.

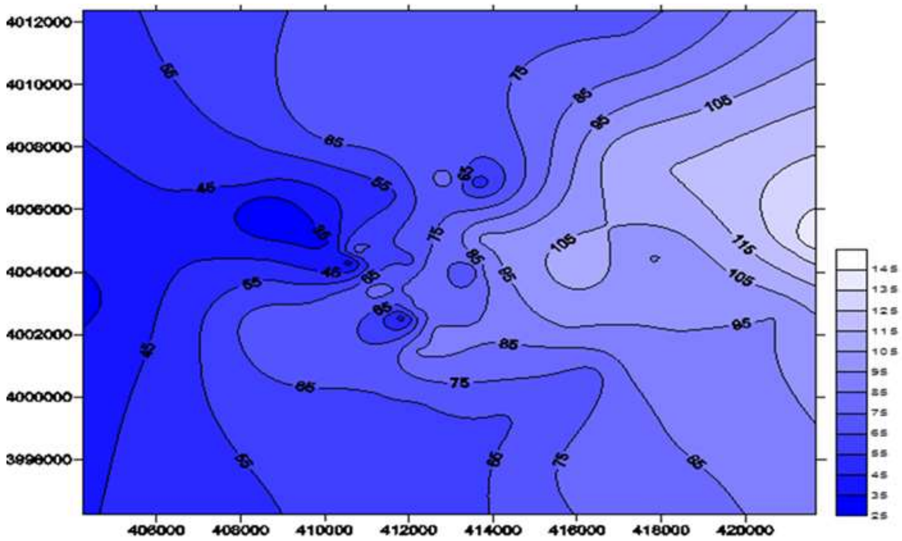

Figure (2). Depth to water in Erbil City

Methods

One of the most widely used methods to assess groundwater vulnerability to a wide range of potential contaminants is DRASTIC [14]. The methodology was developed in the United States under a cooperative agreement between the National Water Well Association (NWWA) and the USA Environmental Protection Agency (EPA) (1987) for detailed hydrogeological of assessment pollution potential and is a model used to spatially and comparatively show elevated vulnerability areas in contrast to low vulnerability areas with respect to the potential to pollute groundwater [15]. In Table (1) Vulnerability Class is classified into four classifications. DRASTIC stands by seven hydrogeological parameters and assigned rank and specific weights to them, presents an index to aquifer vulnerability. These seven parameters are: depth to water table (D), net recharge (R), the aquifer media (A), soil (S), and topography (T), De saturated media (I) and conductivity (C) [16]. In the first step , each DRASTIC factor is assigned a relative weight ranging from 1 to 5, with 5 being the most significant impact and 1 the less significant impact. In the second step, each factor has to be subdivided into ranges or media types that have an impact on pollution potential, these ranges or media types receive ratings between 1 and 10, with 10 being the highest pollution potential and 1 being the lowest pollution potential. Most factors receive one rating per range: other factors, *i.e.* aquifer and vadose zone media receive “typical ratings “or ratings based on site-specific knowledge [17]. With this numerical arrangement one could obtain the *DVI* (Drastic Vulnerability Index) value using a simple additive model:

$$DVI = DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw \quad (1)$$

Where D, R, A, S, T, I, and C are the seven above mentioned parameters and the subscripts *r* and *w* are the equivalent rating and weights, respectively . This model was selected based on the following considerations. DRASTIC uses a relatively large number of factors (seven parameters) to compute the vulnerability index, which ensures the best representation of the Hydrogeological setting [18]. A numerical ranking system to assess groundwater contamination potential in hydrogeology settings has been formulated using the DRASTIC factors. The system contains three significant parts: weights, ranges and ratings, Weights: Each DRASTIC factor has been evaluated with respect to the other to find the relative importance of each factor. Each DRASTIC factor has been assigned a relative weight ranging from 1 to 5, (Table 2).

Table (1). Broad classification of aquifer vulnerability [19]

Vulnerability Class	Definition
Extreme	Vulnerable to most water pollutants with relatively rapid impact in many Pollution scenarios.
High	Vulnerable to many pollutants, except those highly absorbed and/or readily transformed, in many pollution scenarios.
Moderate	Vulnerable to some pollutants, but only when continuously discharged or Leached.
Low	Only vulnerable to the most persistent pollutants in the long term, when continuously and widely discharged or leached.
Negligible	Confining beds are present and prevent any significant vertical groundwater flow.

