Aquifer Storage and Recovery, is it Useful for Iran in Climate Change Condition?

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Abstract

The method of injecting water into groundwater for the purpose of storage generally has several reasons. For arid and semi-arid regions such as Iran, where surface water storage increases its evaporation due to hot weather, priority is groundwater storage. In the current situation, that climate change has caused several problems, especially in the area of lack of access to freshwater; storage is a very important solution for the countries involved in the water challenge. In addition, for areas near the coast, extraction of groundwater causes interference with fresh and salty water and a decrease in the quality of groundwater. Because of the vastness of Iran and the presence of warm and dry areas as well as coastal areas and population density in coastal areas, there are problems with the evaporation of water and the interference of fresh and salty water in our country. In addition, due to different types of water storage methods, the ASR method is one of the methods that, if used correctly, helps to reduce the overall cost of water production. Considering that about 11% of the area of Iran is in the form of a karst aquifer, part of this article deals with this type of aquifer and how water is stored in it.

Keywords: ASR, karst aquifer, climate variability, remediation, groundwater

1. INTRODUCTION

Groundwater is such reservoirs that normally store water during dry seasons and, unlike surface water and dams, do not occupy much land. Excessive use of groundwater in Iran can cause problems such as the interference of saline and fresh water, especially near the sea and, most of all, the catastrophic subsidence of the land and the aquifers die in arid and semi-arid areas.The aquifer's artificial feeding is of two types: direct and indirect.

Direct methods are Surface and subsurface and Surface methods can be included"flood spreading, pools and storage tanks, flow path enhancement, atmospheric and stack irrigation, surplus irrigation, construction of dams, flood irrigation".

On the other hand, direct subsurface methods can be included feed wells or injection wells, natural and artificial pits and trenches.

Due to the wide range of effective parameters, the necessity of using GIS plays an important role in the process of locating suitable aquifer recharge areas. [1]

A groundwater flow model is able toexhibit precise representation of hydrological and geological systemsand it can give a real insight into relationship and interactionsbetween system components. Modeling using computer programs can betruly beneficial when there are karst aquifers in the case study location.This is mainly because karst aquifers are very heterogeneousand anisotropic and have a complex structure.Nowadays, by developingcomputer programs and due to the need of acquiring moreresults that are valid as the output of modeling, three-dimensional models aremore acceptable despite the possible complex procedure of setting themup.Mostly, numerical analysis and tools should be used to solve complexdifferential equations of groundwater flow. On the other hand, numerical modeling approachesare taken by modelers to simulate complex groundwater systems. Numerical modeling tools often take advantage of finite-difference andfinite-element techniques to solve complicated equations that governshydrological system dynamics in an aquifer. For karst aquifers, lumpedmodels and spatially distributed models are considered as two generalmodeling approaches that can be used in certain conditions. In addition,various computer-based models such as MODFLOW are very common. A combined set of models can be used to simulategroundwater flow and contaminant transport in either steady state or transient form. Additionally, application of remote sensing and GIS in assessing water resources in karst and for modeling purposesis usual and practical. [2]

Pollution in aquifers are very vast asNitrate, Metals, LNAPL [1]& DNAPL[2], VOC[3], Pathogens and Chloride [2]

Modeling methods can simulate water flow and contaminant transport around streams and within aquifer using mathematical equations. Although they can predict the behavior of a hydrogeological system, their application in karst is limited. Usually, simplifying assumptions are made during modeling process of SWGWI [4]in karst, which result in uncertainties. However, by taking advantage of new techniques/technologies and/or by combing this method with other in-situ measurements, researchers have shown the application and promising future of modeling methods. [2]

ASR has many advantages over surface reservoirs: little to no evaporative losses minimized environmental disturbances and land consumption, and lower costs.The more common practice is to develop a qualitative suitability index that involves classifying and weighting various factors and evaluating those factors over a spatial area.More quantitative methods for estimating the feasibility of locations for ASR-specific systems have been developed as well. These methods involve deriving dimensionless parameters that describe a physical process governing the recovery efficiency of an ASR system.

ASR can never completely replace surface storage, as it cannot match some benefits of surface storage, especially in regards to storm water management.ASR can be implemented as part of a water storage portfolio.[3]

2. ASR AND ITS APPLICATION

Storage of storm water in an aquifer has been shown to affect water quality but it has also been claimed that storage will also decrease the storm water quality variability making for improved predictability and management.

It has been documented that MAR [5]provides not only a storage zone but also can provide for passive treatment processes and attenuation is known to occur for pathogens, organic chemicals, nutrients and metals.

The aquifer could function as a natural treatment system before or after an engineered system. A further advantage ascribed to natural treatment systems such as aquifers is that they act as a sort of environmental buffer and smooth out variations in water quality.

