Optimization of Groundwater Abstraction Management in the Tabriz Plain New Approaches and Challenges

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Abstract

Water scarcity, as one of the most important challenges facing humanity, has had irreparable consequences. Climate change, reduced rainfall, and excessive extraction of groundwater resources, especially in the plains, are among the main factors of this crisis. The Tabriz Plain, as one of the important agricultural and industrial regions of the country, has been facing water shortage problems since the past. Excessive extraction, in other words, the process of extracting groundwater beyond the equilibrium yield of the aquifer from agricultural and industrial water wells, has led to a drop in groundwater levels, causing salinization of the water and the destruction of agricultural lands. On the other hand, the entry of untreated industrial and domestic wastewater into the aquifers has brought about severe pollution of these valuable resources.This article seeks to increase awareness in this field by examining the reasons for the water crisis in the Tabriz plain, its effects on human life and the environment, and providing solutions for optimal management of water resources. The results of this study show that to deal with this challenge, we need a comprehensive and inclusive approach in which all sectors of society participate.

Keywords: Groundwater, Water Consumption Management, Tabriz plain

1. Introduction

Water scarcity, as one of the fundamental challenges of the current century, has affected many regions of the world, including the Tabriz plain. Reduced annual rainfall, excessive groundwater extraction, improper wastewater treatment, and its entry into aquifers have all contributed to the exacerbation of this crisis. Groundwater refers to water that has accumulated in saturated and aquifer-bearing layers underground. This water constitutes only about 4% of the total water that is actively involved in the hydrological cycle. However, about 50% of the world's population relies on this groundwater for drinking water, and groundwater can be exploited by digging wells [1]. The modeling of water flow in aquifers is based on Darcy's law and the principle of conservation of mass [2].

Given the vital importance of water in all aspects of human life, it is essential to examine solutions for optimizing water consumption and sustainable management of groundwater resources, especially in areas such as the Tabriz plain. In this article, the current status of groundwater in the Tabriz plain is examined, and various methods of optimizing water withdrawal are examined in order to find solutions to improve the status of groundwater in the Tabriz plain.

2. General Status of Groundwater in the Tabriz plain

The Tabriz plain, which includes part of the Aji Chai watershed, is located at 46°15' to 45°30' east longitude and 38°17' to 37°56' north latitude. The northern and eastern parts of the Tabriz plain are limited by the Eynali heights, the Moro and Mishu mountains. The Sahand mountain range is located to the south and southwest of it and extends from the west to the shore of Lake Urmia. The elevation of this plain above the free water level is about 1350 meters and the slope of the plain is from east to west [3]. Figure (1) shows the geographical location of the Tabriz plain. The Tabriz plain aquifer consists of three aquifers: free (firstaquifer), semi-pressurized (second aquifer), and pressurized (thirdaquifer). The thickness of the first aquifer is seen in the plain area with variable thicknesses from less than 25 meters to more than 60 meters. The second aquifer of the Tabriz plain aquifer is observed from around Shariati Street to the west with variable thicknesses under the first aquifer with a maximum total alluvial thickness of more than 95 meters in BaghGolestan and less than 30 meters on the outskirts of the city. The third aquifer also begins and extends in the northwest extreme near Azarbaijan Square and Cento Road towards the entrance and center of the Tabriz plain [4]. Parts of the Tabriz plain where the wells are scattered are selected as study areas and investigations have been carried out on these parts.

Fig. 1. Geographical location of the Tabriz plain

To conduct this research, data from 42 piezometric wells were used in the study area. The time period used in this research is a 13-year period from 2001 to 2013. The results obtained from the analysis of statistical parameters in the article [5] show that the minimum depth of the wells is 1.37 m (West Qorigol Artesian Well) and the maximum is 130.88 m (DarrehHeraviWell). Therefore, the range of changes in the depth of the wells, which is the difference between the minimum and maximum depth, is 129.51 m. Considering that the network of waterways, geology, and land use in a region play a very important role in the recharge and discharge of groundwater, therefore, the zoning should be compared with the maps of the network of waterways, geology, and land use of the study area to ensure the accuracy and precision of the zoning and to understand the changes in the depth of groundwater in the study area. According to the land use map of the study area, the largest share of land use is agriculture and orchards

And the highest density of wells is also dependent on these sectors and can be considered as a serious risk for the region. The main waterways in the study area include the Aji Chai River, Basmanj Chai, Zinjanab Chai, Mehran Rud Chai, and Saeed Abad Chai. The discharge point of all rivers is Lake Urmia. However,except for the main Aji Chai River, whose flow reaches the lake during the rainy season, the rest of the rivers of the studied plain are inaccessible due to agricultural uses, infiltration, or evaporation and do not reach Lake Urmia. According to the map of the waterway network and its comparison with the zoning map, it is clear that around the Aji Chai and Zinjanab Chai rivers, the depth of groundwater is close to the ground surface, which can be explained by the evaporative sediments present in the area and the feeding of aquifers from the river.

