International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com

ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105

JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395

Volume 7, Issue 1 - January 2019 - Pages 41-47

Research on Improving Groundwater Quality by Reusing Rainwater

Dr. A RENGANATHAN[1], ATHIRA PAVITHRAN [2], MARIA JACOB[3], DINU THOMAS[4]
Professor[1], Assistant Professor[2,3,4]

Department of Civil Engineering, Indira Gandhi Institute of Engineering and Technology,
Nellikuzhi P.O, Kothamangalam, Ernakulam (Dist) Pincode 686691

Abstract

The artificial recharging of groundwater with rainwater is currently the most popular method that has been observed to improve both the quality and quantity of groundwater. Despite this, it is still a challenge for researchers and technocrats to determine the exact quantification of the quality and quantity improvement of groundwater through the use of rainwater. This is because there are variations in the allied factors that affect groundwater quality, such as topography, hydro geological phenomena, rainwater availability, land use pattern, and so on, in the area under study. In this work, an effort is made to extract the improvement in groundwater quality by introducing the collected rainwater with known quality parameters to the created aquifer stratum in a laboratory setting with a controlled laboratory setup and under circumstances that are anticipated to be developed in a manner that is similar to the conditions of the study area aquifer.

Keywords: Groundwater, Quality, Hardness, Aquifer and Rainwater

1. Introduction

There is a consistent and unavoidable fluctuation in both the quality and quantity of groundwater, which is a reflection of the current state of groundwater in the area as a whole. To a certain degree, the conceptual phenomenon of groundwater recharge has to be verified in order to provide support for the investigation of groundwater quality and its enhancement in the aforementioned research region. In order to get such verification, a variety of methods, ranging from the traditional laboratory experiments to the more complex experimental setups, may be used. The application of these methods is contingent upon the degree of precision of the verification. Groundwater quality itself is the collective term made of its allied quality parameters which vary as per the study area however researches can be focused to governing groundwater quality parameters of the projected study area which are acknowledged under the consideration by available researches and studies. As an instance, if the study is discovered to be significantly influenced by TDS and chlorides, then the quality of the groundwater that is being observed in the experiment is tested for TDS and chlorides rather than taking into consideration all of the groundwater quality parameters for the experiment. The experimental setup that is produced in the laboratory ought to fairly mimic the state and circumstances of the aquifer in the field; nevertheless, it is extremely difficult to reproduce the precise conditions of the aquifer in the laboratory. For the purpose of ensuring that the whole aquifer mass of the experimental setup is saturated with the supplemented groundwater, this produced aquifer setup is enriched with groundwater that has been obtained from the aquifer that is located in the research region. This process is then allowed to stabilise for a certain amount of time. By incorporating actual water from the aquifer into the mass of the developed aquifer, it is possible to achieve a groundwater quality that is comparable to that of the developing area.

Once the saturated aquifer of the setup has been diluted with rainwater of regulated quality and volume, ideally fresh rainfall, the aquifer is left to dilute for a long amount of time. After that, the samples that have been diluted are examined once again in the laboratory. The concentration of groundwater quality parameters that are being considered is compared with the same aquifer water that was used before the dilution process, and the improvement in groundwater quality is recorded. As a result of the fact that numerous factors are involved in the hydrogeological phenomenon of mixing rainwater to aquifer water during the process of recharging, it is somewhat difficult to get the exact chemistry involved during the mixing process. However, it is possible to cautiously project an improvement in groundwater quality by considering the conventional dilution procedure, which can be argued to be a theoretical improvement in groundwater quality.

2. Experimental Setup

The current research was conducted with the purpose of determining whether or not recharging with rainwater may reduce the concentration of governing factors, namely Total Dissolved Solids (TDs), Chlorides, and Hardness. In this case, the diluting phenomenon of the existing groundwater quality with rainfall is employed in the context of the computation of the enhanced groundwater quality. The development of an experimental setup in the laboratory that approximates the conditions of the aquifer in the research region is the means by which this work is done. Therefore, the experiments were carried out in two municipal zones of Surat city, which is located in Gujarat state in the western part of India. These zones are the West Zone and the South West Zone. The projected experimental work is the study portion of the research work that is being done to enhance the quality of groundwater via the use of an artificial recharging method. There are around 4–4.5 million people living in Surat city, which is located 16 kilometres away from the coast of the Arabian Sea at a latitude of 21°15' North and a longitude of 72°52' East. Surat city is surrounded by an area of 335 square kilometres.