Similarly, the presence of reactive minerals in the aquifer will affect the recovered water quality, especially with regard to the mobilization of metal (loid) species.A more robust statistical method is required to examine the effects of dispersion on censored data. Regression on order statistics (ROS) is obtained by computing a linear regression on the logarithms of the uncensored data versus their normal scores, the order statistic of the normal distribution corresponding to the rank of the observation where ranking accounts for censored data.

In this research [4] they have worked on four sites in South Australia. Analysis of data for ASR systems has often been limited due to it being highly left censored. An example of highly left censored E. coli data for the four ASR systems is shown in figure -1.

[1]light non-aqueous phase liquid
2 dense non-aqueous phase liquid
3 Volatile organic compounds
4 surface water and groundwater interaction
5 manage aquifer recharge

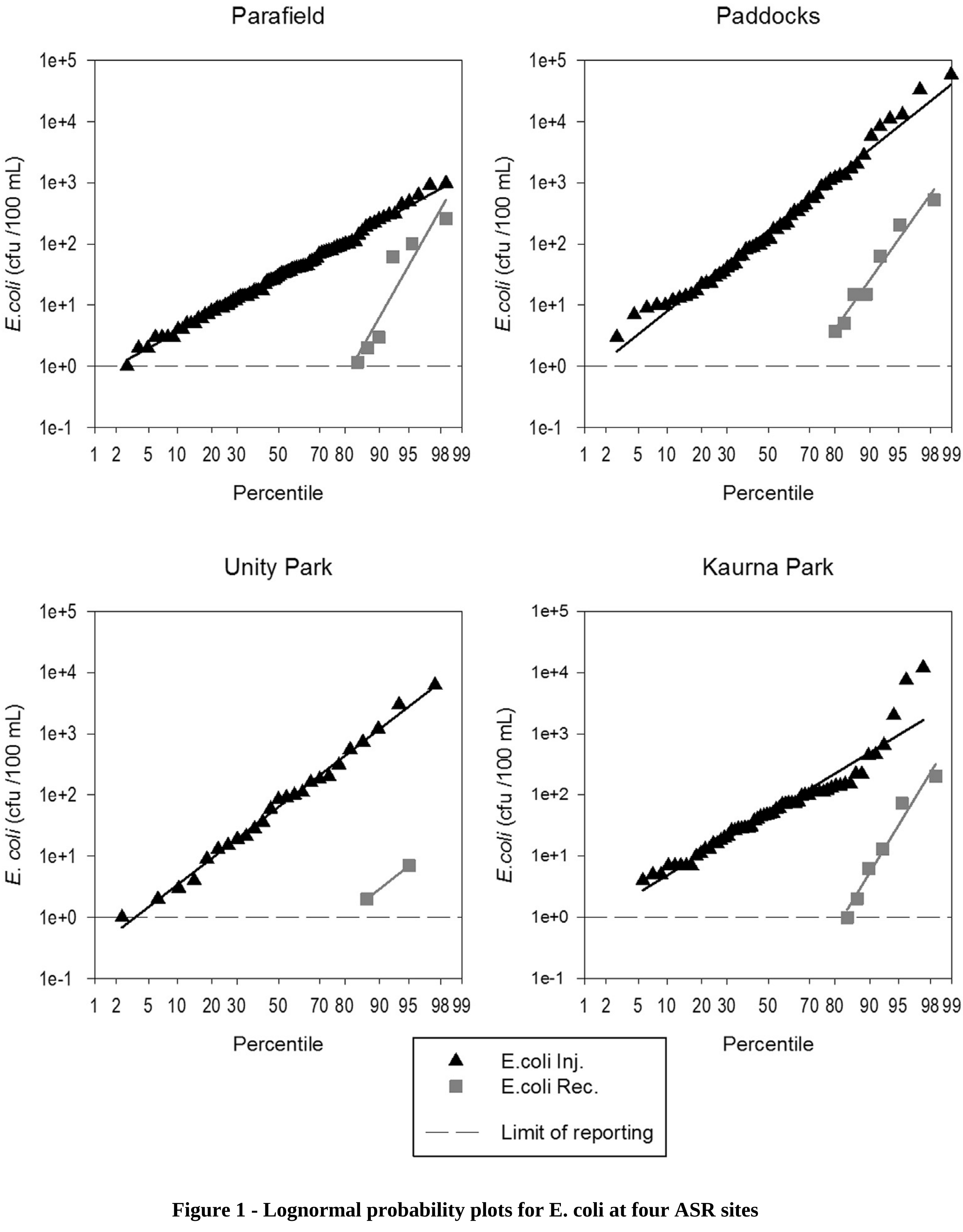

Figure 1 - Lognormal probability plots for E. coli at four ASR sites

ASR influences recovered water variability differently depending upon the parameter. E. coli in the recovered water is generally lower than the injectant and has a decreased variability, which demonstrates the potential utility of ASR in improving microbiological water quality. Turbidity removal and variability is highly dependent on ASR well operation and therefore can be managed through improved operational regimes and continuous monitoring. Other parameters such as nutrients show overall removal but increases in parameter variability due to changes in the near well environment.

