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Groundwater Depletion in the Western Desert of Karbala Governorate

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Abstract:
This research discusses the excessive exploitation of groundwater in the western desert of the holy Karbala Governorate, specifically the Ain al-Tamr district. This area relies on groundwater from the Dammam aquifer for various agricultural, industrial, and domestic water uses. Continuous extraction leads to rapid groundwater depletion. To provide a clear picture of the extent of water depletion in the study area, geochemical methods were used to estimate the age of the aquifer water, using the tritium/helium method to estimate the age of modern and more recent water, and carbon dating to estimate the age of ancient water. A program was also usedGenstat was used to analyze the results of laboratory water tests, using Complete Randomize Block Paving (CRBP) statistical analysis based on the one-way method. The study found that old water was being depleted. It also confirmed that the majority of the water in the Dammam reservoir was fresh, confirming that the reservoir was overused and that the majority of its water was being depleted prematurely.

INTRODUCTION:

Iraq's water reserves are limited, relying primarily on the Tigris and Euphrates rivers. The presence of two rivers in a country increases the availability of renewable water resources and achieves water security. However, what raises concerns and threatens water security in Iraq, and the study area in particular, is that these rivers are international, and Iraq is a downstream country, not a source. What makes the situation worse is that the water reserves of the study area are not affected by the waters of the two rivers, due to its distance from surface water sources. Therefore, the region relies entirely on rainfall and groundwater to provide water reserves. Climate change has also contributed to a decrease in rainfall, and the newly added rainfall contributes to the recharge of nearby shallow aquifers, which are quickly exploited. It is important to note that the deep groundwater reserves in the study area are also transboundary, which exacerbates the situation and exposes water reserves to rapid depletion. This exposes all existing investments in the region to risk and losses, and also causes the destruction of natural ecosystems. Therefore, this resource must be handled with caution.

First: The study problem: Is the groundwater of the Dammam aquifer in the western part of the Karbala desert being over-depleted, and prematurely?

Second: Study hypothesis: The Dammam reservoir, located in the western part of the Karbala desert, is subject to excessive withdrawal of large quantities of its water to meet the needs of existing investments (agricultural, industrial and domestic) in the study area, which exposes the reservoir to the loss of large quantities of water prematurely.

Third: The aim of the study: The study aims to estimate the age of groundwater in the Dammam reservoir to provide an idea of the extent of current depletion.

Fourth: The concept of water depletion and its causes:

The concept of water depletion is linked to many other concepts, all of which lead to a negative impact on water. Depletion, waste, squandering, loss, excess and depletion express what happens to water. Water in various regions of the world, whether surface or groundwater, is exposed to varying degrees of inefficient use of its water resources.[1)]Groundwater depletion is defined as the prolonged, multi-year withdrawal of an aquifer in quantities that exceed the average annual replenishment, resulting in a continuous decline in groundwater levels and declining groundwater volumes. Accelerated extraction rates put groundwater resources at risk. Eventually, groundwater users will face a critical tipping point when the water table drops below the well depth. This poses risks to food systems and

[1]Hadi Ahmed Al-Faraji, Rationalization of Water Consumption, Arab Bureau of Education for the Gulf States, Muscat, 2006, p. 36.

consumers.[1]).Groundwater depletion can be viewed from two different perspectives: In the first case, depletion is literally and simply a decrease in the volume of water in the saturated zone, regardless of water quality considerations. A second perspective sees depletion as a decrease in the usable volume of stored fresh groundwater. For example, seawater intrusion into an aquifer is a significant depletion in terms of water quality, but it does not lead to a depletion of the total volume of fluid.[2]).

Groundwater depletion in an area is often caused by the following reasons:

1 - Random extraction from private wells, lack of cooperation with official authorities, and the user's insistence on enjoying complete freedom in water use without any kind of oversight or controls.

2- Farmers' ignorance of the actual water requirements of each type of plant.

