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Improving The Quality of Ground Water in Some Areas of Al-Anbar Governorate by Recharging with Rainwater

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Abstract. Artificial groundwater recharged with rainwater is the most popular technique for groundwater quality and quantity. Nevertheless, it is still a challenge for researchers to provide precise quantification of groundwater quality and quantity enhancement by recharging with rainwater due to variations in groundwater quality factors such as topography, hydrogeological phenomenon, availability of rainwater, land use pattern, etc. An attempt is being made here to extract the improvement of groundwater quality by adding the collected rainwater of known quality parameters into the developed aquifer strata in the laboratory with regulated laboratory setup and under similar conditions to the aquifer area of analysis. The results showed a decrease in the pH at all sites, especially A1, where it decreased from 8.2 to 7.3. As for Total Dissolved Solids (TDS), the results showed a decrease in all sites, especially A1, where it decreased from (2860 to 2390) mg\lit. Also, for CL-, the greatest decline was in A1, falling from (2.400 to 205) mg \lit. As for the EC values, the site A2 was the lowest, dropping from (5.6 to 4.29 mS/cm). Regarding hardness, the best result was in site B1, where the decrease was from (286 to 220) mg\lit and finally nitrate experienced the greatest decrease in site B2, where it was from (122 to 78) mg\lit.

1. Introduction

Groundwater is a vital water source, especially in arid and semiarid areas. Ground water has applications in many areas of life including, industrial, domestic, and agricultural use[1]. The quality and quantity of groundwater fluctuates on its own, representing the time-to-time groundwater status for a country [2]. The investigation and improvement of groundwater quality in the study area needs supporting verification with the scientific phenomenon of groundwater recharging to some extent [3]. To achieve such verification, different methods can be applied depending on the accuracy of the verification, ranging from conventional laboratory experiments to complex experimental setups [4]. Quality of groundwater itself is the collective term made up of its related quality parameters which vary according to the study area. However, work may concentrate on the management of groundwater quality parameters in the study area that are recognized by available data and studies [5] for example, if the analysis is found to be highly affected by Total Dissolved Solids (TDS), then the groundwater quality under experimental observation is checked for TDS and chlorides instead of considering all groundwater quality parameters [6]. The experimental model prepared in the laboratory can accurately reflect the aquifer field state and conditions but replicating the exact aquifer conditions in the Pet runic laboratory is very cumbersome [7]. The groundwater obtained from the aquifer from the study area enriches this established aquifer setup and allows for stabilization for some time so that the entire aquifer mass of experimental setup can be filled with the supplemented groundwater [8]. The groundwater quality of a field can be considerably replicated by adding real aquifer water to the existing aquifer area [9]. This saturated installation aquifer is ideally diluted by the fresh rainwater with regulated quality and rainwater volume and permitted to dilute for a significant period [10]. After



these diluted samples are again checked in the laboratory and the concentration of groundwater quality parameters is compared before dilution with the same aquifer water and the respective improvement of groundwater quality is reported. As many factors conflict with hydrogeological phenomenon of combining rainwater with aquifer water during recharge [11]. It is therefore, quite difficult to get accurate chemistry involved when mixing method improvement of groundwater quality can be timidly predicted by considering traditional dilution technique, which can be stated as theoretical improvement of groundwater quality where the quality and quantity of solvent and solute are reported and theoretical concentration of particular parameters is enrolled [12].

Therefore, the objective of this study was to evaluate the improvements in the quality of groundwater in some areas of Al-Anbar Governorate by recharging with rainwater.

2. Materials and Methods

2.1. Study area

Present study was carried out to determine the reduction in concentration of governing parameters essentially, Total Dissolved Solids (TDS), Chlorides, Hardness Nitrate (NO_3) by recharging with rainwater[13]. Here the dilution processes of prevailing groundwater quality are added with rainwater where enhanced groundwater quality is computed[14]. This objective is achieved by designing the laboratory experimental set-up which is close to the aquifer conditions of the field of study.

Projected experimental work is the study portion of groundwater quality management analysis through artificial recharge method[15]. Therefore, the experiments were carried to two municipal zones- West Zone (35 Kilo) and (Zangoura) and East Zone (Al- Saqlawiyah) and (Amiriyat al-Fallujah) of Al-Anbar Province in West parts of Iraq (Figure 1)



Figure 1. Map of collection site of the study area of Al- Anbar Province in West parts of Iraq

2.2. Experimental Design

Groundwater quality parameter calculated with the following equation[16]; [17].