Table(2). Weights of the factors in the DRASTIC method [19]

Factor	DRASTIC method
D: Depth to Water	5
R: Net Recharge	4
A: Aquifer Media	3
S: Soil Media	2
T: Topography	1
I: Impact of the vadose zone	5
C: Hydraulic Conductivity	3

The most important factors have weights of 5; the least significant, a weight of 1. Ranges: Each DRASTIC factor has been divided into either ranges or significant media types which have an influence on pollution potential (Tables 3 to 9). Ratings: Each range for each DRASTIC factor has been assessed with respect to the others to determine the relative significance of each range with respect to pollution potential. Based on the graphs, the range for each DRASTIC factor has been assigned a rating, which varies between 1 and 10 (Tables 3 to 9). The factors of D, R, S, T, and C have been assigned one value per range. A and I have been gave a “typical” rating and a variable rating. The variable rating allows the user to choose either a typical value or to adjust the value based on more particular understanding [19].

Table (3). Ranges and rating for depth to groundwater [19]

Depth to water (m)	Rating
Between 0 and 1.5	10
1.5 - 4.5	9
4.5 - 9	7
9 - 15	5
15 - 23	3
23 - 30	2
More than 30	1

Table (4). Ranges and rating for the net recharge in (mm/year) [19]

Factor	Range (mm/year)	Rating
Net Recharge	Less than 50	1
	50 - 100	3
	100 - 175	6
	175 - 250	8
	More than 250	9

Table (5). Ranges and rating for the Aquifer media [19]

Factor	Range	Rating	Typical rating
Aquifer media	Massive shale	1 - 3	2
	Metamorphic/ Igneous	2 - 5	3
	Weathered metamorphic/ Igneous	3 - 5	4
	Glacial Till	4 - 6	5
	Bedded sandstone, limestone, shale	5 - 9	6
	Massive sandstone ,massive limestone	4 - 9	6
	Sand and gravel	4 - 9	8
	Basalt	2 - 10	9
	Karst limestone	9 - 10	10

Table (6). Ranges and rating for soil media [19]

Factor	Range	Rating
Soil media	Thin or Absent ,Gravel	10
	Sand	9
	Peat	8
	Shrinking and/or aggregated clay	7
	Sandy loam	6
	Loam	5
	Silty loam	4
	Clay loam	3
	Muck	2
	Non shrinking and non-aggregated clay	1

Table (7). Ranges and rating for topography [19]

Factor	Range (percent slope)	Rating
Topography (%)	0 - 2	10
	2 - 6	9
	6 - 12	5
	12 - 18	3
	More than 18	1

Table (8). Ranges and rating for impact of the vadose zone [19]

Factor	Range	Rating	Typical rating
Impact of the vadose zone media	Confining layer	1	1
	Silt/ clay	2 – 6	3
	Shale	2 – 5	3
	Limestone	2 – 7	6
	Sandstone, Bedded limestone, sandstone, shale, sand and gravel	4 – 8	6
	Metamorphic/ Igneous	2 - 8	4
	Sand and gravel	6 – 9	8
	Basalt	2 - 10	9
	Karst limestone	8 - 10	10

Table (9). Ranges and rating for the hydraulic conductivity [19]

Factor	C (m/day)	Rating
Hydraulic conductivity	Less than 4.0	1
	4.0 – 12.0	2
	12.0 – 30.0	4
	30.0 – 40.0	6
	40.0 – 80.0	8
	More than 80.0	10

To determine the net recharge percolated to the basin for Erbil plain conditions, a linear equation can give suitable results for net recharge estimation as derived in equation (2) by using two methods [20]:

1- Method of analysis of Rainfall-Recharge Relationships (R.R.R):

$$Re = 0.87(P - 50) \quad (2)$$

Where:

Re is annual net recharge (mm/year).

P is the mean monthly precipitation (mm).

2- Maximum Water Surplus Method by using (Table 11, 12).

The DRASTIC Index calculations divided the studied area into four zones. The final ground-water vulnerability map was obtained using the seven hydrogeological data layers in GIS environment.