3- Reclamation of more desert lands requires the waste of large quantities of groundwater.[3]

Fifth: The depletion of groundwater in the western desert of the holy Karbala Governorate:

Over pumping and exploitation of groundwater for agricultural, industrial, and urban purposes has contributed to the depletion of large quantities of groundwater in the study area. This type of investment by economic activities aimed at increasing local production in the short term has led to the immediate depletion of natural capital. Agricultural intensification is a major factor pushing us towards a tipping point in the risk of groundwater depletion, as groundwater is the sole water source for agriculture in the study area. Recent years have witnessed the addition of large areas to the agricultural plan each year, and the continuous reclamation of new areas in an attempt to achieve self-sufficiency, especially in strategic crops and fish. This has increased water withdrawals in the region, and the field study revealed that this extensive investment has contributed to the depletion of large quantities of water from the Dammam Aquifer. During the 2023 and 2024 planting seasons, a large number of farmers worked to increase the depth of wells to more than 15 meters compared to previous levels due to the low water level and low flow from the well. A small number of wells have also become unusable due to changing water properties, prompting farmers to close them and dig new ones instead.Currently, many investors are seeking to expand and invest in various industrial and agricultural projects in the Western Sahara for personal gain, without taking into account that flooding the market with more products will lower their prices and reduce the value of water. This will make the product incapable of covering the value of the water contained in the product.

Sixth: Estimating the consumption of groundwater Using (traditional method):

Groundwater consumption is defined as: water withdrawn from the groundwater reservoir (for a specific use) that evaporates, seeps into, or is incorporated into products or crops and consumed by humans and livestock. This water is withdrawn by a user or by an investment authority, and water is consumed by a group of users in a geographical area. Consumption begins from the beginning of withdrawal and continues until the consumer.[4]).

It is shown in the table (1) Map (1) shows the excessive consumption of water in the study area, which is evident through the various activities that have increased the quantities of withdrawals in recent years, and the consumption of larger quantities of blue water stored in the Dammam Basin, as a result of the increase in the water footprint for various uses.

Table (1) It shows the consumption of blue water from the Dammam reservoir in agricultural production in the study area.

Blue Water Footprint/Season	crops	Seq.	Blue Water Footprint/Season	crops	Seq

[1]Sadiq Ibrahim, Mahmoud Abdel Gawad, Water Security and Strategic Water Storage in Kuwait and the Arab World, Journal of Science and Technology, Issue 51, Kuwait, 2000, p. 5.

([2]) Lenard F. konikow, Eloise .Kendy, grown water depletion: a global problem, hydrologic consulting, USA, vol13, 2005, pp 317-320.

[3])) Muhammad Bahjat Thamer, The Impact of Agricultural Activity on Groundwater Depletion in Al-Mahmoudiya District, Al-Mustansiriya Journal of Arab and International Studies, Issue 55, 2014, p. 260.

([4]) Kimberly H. Shaffer, Donnarunkle, consumptive water. Use coefficients for The great lakes bosinclmatically similar areas to us, geological, survey report USCS, report 2004, pp 9.

4471200	Broad beans	16	4,860,000	Palm and lote tree	1
4471200	onion	17	6998400	citrus fruits	2
4471200	covered option	18	6220800	figs	3
4471200	lettuce	19	5832000	olives	4
4471200	Spang	20	7776000	shifts	5
4471200	Leek	21	7387200	Okra	6
4471200	ring	22	5832000	eggplant	7
4471200	radish	23	6415200	sophistication	8
4471200	Shabnat	24	6415200	watermelon	9
4471200	Turnip	25	10692000	wheat	10
4471200	boil	26	10692000	barley	11
4471200	celery	27	5054400	yellow corn	12
4471200	Rashad	28	5054400	sunflower	13
4471200	Beetroot	29	5248800	Jet	14
4471200	Spring potatoes	30	4471200	Given pepper	15

Source: Field study.

Source: Data from Table (1).

Agricultural operations are the primary consumer of water in the study area. Groundwater depletion from perennial crops ranged between 4,860,000 liters/dunum for palm and jujube trees, with the highest consumption for rose trees totaling 7,776,000 liters/dunum/year. Summer vegetable crops ranged between 5,832,000 liters/dunum/per season and 7,387,200 liters/dunum/per season for okra.

As for strategic crops, the amount of water consumption ranged between (5,054,400) liters/dunum/season for sunflower and yellow squash and 10,692,000 liters/dunum/season for wheat and barley. While the amount of water consumption for the jatropha crop reached (5,248,800) liters per dunum. As for winter vegetables, the amount of water consumption per dunum and for all types of vegetables reached (4,471,200) liters/dunum/season. It is considered the least consumed compared to other crops.