Based on the information shown in Figure 1, an experimental setup was created in the laboratory to simulate the conditions of an aquifer. A transparent and watertight metallic structure with adequate dimensions (1.05 metres in length, 0.75 metres in width, and 0.45 metres in height) and the essential arrangements are given for the input of rainfall to the aquifer material and for the collection of water samples from the setup should be present. Two PVC pipes of varying diameters were equipped with control valves in order to intrude the groundwater sample that was obtained from bore wells in the research region. Additionally, two pipes were installed in order to enter the rainfall in a measured amount. These pipes are functioning as various diameter recharge wells in the field. It was possible to get a homogenous mixing of rainfall and the water that was already present in the aquifer mass by positioning these recharge well pipelines in such a configuration. This allowed for the dilution to take place.

Figure 1 Experimental Setup for the Components and Sample Collection Point

Setup was filled with the calculated amount of aquifer material (a mixture of silty and coarse grain sand) taken from the research region, and it was packed in layers. The height of such material was altered for each of the several situations that were being investigated. For the aim of the experiment, four different areas within the research region were taken into consideration.It was necessary to collect water samples from the aquifer that was located in the specified location in order to get the precise aquifer groundwater conditions in the setup. The aquifer material that was being used in the setup was then saturated with the water samples that were acquired from the same aquifer, and the mass was allowed to become saturated for an adequate amount of time. The appropriate valves were installed during the setup process in order to manage the flow rate, and it was noted that the aquifer water was thoroughly mixed with the aquifer material.

3. Results And Discussion

As was mentioned in earlier sections, four well locations within the study area were chosen, and respective aquifer material was collected from these sites to feed in the experimental setup. However, such aquifer materials were collected from drilling sites of bore wells in the vicinity of the well location, which meant that a perfect undisturbed sample could not be obtained. For the purpose of saturating the aquifer material and obtaining a fairly accurate representation of the genuine field aquifer in the laboratory, groundwater samples were taken from bore wells in the same four sites. Two sites were chosen from the South West zone, while the other samples were taken from the West zone of Surat city. The numbers A1, A2 were assigned to the samples taken from the South West zone, and the codes B1, B2 were assigned to the samples taken from the West zone.

For the purpose of testing the groundwater samples that were obtained from bore wells at selected areas, the samples were collected from the sample collection point of the experimental setup after being fed to the system. The amount of groundwater samples that were fed into the setup was determined by taking into account the average porosity of the material that was used for the setup.The collected rainwater was put through a series of tests before being fed into the experimental apparatus.Each and every one of these tests was carried out for the criteria of pH, TDS, chlorides, electrical conductivity (EC), and hardness. The porosity of the components that

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 7, Issue 1 - January 2019 - Pages 41-47

make up the aquifer was evaluated by taking the average of the porosity that was found for each sample from each zone. It is important to note that in order to prevent a septic condition and ensure that air is properly circulated, aquifer water is introduced to the material of the experimental system in a quantity that is less than the amount of pore space that is available. Rainwater was collected from an open terrace and placed in a large vessel-type pan that was equipped with typical mesh for the purpose of conducting tests. Table 1 displays the specifics of the volume of the aquifer (which was determined by adjusting the thickness of the material pack in the experimental setup), the porosity that was taken into consideration, the available pore space that was obtained by multiplying the volume of the aquifer material by the porosity, the actual amount of aquifer water that was added in litres, and finally the amount of rainwater that was added to the experimental setup.

Table 1 Computed Details and its Elements

Test ID	Volume of aquifer Material Feeded in Setup (Mt^3)	Porosity (%)	Available Pore Space (Litre)	Aquifer water Added to setup (Litre)	Rainwater Added (Litre)
A1	0.75 x 1.05 X 0.32 ≈ 0.250	30	75	50	10
A2	0.75 x 1.05 X 0.16 ≈ 0.125	30	37.5	25	7.5
B1	0.75 x 1.05 X 0.16 ≈ 0.125	30	37.5	20	10
B2	0.75 x 1.05 X 0.16 ≈ 0.125	30	37.5	20	8

The fact that rainfall works as a solute and water that is trapped in aquifer mass functions as a solvent during the process of recharging is something that should be taken into consideration. As a result, it is vital to have an understanding of the concentration of both types of water before the process of mixing and recharging takes place. In Table 2, the concentrations of pH, TDS, EC, and Hardness of Rainwater that were collected are shown, and in Table 3, the concentrations of pH, TDS, EC, and Hardness of water that were stored in the experimental aquifer are presented at both the stage before and after the recharging process. This is done in order to reach the association of theoretical computation and experimental result of concentration for the aforementioned groundwater quality parameter after recharging. Table 4 illustrates the comparative scenario of theoretical and experimental groundwater quality improvement by working with the methodology described in the sections that came before it and making use of the data that is currently available. On the other hand, this link between the theoretically predicted concentration and the empirically found concentration is computed here by employing the statistical term of R2, which is reported in Table 5. Figure 2 is a graphical depiction of the percentage decline in groundwater quality parameter concentration that occurs after recharge phenomenon. This representation is based on Table 4, and it takes into account both theoretical and experimental calculations.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com

ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105

JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395

Volume 7, Issue 1 - January 2019 - Pages 41-47

Table 2 Rainwater Quality

Test ID	Concentration of Rainwater Quality Parameters				
	pH	TDS (mg/lit)	Chlorides (mg/lit)	EC (mS/cm)	Hardness (mg/lit)
A1	7.8	135	107	0.46	122
A2	6.4	164	148	0.36	134
B1	7.3	108	76	0.355	68
B2	6.8	125	88	0.225	72

Table 3 Groundwater Quality Feeded

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	pH	TDS	Chlorides	EC (mS/cm)	Hardness
A1	7.7	2850	2375	5.4	336	7.3	2365	2038	4.64	301
A2	7.4	2680	2375	5.26	342	7.2	2235	1950	4.24	294
B1	7.3	1245	876	2.88	286	7.1	1062	745	2.56	205
B2	7.4	1062	695	1.82	286	7.2	864	572	1.52	224

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

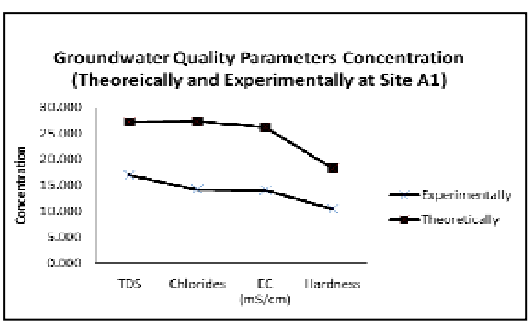
Table 4 Comparison of Theoretical and Experimental Groundwater Quality Improvement

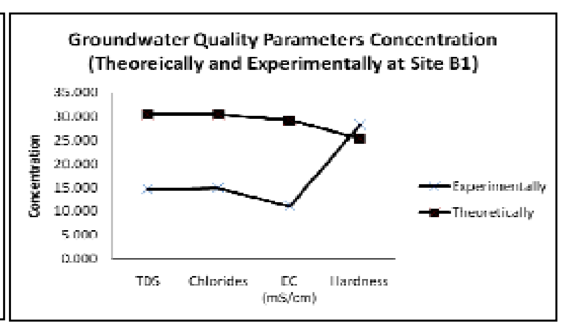
Location	A1		A2		B1		B2	
Parameter	*Reduction in Concentration*							
	Exp**	Th.**	Exp**	Th.**	Exp**	Th.**	Exp**	Th.**
TDS	17.018	27.22	16.604	21.665	14.699	30.442	18.644	25.209
Chlorides	14.189	27.28	17.895	21.639	14.954	30.441	17.698	24.954
EC (mS/cm)	14.074	26.14	19.392	21.498	11.111	29.225	16.484	25.039
Hardness	10.417	18.20	14.035	18.065	28.322	25.408	21.678	21.379

** Th= Theoretical Exp= Experimental

Table 5 Value of R2 between Theoretical and Experimental Reduction

Location	R^2 Value	Location	R^2 Value
A1	0.786	B1	0.730
A2	0.732	B2	0.813





International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 7, Issue 1 - January 2019 - Pages 41-47

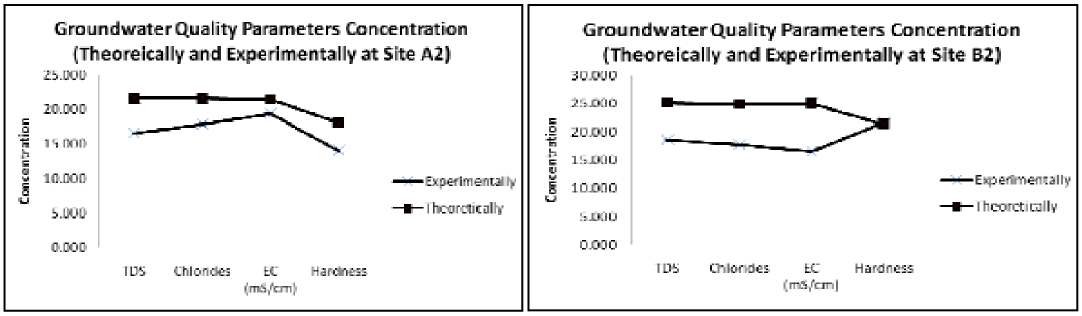


Figure 2 Theoretically Computed and Laboratory Tested Percentage Reduction in Concentration of Groundwater Quality Parameters after Recharging