Results and Discussion

Depth to water table map (d)

The depth to water important, because it provides the maximum opportunity for oxidation by atmospheric oxygen. Therefore, the depth to groundwater is assigned the maximum weight of 5 in determining the vulnerability using DRASTIC method (Table 2) [19]. Depth to water in the studied area varies between 26 m at well no.39 in the west to 128 m at well no.13 in the east as shown in (Figure 2). Range values of depth to water table are divided into two levels from <30 m to depth of >30 m (Table 3). The rate for depth water table varies from 2(for 23-30 m water table depth) to 1 (for more than 30 m depth) based on the ranges and the rating for depth to water table proposed by [19] (Table 3) and (Figure 3) show depth to water map for Erbil city depend on DRASTIC method.

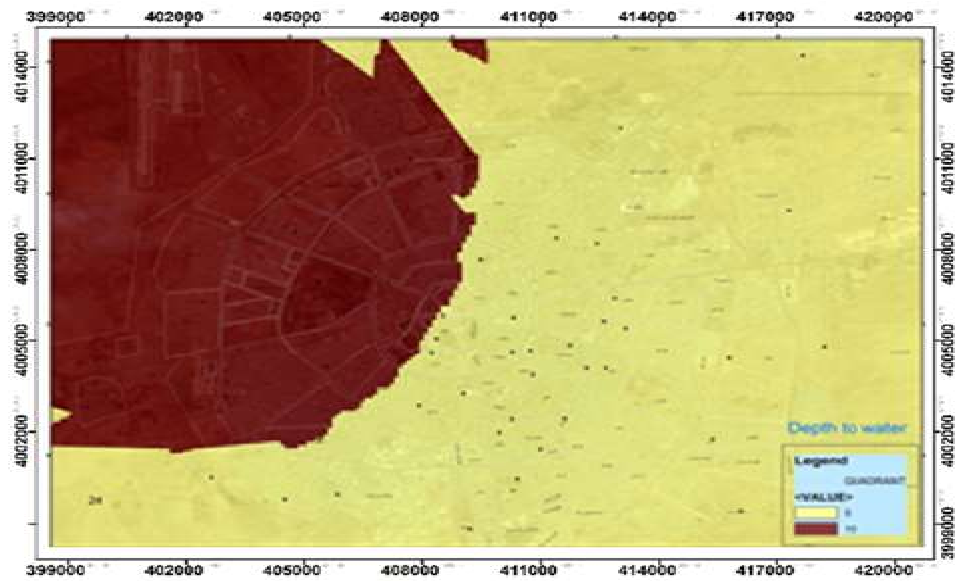

Figure (3). Rating map of (Depth to water in Erbil City) by using GIS

Net Recharges (R)

In order to find the net recharge infiltrate to the basin for Erbil city, we used two methods:

1- The first method of analysis of Rainfall-Recharge Relationships, equation (2) had been using the result had been listed in Table (10).

Table (10). Amount of rainfall (mm)

Months	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	*sum*
Rainfall (2013)	174.4	55.8	17.7	37.4	40.6	0	0	0	0	0.2	19.1	86.6	*431.8*
Recharge	108.23	5.05	0	0	0	0	0	0	0	0	0	31.84	145.12

2- The second method for estimation net recharge in this work is the Maximum Water Surplus method by using Table (11).

Table (11). Maximum Water Surplus method

No.	Case	WSj (mm depth)	WLj (mm depth)	Monthly Climate
1	Pj≤	0	=Pj	Arid
2	tj < Pj ≤ 2tj	=Pj-tj	WLj=tj	Moist
3	Pj > 2 tj	WSj=Pj-2tj	WLj=2tj	Humid

The method applied to Erbil City meteorological station data and the results are shown in Table (12).

Then:

WS% = WS/ (summation of rainfall by a year).

So WS% = 292.35/431.8

= 0.67704956 = 67.705%

R_e = 292.35*0.677 = 197.935

Average Net Recharge = (197.920+145.12) /2 = 171.520 mm/year.