Water consumption for both animal and industrial production is another investment that depletes groundwater in this study area.

Table (2) shows the consumption of blue water from the Dammam reservoir in industrial activity in the study area.

Unit of measurement	Water footprint per investment	Investment type	Seq
liter/field/day	669.6429	poultry farms	1
Liters/day/dunum	777600	fish lakes	2
Liters/8 hours/day	259200	construction industries	3
liters/day	100,000	Desalination plants	4

Source: Field study data 2023-2024.

A single poultry farm required 669,9429 liters/day of freshwater. Fish ponds, which are the largest drain on groundwater, consumed 777,600 liters/day/dunum. Fish ponds require large quantities of freshwater, which increases the water footprint during the farming stages, noting that the area of the lakes in the region ranges from 5 dunums or more. Meanwhile, the amount of water consumed in construction industries and various factories reached 259,200 liters/8 hours per day as an average operating limit. Finally, the amount of water consumed in desalination plants reached 100,000 liters/day, year-round. This variation in water consumption for various investments is a result of the difference in the water footprint of each investment and use, depending on the nature of the use. Local climatic conditions also significantly affected the type of use.

Seventh: Using geochemical methods to estimate the age of groundwater in the Western Desert (Dammam Aquifer).

Knowing the age of groundwater is an urgent necessity in semi-arid and arid regions, given its significant role in achieving sustainable development in the region. To estimate the age of groundwater, the tritium/helium technique was used.He/3HIn estimating the ages of modern water in the study area, a technique was also used to estimate the ages of ancient water, which reach more than 500 years.14C

It is clear from Table (3) that the percentage of3HIn all wells, this indicates that the wells were recently fed with rainwater during the past (12) years. The rise may also indicate that3HThe presence of flow paths such as faults and cracks contributed to its replenishment with water due to the mixing of the underground layers. This indicates that all samples contained all radioactive elements. The decrease in the amount of each of them also indicates14 c, HeThe less recent and old groundwater has been consumed for a long time, so the highest concentration of helium (2.89) confirms the consumption of modern water, as the concentration of tritium is high and reached 89.45. The old water has also been consumed, and only small quantities of it remain, and this is confirmed by the low concentration.14CAll the study wells confirm that the largest amount of old water is consumed in Dammam.

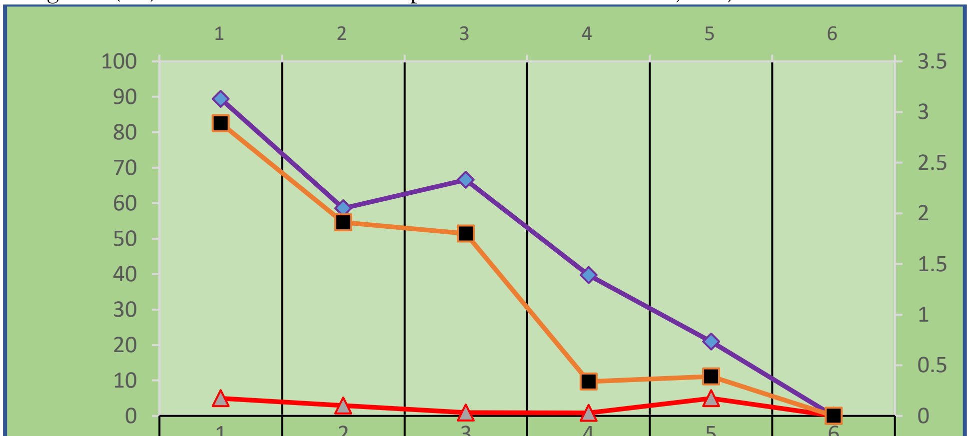
Table (3) shows the concentrations of radioactive isotopes in the groundwater of the western part of the Western Desert in the holy Karbala Governorate.

the site	14C	He	3H	Seq
26	4.95	2.89	89.45	1
34	2.89	1.91	58.58	2
16	0.91	1.8	66.55	3
21	0.85	0.34	39.7	4
41	4.95	0.39	20.95	5

Source: Field study 2024.

We conclude from this that there is an inverse relationship between each of them. The lower the14 C , 3H, He3HIncrease and direct relationship between and as it increasesHeHe14CHerose14CScheme (26).