(A) Theoretical concentration after charging up of specific groundwater quality parameter

$$= \frac{[(\text{Qty of water added to experimental setup collected from field aquifer} \times \text{Concentration of parameter under consideration in such added water}) + (\text{Qty of rainwater added to experimental setup} \times \text{Concentration of parameter under consideration in rainwater})]}{[\text{Qty of water added to experimental setup collected from field aquifer} + \text{Qty of rainwater added}]}$$

(B) Experimental Concentration of particular groundwater quality parameter after recharging =
 Experimental samples are collected and tested in the laboratory using standard processes

due for the specified groundwater quality parameter, which gives the experimental concentration of different groundwater quality parameters after recharge.

The same procedure is followed for other parameters and for all the samples under consideration. Comparison and correlation are formed between the theoretical and experimental concentration's obtained.

2.3. Experimental setup

An experimental setup was developed in the laboratory as shown in Figure 1 to represent aquifer conditions. With transparent watertight metallic structure of proper dimension (1.10 m (L) × 0.75m (B) × 0.20m (H)) and the required arrangements for the inflow of rainwater into the aquifer material and to collect the water sample from the setup. Two PVC pipes with control valves of different diameters were given to intrude the ground water sample collected from the bore wells in the study area and two pipes were positioned to enter the rainwater in a measured quantity where these pipes appear as different diameters of field refilling wells. These recharges well pipes were positioned in such a configuration that for the dilution, homogeneous mixing of rainwater and existing aquifer mass water could occur as shown in the (Figure2).



Figure 2. Experimental laboratory setup displaying the components and the sample collection point.

The system was filled with the measured quantity of aquifer material (silty and coarse grain sand mixture) collected from the study region and it was packed in layers, the height of such material was changed for different cases of the study area have been considered for experimental purposes. In order to obtain the exact groundwater conditions in the set-up, the water samples of the aquifer located in the stated area were collected and the aquifer material in the set-up was saturated with the same aquifer water samples collected and sufficient time was given to saturate the mass [18]. To control the flow rate, the necessary valves were installed and a thorough mixing of aquifer water in aquifer material was observed.

3. Results and Discussion

Four well locations of the study area were selected and the respective aquifer material was collected from these sites for feeding experimental settings, however such aquifer materials were collected from bore well drilling sites in the vicinity of the well so that the perfect undisturbed sample could not be received [15]. Groundwater samples from the same four sites were obtained from bore wells to saturate the aquifer material and to provide a good image of the real field aquifer in the laboratory. There were two locations selected from West of Al-Anbar province and the remaining were from East of Al-Anbar province and the test sites were given codes A1, A2 for West zone samples and B1, B2 for East zone samples.

The groundwater samples obtained from specified bore well locations were checked by collecting experimental setup from the sample collection point after feeding to the same. The feeding quantity of these groundwater samples was determined by taking into account the average porosity of the set-up material. Rainwater collected was tested for pH, TDS, Chlorides, Electrical Conductivity (EC), Nitrate (NO₃) and Hardness parameters before feeding to experimental setup. Porosity of aquifer materials was measured by averaging the observed porosity for each sample in each region [19]. To prevent septic conditions, it should be noted that the proper circulation of air aquifer Water is applied in less amounts than the usable porous space in experimental device material [20]. From the open terrace,

rainwater used in experiments was collected in huge vessel style pan fitted with traditional mesh [21]. Data of Aquifer Volume (by changing material pack thickness in experimental set-up), considered porosity, available pore space obtained by multiplying the volume of aquifer material to porosity, real added aquifer water in liters and finally quantity of rainwater applied to the experimental set-up are shown in (Table 1).