Table (12). Water surplus and water losses calculated by Maximum Water Surplus method

Month	tj (C°)	Pj (mm)	Case	WSj (mm)	WLj(mm)	Monthly Climate
Jan.	9	174.4	3	156.4	18	humid
Feb.	12.05	55.8	3	31.7	24.1	humid
Mar.	14.95	17.7	2	2.75	14.95	moist
Apr.	20.35	37.4	2	17.05	20.35	moist
May	25.3	40.6	2	15.3	25.3	moist
Oct.	23.2	0.2	1	0	0.2	Arid
Nov.	17.35	19.1	2	1.75	23.2	moist
Dec.	9.6	86.6	3	67.4	19.2	humid
Total				292.35	145.3	

The rating of net recharge is one for studying the region because all Erbil city has one rain line due to one meteorological station, The weight assigned for net recharge is 4 (Table 2), the rating in studying area is 6 (Table 4) so the map of the result obtained one zone, which has a value (24) resulting by multiply rating (6) from Table (4) by weight (4) from Table (2), is as shown in Figure (4).

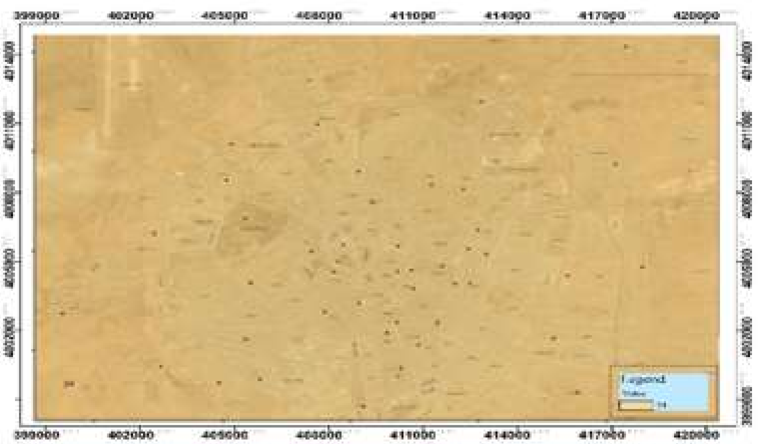

Figure (4). Rating map of (Net Recharge in Erbil City) by GIS

Aquifer Media (A)

Aquifer media for studying area are classified into two zones depending upon data collected from [10] (wells sections), the rating of Aquifer media rating in the study area varies between 6 for gravel and clay, and 8 for sand and gravel (Table 5). The weight assigned to aquifer media is 3. The first zone has a value (18) that mean this aquifer consists of sand, gravel and clay or silt clay. The second zone has a value (24). (Table 5 and Figure 5).

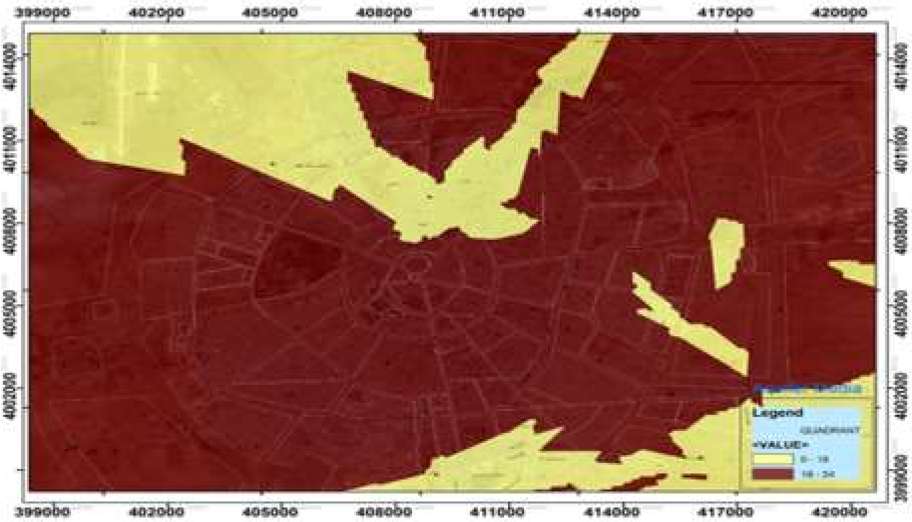

Figure (5). Rating map of (Aquifer media in Erbil City) by GIS

Soil Media (S)

Soil media in Erbil city composed of clay, silt clay, sand, and gravel, the rating values for soil in Erbil city are (3, 4, 6, 9, 10) respectively, DRASTIC weight is (2) .Soil media in studying area have been classified into five zones with values (6, 8, 12, 18, 20) as shown in Figure (6), Table (6).