Diagram (26) shows the relationship between each of:14C, 3H, and He.



	1	2	3	4	5	6
3H	89.45	58.58	66.55	39.7	20.95	0
14C	4.95	2.89	0.91	0.85	4.95	0
He	2.89	1.91	1.8	0.34	0.39	0

Source: Data from Table (3).

To estimate and confirm the relationship between the elements used in estimating the ages of groundwater and to determine the relationship between them, a program was adopted.Genstat statistical and Complete Randomize Block Paving method which is based on one.way method.

It became clear from Table (4) shown below: that all wells gave a significant value, as the calculated table value was 25.551, and this expresses the existence of clear significant differences between the calculated values and those that were subjected to treatment, and that the interaction between them has a confirmed significant effect at a probability level of 0.001.(f)

Table (4) Statistical analysis of each of3H and He and study sourcesC_{14}

source of variation	df	ss	ms	vr	F pr.
Blocking stratum	4	995.9	249	1.14	...
stratum treatment	2	9318.4	4659.2	21.28	<.001
Residual	8	1752	219	...	...
Total	14	12066.3	...	...	...

Source: Field study data 2024.

In order to distinguish the significance between the study factors, we can resort to the mean differences shown in the table below and compare them with the value of the lowest significant difference, which is (21.58).

Table (5) Differences in averages for each of:He and 3H andC_{14}

Grand mean	19.8	19.8	19.8
Treatment	14C	He	3H
	2.9	1.5	55
lsd			21.58

Source: Field study data 2024.

It is clear from Table (5) that there is no statistical significance between each of:14CThis is because the least significant difference between them is smaller than the value of the calculated averages, as the value between them was recorded as (1.4), while it is clear that there is a clear significant difference between each of and, and the value of the difference between them is greater than the value of the least significant difference, and the difference between each ofHeHe3HHeand3H(53.5), and a clear significant difference was recorded between both and with a value of (52.1).C_{14}3HThis means that the more water there is, the more it will be.3HHeAnd the quantity decreasedC_{14}vice versa.

If we determine the correlation coefficient between each of the elements adopted in the treatment, it becomes clear that all values are positive, and this indicates the presence of a strong correlation between the elements, and when any element increases or decreases, it is reflected in the other elements by increase or decrease. Since all correlation values in the matrix are 1000, this means that the variables are linked to themselves (their locations), meaning that the samples from any well represent all the wells of the study area, Table (6) and Chart (2).

Table (6) shows the correlation coefficient between the wells for radioactive elements.14C, He, 3H.

WALL	1	....				
WALL	2	1.0000	....			
WALL	3	1.0000	1.0000	....		
WALL	4	1.0000	1.0000	1.0000	....	
WALL	5	1.0000	1.0000	1.0000	1.0000	....
Correlation coefficient		1	2	3	4	5

Source: Field study data.

Anyone who follows the groundwater age map in the study area can conclude that fresh water represents the majority of the study area, especially in the western and southeastern parts. This indicates that these areas were exposed to extensive withdrawal operations, which led to the depletion of deep water, as they are the main agricultural and settlement areas in the region.

The less modern areas appear in the form of a range adjacent to the modern waters to the east and south of Lake Razzaza. Most of the water in these areas is used primarily for agricultural and industrial investments. As for the old groundwater ranges, they are concentrated in the middle of the Western Desert. These areas are new to agricultural investment and there are no industrial plants there, so they still retain limited quantities of strategic reserves. It is clear that the strategic reserves in the other parts have been subjected to depletion processes, and only a small portion of the old water remains, and the majority of the water ages in the study area date back to the past (12 years).

CONCLUSIONS:

1 - The agricultural sector contributes to the consumption of large quantities of groundwater, especially strategic crops (wheat and barley).10,692,000 liters/hectare per season.
2 - The low levels of carbon in the water indicate that the Dammam reservoir has been subjected to extensive depletion in most of its parts.
3- The high levels of tritium and helium in the water indicate that the majority of the reservoir's water is recent and concentrated in most of its parts. This indicates the consumption of very old atmospheric water.
4 - The study samples did not find a significant correlation between carbon and tritium, which indicates a decrease in the amount of water in the reservoir in the near future.

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