Metals are generally increased in concentration because of aquifer storage and the recovered water highly variable in concentrations.Combined and hybrid natural-engineered treatment systems would need to be tailored to the specific end use. [4]

There is a general agreement that deep aquifers experience significant lag time in their response to climatic variations.Analysis of Temporal Gravity Recovery and Climate Experiment, Soil, Moisture and Ocean Salinity mission, satellite altimetry, stable isotopic composition of groundwater, and precipitation and static global geo-potential models over the Nubian Sandstone Aquifer System (NSAS) revealed rapid aquifer response to climate variability. Findings include:

(1) The recharge areas of the Northern Sudan Platform sub-basin witnessed a dry period (2002−2012), where average annual precipitation was modest (85mm) followed by a wet period (2013–2016; AAP: 107 mm), and during both periods the AAP remained negligible (b10 mm) over the northern parts of the Northern Sudan Platform sub-basin;

(2) The secular trends in terrestrial water storage over the sub-basin were estimated at −3.8 ± 1.3 mm/yr and + 7.8 ± 1 mm/yr for the dry and wet periods, respectively;

(3) Spatial variations in terrestrial water storage values and phase are consistent with rapid groundwater flow from the Northern Sudan Platform sub-basin and Lake Nasser towards the sub-basin during the wet period and from the lake during the dry period;

(4) Networks of densely fractured and karstified bedrocks provide preferential pathways for groundwater flow. The proposed model is supported by;

(1) Rapid response in groundwater levels in distant wells and in soil moisture content in areas with shallow groundwater levels to fluctuations in Lake Nasser surface water;

(2) The isotopic composition [5]

Attempts have been made to minimize the interaction between polluted SW and GW in karstic areas by placing an impermeable seal along canal bottoms or riverbeds, constructing small dams/weirs, building grouting curtains, changing the flow direction of surface waters, plunging and creating reactive barriers by pumping freshwater into aquifer. [2]

3. ASR IN KARST AQUIFERS

Karst aquifers, capable of storing and transmitting large amount of water, are the main source of drinking waterin many regions worldwide. Their excessive permeability leads to an enhanced vulnerability to retain and spreadthe contamination accordingly.Karst aquifers are responsible for providing potable water for40% and 25% of the US and world's population, respectively.Due to the presence of karstic aquifers in many parts of the world, water fromprecipitation can rapidly percolate into underground. This rapidmovement makes karst aquifer highly vulnerable to emerging contaminationfrom several sources of contamination induced by agriculturaland industrial activities in addition to proximity to urban areas.Comprising of chemically soluble rocks with large passages or networkof conduits and caves inside, karst aquifers are very permeableand capable of storing and transmitting large amount of water.Approximately 10% of the world's land surface areas havekarst aquifer beneath them.Limestone, dolomite, gypsum and anhydrite are the most commonmaterials forming karst aquifers. Two important characteristics of karst aquifers are heterogeneityand anisotropy, which make it hard for hydrogeologists and researchersto develop models using simplifying assumptions.The recharge and discharge rate of karstsprings can vary a lot due to several reasons such as fluctuations inwater table level caused by hydrological events or seasonal variations. In groundwater hydrology, hydraulic conductivity quantifies theability of soil in transferring water.Hydraulic conductivity of karst limestone is thegreatest comparing to many other aquifer types.Laboratory, field and numerical methods are three main means ofmeasuring hydraulic conductivity. Numerical and finite element-basedmethods are used for determining vertical and horizontal hydraulic conductivities.Hydraulic tomography is a novel method that can be used for imagingthe heterogeneity in karstic terrains.In karst aquifers, the average range of K can vary depending on several factors such as geology, slope, level of heterogeneity and karstification.Based on the aforementioned complex characteristics of karst, several techniques and tools associated with modified and researchers for understanding the behavior of karst aquifers have employed reformed conventional methods (such as hydrologic and hydraulic methods, geophysical and geological methods, modeling techniques and tracer tests).Some researchers studied karst aquifers by taking advantage of modeling methods. In addition, taking advantage of geological methods, which help understanding the aquifer geometry and hydraulic properties such as permeability in addition to orientation and characteristics of potential flow paths, can boost the accuracy of modeling results. Geophysical techniques can also be employed in conjunction with geological methods to understand geologic structures and overburden thickness of the aquifer.Due to the complex patterns of SW and GW flow in karst, several studies have denied coincide of surface water and groundwater drainage divides. [2]