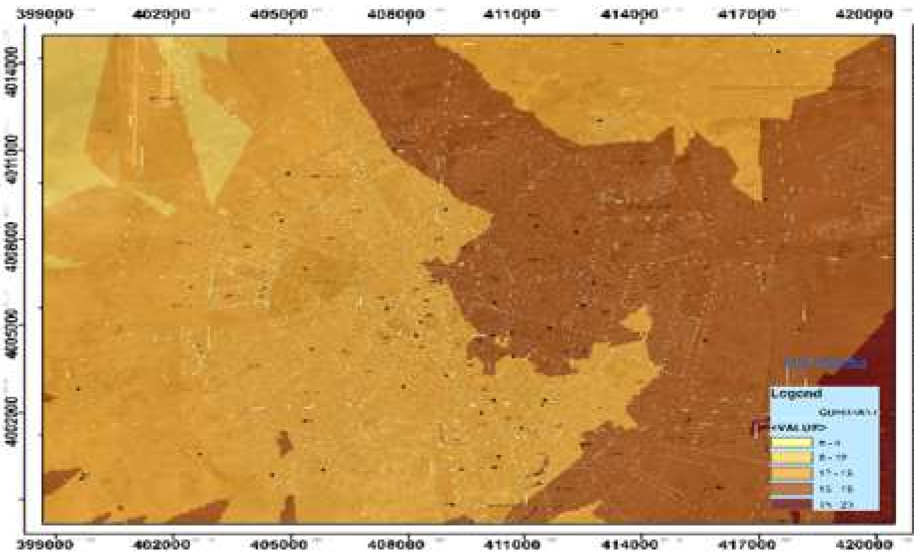

Figure (6). Rating map of (Soil Media in Erbil city) by GIS

Topography (slope) (T)

By using GIS software and using Digital Elevation Model (DEM) for Erbil city the result shows that topography or the slope of Erbil City ranging between (0 - 2.9%). The rating value from Table (7) will be (10) and the DRASTIC weight assigned for topography is (1), the entire city has one zone for Topography parameters with value (10), (Table 7 and Figure 7).

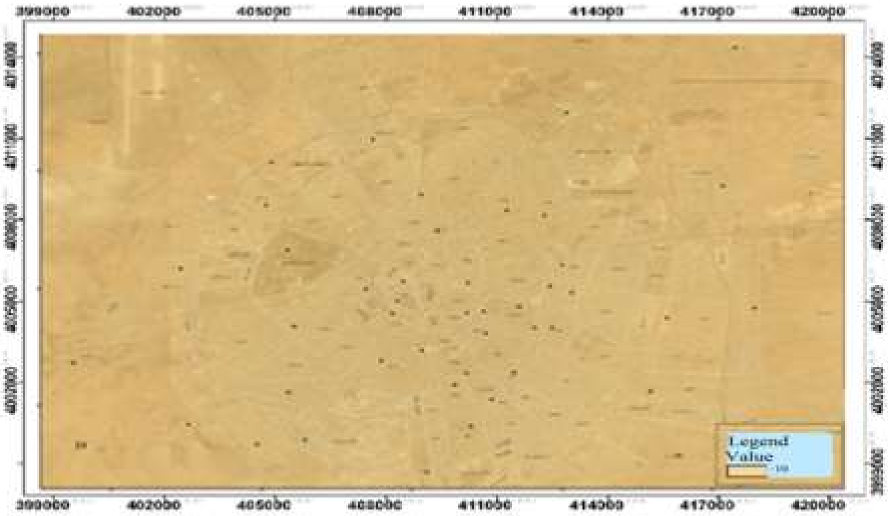

Figure (7). Rating map of (Topography in Erbil city) by GIS

The Impact of Vadose Zone (I)

Vadose zone in Erbil city has been classified into four zones depending on the data collected and analyzed of the unsaturated zone in the studied area, the rating values in studying area are (1, 3, 6 and 8 respectively) the DRASTIC weight is (5) these zones have Index values (5, 15, 30, 40), (Table 8 and Figure 8).