Table 1. Computed details of experimental setup and its constituents

Test ID	Volume of aquifer Material Fedded in Porosity (%)	Available Pore Space (Litre)	Aquifer water Added to setup (Litre)	Rainwater to Added (Litre)
A1	$0.75 \times 1.10 \times 0.20 \approx 0.165$	28	42.6	48
A2	$0.75 \times 1.10 \times 0.20 \approx 0.165$	28	35.5	23
B1	$0.75 \times 1.10 \times 0.20 \approx 0.165$	28	35.5	18
B2	$0.75 \times 1.10 \times 0.20 \approx 0.165$	28	35.5	18

Rainwater acts as a solute and water in the aquifer mass acts as a solvent during recharge [15]; [22]. Therefore, the concentration of both before their combining and recharging phase is generally understood. (Table 2) represents the concentration of pH, TDS, EC, Nitrate (NO₃) and Hardness of Rainwater collected. (Table 3) shows the concentration of pH, TDS, EC, Nitrate (NO₃) and water hardness retained in experimental aquifer both before and after recharging. Table 4 illustrates the comparative scenario of theoretical and experimental improvement of groundwater quality by using the methodology described in the preceding sections using the available data. In reality, this is exercised in order to reach the combination of theoretical computation and the experimental result of concentration for the groundwater quality parameter after recharge. However, this relation between theoretically measured concentration and the experimentally observed concentration is here determined using the statistical term of R² that is tabulated in Table 5. The graphical representation of percentage reduction in groundwater quality parameter concentration after theoretically and experimentally recharging of phenomena based on (Table 4) is shown in (Figure 3).

Table 2. Quality of rainwater feeded to experimental setup

Test ID	Concentration of Rainwater Quality Parameters					
	pH	TDS (mg/lit)	Chlorides (mg/lit)	EC (mS/cm)	Hardness (mg/lit)	Nitrate (NO ₂) (mg/L)
A1	8	140	112	0.49	127	35
A2	6.8	169	152	0.39	141	40
B1	7.6	113	80	0.382	72	38
B2	7	130	92	0.245	78	30

Table 3. Groundwater consistency feeded to experimental system (Pre- and Post-Recharge)

Test ID	Concentration of Groundwater Quality Parameters (Collected from Experimental Setup Aquifer material)											
	Before Recharging*						After Recharging with Rainwater*					
	pH	TDS	Chloride	EC (mS/cm)	Hardness	Nitrate (NO ₂) (mg/L)	pH	TDS	Chlorides	EC (mS/cm)	Hardness	Nitrate (NO) (mg/L)
A1	8.2	2860	2400	5.8	336	120	7.3	2390	2055	4.69	309	82
A2	7.9	2720	2375	5.6	342	135	7.2	2288	1970	4.29	299	88
B1	7.8	1290	920	3.22	286	118	7.1	1090	766	2.54	220	68
B2	7.9	1100	720	2.20	286	122	7.2	889	570	1.59	230	78

* Except pH and EC, all parameters are in mg/lit.

Table 4. Comparative scenario of theoretical and experimental groundwater quality improvement

Location	Reduction in Concentration							
	A1		A2		B1		B2	
Parameter	Exp.**	Th.**	Exp.**	Th.**	Exp.**	Th.**	Exp.**	Th.**
TDS	14.012	24.22	13.7	18.65	12.70	28.44	16.64	22.20
Chlorides	11.18	24.28	13.81	19.63	12.54	28.44	15.68	22.94
EC (mS/cm)	11.04	22.17	16.41	19.49	9.11	26.22	14.84	22.39
Hardness	8.417	16.20	11.16	16.06	25.32	23.40	19.78	19.37
Nitrate (NO ₃) (mg/L)	10.02	18.04	11.23	19.2	9.78	18.9	13.2	19.33