Karst aquifers, which are portrayed as high permeable soil/rock systems with caves and fractures inside and recharged by sinkholes and rivers, have shown high vulnerability to contamination.[2]

Agricultural, industrial, residential, commercial and municipal development are considered as the main sources of groundwater pollution in recent decades. In particular, leakage of storage tanks, chemical spills, landfills, fertilizers and pesticides, sanitation systems, untreated waste discharge and sewage are some of the main sources of contamination due to anthropogenic activities. Generally, regardless of the source of contamination, pathogens, organic compounds, metals, and other inorganic compounds (e.g., nitrates, chlorides) are often found in groundwater.

The most commonly found contaminants in karst groundwater are presented below.

Nitrate
Metals
LNAPL & DNAPL
VOC
Pathogens
Chloride.[2]

Remediation in karst is even more challenging than in other hydrogological environments due to the presence of highly permeable conduits of unknown extent.Most remediation processes in karst have lower efficiency compared to other aquifer types because of their time-dependent characteristics.In situ thermal treatment, in situ chemical oxidation, and in situ bioremediation are increasingly being applied at fractured rock and karst site. The main challenge associated with these techniques is to identify the zone that requires treatment. Based on site conditions and the type of contaminants, the most effective technology should be employed.Assessment of remediation technique requires an appropriate monitoring approach (for locations consist of springs, streams, extraction systems, and previously tested wells) and comprehensive hydrogeological and water quality sampling data.Remediation by mitigating exposure pathways. Because of interconnectivity betweenconduits and fractures within karst aquifer, controlling exposurepathways is more difficult compared to other aquifer types.Mitigating exposure pathways can be done by treating at the tap, replacingdrinking water supplies, treating spring flow using active andpassive methods, land cover control using fences, signage, deed restrictionand local law enforcement.[2]

The karstic groundwater aquifers are heterogeneous underground reservoirs that collect water in a network of fissures, caves, and connected canals.The Yasuj aquifer is one of the most important karst aquifers in Kohgiluyeh and Boyerahmad province, with several drinking water wells drilled almost to the bottom of the aquifer to provide some of the water needed for urban use. Unfortunately, the landfill site of Yasuj city in the aquifer area. Karsty is located at a height much higher than that of drinking water wells so that the waste leachate can easily reach the karstic aquifer, thus the likelihood of karstic aquifer contamination and as a result of contamination of pumping water from drinking wells is very high.The term karst is used to describe a particular type of landscape that encompasses widespread underground caves and water systems, especially developed in soluble rocks such as limestone, salt, and gypsum.There is not enough time for microbial degradation and spoilage in these aquifers.The karstic aquifer and groundwater aquifers have very low self-purification, unlike porous aquifers; in other words, any contamination in the karstic aquifer is rapidly spreading.During the wet winter season, the aquifer reacts to precipitation in a tangible manner, so that with heavy rainfall, the groundwater level responds and increases in less than 5 hours.The karst is very heterogeneous; wells drilled in it may exhibit very different hydrogeological behavior only within a few meters.Wells can have varying degrees of vulnerability and susceptibility to microbiological contamination. [6]

4. CONCLUSIONS

The risk of karst water contamination is high due to the rapid movement of pollutants in them. 11% of Iran's area is karstic carbonate formations. Dam construction in karstic formations causes water to escape. [7]

Iran is located in arid and semi-arid land. On the other hand, coastal strips of Iran, both in north and south, are more populated than in other parts of Iran, and groundwater is very common for freshwater access.As stated at the beginning of this article, the construction of dams in the arid and desert areas causes high water evaporation. In addition, groundwater harvesting causes the catastrophic subsidence of the land and the aquifers die, as in Hamadan plain and Tehran provinces.

In coastal areas, due to high consumption of freshwater aquifers, interference between freshwater and saline occurs, which reduces the water quality in aquifers.The use of ASR for such a situation is one of the most sensible and logical approaches to Iran's climate and in climate change in the entire world. The use of the dam will also help to manage surface runoff, but in combination with ASR will certainly increase the efficiency of freshwater storage in a land like Iran.

Obviously, because more than ten percent of Iran's aquifers are karstic, they are highly permeable, so measures to improve water quality need to be considered to prevent contamination in karstic aquifers. In addition, dam construction in karst zones due to the permeability of the soil will cause water to exit the dam reservoir and enter the groundwater. Therefore, ASR is recommended instead of dam construction in these areas.

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