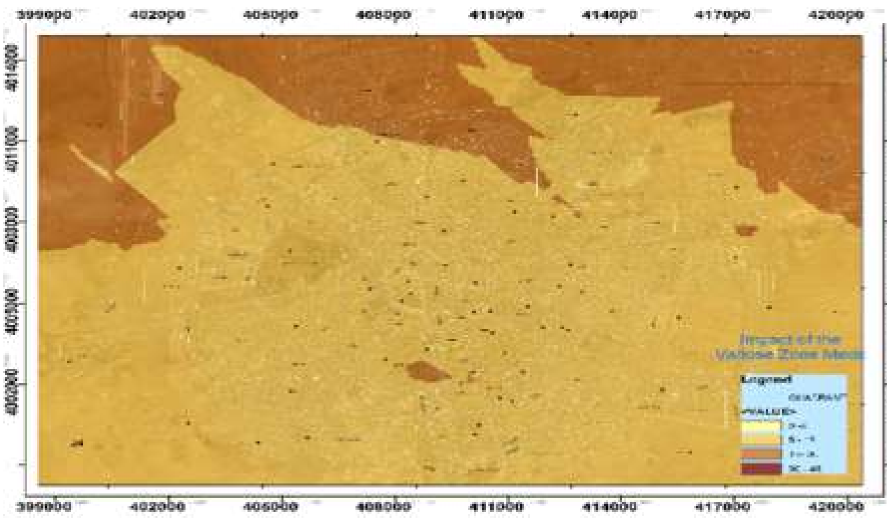

Figure (8). Rating map of (Impact of vadose zone in Erbil city) by GIS.

Hydraulic Conductivity of The Aquifer (C)

The value of Hydraulic Conductivity of Erbil for unsaturated zone and aquifer is calculated by using Table (15). The rating values are 4, 6, 8, 10 respectively; the DRASTIC weight is (3). These calculations divided the studied area into four zones with Index values 12, 18, 24 and 30, (Table 9 and Figure 9).

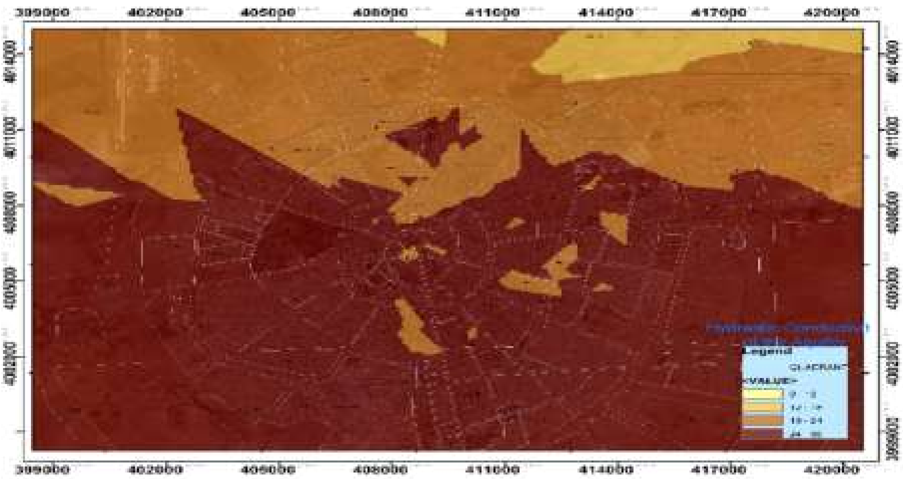

Figure (9). Rating map of (Hydraulic Conductivity in Erbil city) by GIS.

Figure (10). Groundwater vulnerability map of Erbil city by GIS

By using equation 1 to compute DRASTIC Value Index the result for each point represent Vulnerability for this point. The large value of (DVI) means large vulnerability value in the region. The final groundwater vulnerability map was obtained using the seven hydrogeological data layers in GIS environment. The value of DRASTIC in the studied area ranged from 104 to 153. Accordingly, vulnerability classes of the study area were reclassified into three classes based on the proposed table recommended by [19], (Table 13 and Figure 10).