4. Conclusion

- Due to the fact that groundwater recharging is a complex phenomenon in its own right, it is surrounded by a multitude of static and variable aspects such as geohydrological setup, lithology, topography, rainfall pattern, and surrounding establishments, amongst others. As a result, it is more difficult to accurately predict or analyse groundwater studies than it is to do so with surface water. In this respect, the current research made an effort to establish a pilot experiment for the purpose of analysing the behaviour of groundwater recharging phenomena and investigating the enhancement of groundwater quality via the process of recharging the actual field aquifer groundwater that was fed to the experimental setup by rainfall.
- • The experimental findings of groundwater quality improvement through the reduction in concentration following the recharging process for the parameters of total dissolved solids (TDS), chlorides, electrical conductivity (EC), and hardness were found to be 17.0%, 14.2%, 14.1%, and 10.42% for site A1 - 16.6%, 17.9%, 19.3%, and 14.03% for site A2 - 14.7%, 14.95%, 11.1%, and 28.32% for site B1 - 18.6%, 17.7%, 16.5%, and 21.7 percent for site B2.
- Through the utilisation of standard equations and dilution equations, the same improvement was discovered theoretically. This improvement was computed as 27.2%, 27.3%, 26.1%, and 18.20% for site A1; 21.7%, 21.65%, 21.50%, and 18.06% for site A2; 30.44%, 30.44%, 29.22%, and 28.41% for site B1; 25.2%, 24.9%, 25.0%, and 21.38 percent for site B2.
- For the purpose of establishing a correlation between these two observations, namely the theoretical and the experimental, the coefficient of determination (R2) was determined to be 0.786, 0.732, 0.73, and 0.813 for the locations A1, A2, B1, and B2, respectively.
- Despite the fact that the average R2 was determined to be 0.765, the zone-wise averages for sites belonging to the A category that were located in the south-west zone and sites belonging to the B category that were located in the west zone were calculated to be 0.759 and 0.771 respectively.

International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Available online at: www.jrrset.com
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395
Volume 7, Issue 1 - January 2019 - Pages 41-47

5. References

[1]. De A.K., "Environmental Chemistry", (1998) 2nd Edition, Wiley Eastern Publication

[2]. D.K. Todd, "Ground Water Hydrology", Wiley, 2006, New York

[3]. Chenini and S. Khemiri, "Evaluation of ground water quality using multiple linear regression and structural equation modeling", International Journal of Environmental Science and Technology, 6(3), 2009, 509-519

[4]. Joarder, M.A.M., Raihan, F. and Alam, Regression analysis of ground water quality data of sunamganj district, Bangladesh", International Journal of Environment, 2(3), 2008, 291-296

[5]. APHA-AWWA-WPCF, "Standard methods for the examination of water and waste water", Ney work: American Public Health Association, 2002

[6]. Jain, C.K. and Sharma, M.K., "Relationship among Water Quality Parameters of Groundwater of Jammu District", Pollution Research, 16(4), 1997, 241-246

[7]. Nair, G.A., J.A. Bohjuari, M.A. Al Mariami, F.A. Attia and F.F. El Toumi, Ground water quality of north-east Libya", Journal of Environmental Biological, 27, 2006, 695-700

[8]. Kumar, Garg and Gopal, "Relationship between electrical conductivity and cationic and anionic contents in ground water", Indian Journal of Environmental Protection, 14(7), 1994, 595-603

[9]. Pathak J.K, Mohd Alam and Sharma Shikha, "Interpretation of groundwater quality using multivariate statistical technique in moradabad city, western Uttar Pradesh state, India", E-Journal of Chemistry, 5(3), 2008, 607-619

[10]. Dismas J, Mulungu DM, Mtalo FW. Advancing rainwater harvesting as a strategy to improve water access in Kinondoni municipality, Tanzania. Water Science and Technology: Water supply. 2018 Jun 1;18(3):745-53.

[11]. Oviedo-Ocaña ER, Dominguez I, Ward S, Rivera-Sanchez ML, Zaraza-Peña JM. Financial feasibility of end-user designed rainwater harvesting and greywater reuse systems for high water use households. Environmental Science and Pollution Research. 2018 Jul;25:19200-16.