**Th.= Theoretical, Exp. = Experimental

Table 5. Value of R2 between theoretical and experimental reduction

Location	R2 Value	Location	R2 Value
A1	0.8507	B1	0.735
A2	0.959	B2	0.773

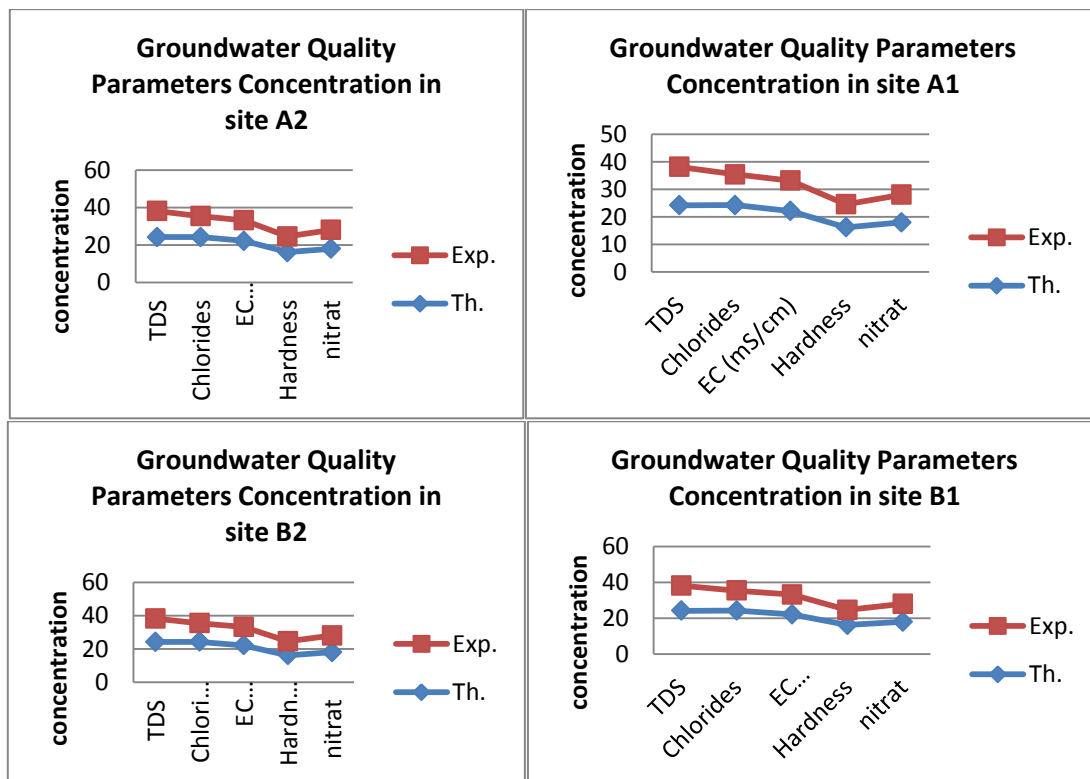


Figure3. Theoretically calculated and laboratory checked percentage reduction in groundwater quality parameter concentration after recharge

Groundwater recharge is a complex phenomenon, as it is circumscribed by various permanent and variable factors such as geo-hydrological structure, lithology [15]; [22], topography, weather patterns, institutions surrounding, etc., due to which accurate groundwater prediction or study is more difficult than surface water [13]. In this regard, the present study attempted to prepare a pilot experiment to

investigate the behavior of groundwater recharging phenomena and to evaluate the improvement of groundwater quality by recharging the actual field aquifer groundwater fed to rainwater experimental set-up. Experimental results of improving groundwater quality by reducing concentration after recharging phase for TDS, Chlorides, EC and hardness parameters [15]. found. 14.012%, 11.18%, 11.04%, 8.417% and 10.02% for site A1 - 13.7%, 13.81%, 16.41%, 11.16% and 11.23% for site A2- 12.70%, 12.54%, 9.11%, 25.32% and 9.78% for site B1- 16.64%, 15.68%, 14.84%, 19.78% and 13.2% for site B2. By using the standard equations and dilution equations same improvement was found theoretically which was computed as 24.22%, 24.28%, 22.17%, 16.20% and 18.4% for site A1 - 18.65%, 19.63%, 19.49%, 16.06% and 19.2% for site A2 - 28.44%, 28.44%, 26.22%, 23.40% and 18.9% for site B- 22.20%, 22.94%, 22.39%, 19.37% and 19.33% for site B2. These two results correlate i.e. theoretical and experimental, determination coefficient (R²) was observed as 0.850, 0.959, 0.735, 0.773 for sites A1, A2, B1 and B2, respectively. Nonetheless, as the average R² was found to be 0.829, zone wise means were determined to be 0.904 and 0.754 respectively for category A sites located in the southwest zone and category B sites located in the west region.

4. Conclusion

The results were revealed that the rainwater can be recharging will be enhances groundwater quality is dependent on how much rainwater is recharged and the rainwater storage and recharge environments.

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