After it has been drawing drastic criteria upon which to build maps susceptibility pollution so the final map of the sensitivity which is a compilation or the accumulation of the seven maps expressing these standards may result appeared in the form of sectors or zones, and each one of them has a numerical value represented by Drastic Index. According to maps extracted for studying area using GIS software, the results showing almost of the studied area have moderate vulnerability value. These values concentrated in the center part of the studied area, the south- eastern and some region in the upper of the center part of Erbil city has high value of vulnerability and low vulnerability value is located in very little region in the south and north part of the city. The low vulnerability index in some regions may be related to soil media it consists of clay and unsaturated zone materials contain clay with sand or gravel all these reasons are shown and will be more clearly shown in Table (14). The coefficient of variation (CV) indicates that a high contribution to the variation of vulnerability index is made by the soil media (56.3%).Moderate contribution is made by the depth to water level (33.1%), and Hydraulic conductivity (26.0%) while the impact of vadose zone (19.8%), and Aquifer media (10.1%), net recharge (0%) and Topography (0%) are the least variable parameters . The low variability of the parameters means a smaller contribution to the variation of the vulnerability index across the studied area (Table 15).

Table (13). Ranges of vulnerability using DRASTIC method [19]

Index of vulnerability	Vulnerability degree
Less than 100	Very low
100-125	Low
125-150	Medium
150-200	High
More than 200	Very High

Table (14). Correlations for DRASTIC parameters

Parameter	Depth to water	Aquifer Media	Soil Media	Impact of Vadose Zone	Hydraulic Conductivity	DRASTIC Index
Depth to water	1					
Aquifer Media	-0.149	1				
Soil Media	.229*	-0.042	1			
Impact of Vados Zone	0.145	0.094	0.212	1		
Hydraulic Conductivity	-0.022	0.183	0.188	-.228*	1	
DRASTIC Index	0.137	.320**	.707**	.518**	.564**	1
*. Correlation is significant at the 0.05 level (1-tailed).						
**. Correlation is significant at the 0.01 level (1-tailed).						

Table (15). Descriptive Statistics for DRASTIC parameters

	Minimum	Maximum	Mean	Std. Deviation	C_V%
Depth to water	26.00	141.00	71.31	23.57	33.06
Aquifer Media	18.00	24.00	22.92	2.32	10.15
Soil Media	6.00	20.00	11.08	6.23	56.26
Impact of Vadose Zone	5.00	40.00	31.23	6.17	19.75
Hydraulic Conductivity	12.00	30.00	25.48	6.63	26.03
Recharge	24.00	24.00	24.00	0.00	0
Topography	10.0	10.0	10.00	0.00	0

Conclusion

Drastic method with GIS environment has been used to provide a spatial analysis of the parameters and conditions that affect the ground water. It is found that in South East part of the studied area, the vulnerability to contamination is high due to aquifer media that consist of gravel and sand. It is found also that the most factors that affect the vulnerability is soil media and when soil is gravel, the hydraulic conductivity is high and the largest drastic index is found to be occurred at these regions. Finally, it is found that most of the studied areas are moderate to vulnerability contamination. The results of this study shows that about 3.8% of the total area of lies in the low vulnerable zone with a DRASTIC index range between 104 and 120.Also about 94.7% of the total area of are in the moderately vulnerable zone with a DRASTIC index ranging between 121 and 136 and 1.5% are in the high vulnerability zone with a DRASTIC index ranging between 137 and 153.Correlation between DRASTIC and soil media, Hydraulic Conductivity, Impact of Vadose Zone and Aquifer Media parameters are 0.707 ,0.564,0.518, 0.320 respectively. Correlation analysis obtains there is no correlate between Depth to water and DRASTIC Index.

References

[1] Ministry of municipality, Directorate of water in Erbil city, KURDISTAN REGION OF IRAQ, unpublished data, 2014.

[2] Alhassan H. Ismail, Muntasir, A.H., Reem, J. Channo, “Groundwater Quality Assessment in Urban Area of Baghdad, Iraq,” Using Multivariate Statistical Techniques”, *Eng. &Tech. Journal*, Vol.33, Part (A), No.2, 2015.

[3] Neha Gupta, “Groundwater Vulnerability Assessment using DRASTIC Method in Jabalpur District of Madhya Pradesh,” *International Journal of Recent Technology and Engineering (IJRTE)*, Volume-3 Issue-3, p (37), 2014.

[4] Jessica E. Liggett and Sonia Talwar, “Groundwater Vulnerability Assessments and Integrated Water Resource Management,” *Streamline Watershed Management Bulletin*, Vol. 13, No. 1, p (18), 2009.

[5] Muheeb M. Awawdeh & Rasheed A. Jaradat, “Evaluation of aquifers vulnerability to contamination in the Yarmouk River basin, Jordan, based on DRASTIC method,” *Arabian Journal of Geosciences*, Volume 3, Issue 3, p (273), 2009.

[6] National Water-Quality Assessment Program–NAWQA, "Improvements to the DRASTIC Ground-Water Vulnerability Mapping Method," USGS Fact Sheet FS–066–99, p (1), 1999. http://pubs.usgs.gov/fs/1999/0066/report.pdf.
[7] Dale Van Stempvoortl, Lee Ewert and Leonard Wassenaar, "Aquifer Vulnerability Index: A GIS Compatible Method for Groundwater Vulnerability Mapping," Canadian Water Resources Journal / Revue canadienne des ressources hydriques, Volume 18, Issue 1, p (26), 1993. http://www.tandfonline.com/loi/tcwr20.
[8] Salahalddin Saeed Ali, Dara Faeq Hamamin,"Groundwater Vulnerability Map of Basara Basin, Sulaimani Governorate, Iraqi Kurdistan Region," *Iraqi Journal of Science*, Vol. 53, No. 3, p (590) 2012.
[9] Ministry of planning, Directorate of Statistics in Kurdistan Regional, KURDISTAN REGION OF IRAQ unpublished data, 2014.
[10] Ministry of Water Resources, Directorate of groundwater in Erbil city, KURDISTAN REGION OF IRAQ unpublished data, 2014.
[11] The Ministry of Transport, meteorology Department, KURDISTAN REGION OF IRAQ, data for monthly rainfall averages for the period (1993-2013), Erbil weather station, unpublished data.
[12] Halaw Huseen Karim, "Geographical Analysis for Solid Waste problem in Erbil city and ways of treatment", University of Salahaddin-Erbil, p (34), 2012.
[13] Migdad El-KheirShuaib Mohammed, "Groundwater Vulnerability Assessment, Using GIS-Based DRASTIC Model," King Fahd University of Petroleum and Minerals, p (7), 2011.
[14] Abdulla M. Al-Rawabdeh, Nadhir A. Al-Ansari, Ahmed A. Al-Taani, "A GIS-Based Drastic Model for Assessing Aquifer Vulnerability in Amman-Zerqa Groundwater Basin, Jordan," Sven Knutsson Engineering, 2013.
http://www.scirp.org/Journal/
[15] B. Dixon, "Groundwater vulnerability mapping: A GIS and fuzzy rule based integrated tool," *Applied Geography,* 25, p (329), 2005.
www.elsevier.com/locate/apgeog
[16] Mostafa Molaie Papkiyadeh, Ali Saremi, Abolhassan Modarreszadeh Barzoki, AmirpouyaSarraf, "Using the AHP method to evaluation of aquifer potential pollution in geographical information system (GIS)," *Journal of Biodiversity and Environmental Sciences (JBES)*, Vol. 6, No. 2, p (368), 2015.
[17] N. L., Mexico, René Alberto DávilaPórcel, ChristophSchüth, Héctor De León-Gómez, "Land-Use Impact and Nitrate Analysis to Validate DRASTIC Vulnerability Maps Using a GIS Platform of Pablillo River Basin,Linares," Andreas Hoppe Rowen Lehné, *International Journal of Geosciences*, 2014 . (http://www.scirp.org/journal/ijg).
[18] Yahia Alwathaf," Assessment of Aquifer Vulnerability Based on GIS and ARCGIS Methods: A Case Study of the Sana'a Basin (Yemen)," *Journal of Water Resource and Protection*, 2011. http://www.scirp.org/Journal/jwarp
[19] Linda Aller, TrumanBennett, Jay H. Lehr, Rebecca J. Petty and Glen Hackett, "Drastic: A Standardized System For Evaluating, Ground Water Pollution Potential Using Hydrogeologic Settings," National Water Well Association Dublin, Ohio, 1987.
[20] Imad Al-Din Omer Hassan, "urban hydrology of Erbil city region," University of Baghdad, Geology department, p (30, 32, 33), 1998.