In the paper [6], the average water level of the wells of the Tabriz Plain from April 2001 to March 2009 was studied and the decrease in the water level of the wells was investigated.The annual zoning map of the groundwater level of the Tabriz Plain region for 2018 is shown in Figure 2 [4].

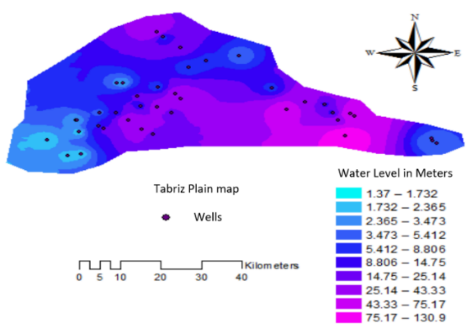

Fig. 2. The annual zoning map of the groundwater level of the Tabriz Plain region for 2018 is shown in Figure 2

The diffusion equation is one of the most important mathematical tools for modeling water flow in aquifers. This equation, based on Darcy's law and the principle of conservation of mass, describes the behavior of water movement in a porous medium. In general, the diffusion equation states that the rate of change of the concentration of a substance at a point in space is proportional to the Laplacian of the concentration of that substance.

The general form of the diffusion equation for groundwater flow is expressed as equation (1):

$$\partial h/\partial t = \nabla (T \nabla h) + Q \quad (1)$$

In this equation, h, t, T, ∇ and Q are respectively, Hydraulic head (height of water above a reference level), time, hydraulic conductivity tensor (which indicates the ease of water movement in different directions), Nabla coefficient (for calculating gradient), and source or well term (e.g. rainfall, well withdrawals).

The term source or well (Q) includes all water inputs and outputs to the system, such as precipitation, evaporation, river flow, and well withdrawals. Key assumptions in using the diffusion equation Isotropic medium: the hydraulic conductivity is the same in all directions.

Homogeneous medium: i.e., the properties of the medium (such as hydraulic conductivity) are the same at all points.

Steady and steady flow: the water flow is so slow that inertial effects can be neglected. Incompressible water: the density of water is assumed to be constant. Due to the complexity of the aquifer geometry and the heterogeneity of their properties, it is usually not possible to solve the diffusion equation exactly analytically. Therefore, numerical methods such as the finite difference method, the finite element method, and the finite volume method are used to solve this equation approximately.

2.1. Investigating various factors of the groundwater crisis in the Tabriz plain

The groundwater situation in the Tabriz plain is currently critical and worrying. Years of excessive and disproportionate extraction of water from aquifers have caused serious problems in this plain [6]. Various factors are involved in this crisis, including the following:

Excessive water extraction: Population growth, agricultural and industrial development without proper planning, have increased water demand, and extraction from groundwater resources has increased significantly. The number of unauthorized wells has also contributed to this problem. Decreased aquifer recharge: Climate change and reduced annual rainfall have reduced the amount of water infiltration into underground aquifers. Also, destruction of vegetation and land use change are effective in reducing water infiltration into the ground.Poor water quality: In many parts of the Tabriz plain, groundwater quality has decreased due to the infiltration of pollutants (urban and industrial wastewater, fertilizers, and agricultural pesticides). This has made it difficult to use water for agricultural and drinking purposes. Lack of proper management of water resources: The lack of comprehensive and sustainable planning for the management of groundwater resources is one of the main reasons for the escalation of this crisis. The lack of enforcement of laws and regulations related to the protection of water resources and the lack of adequate monitoring of withdrawals have contributed to this problem.

2.2. Suggested solutions to improve the situation

To improve the groundwater situation in the Tabriz plain, urgent and comprehensive measures must be taken: Control and reduce excessive withdrawals: Identify and block unauthorized wells and manage water consumption in the agricultural, industrial, and domestic sectors.

Develop modern irrigation methods: Use drip and sprinkler irrigation methods to reduce water consumption in the agricultural sector. Optimize water consumption in the industrial sector: Use modern technologies and water consumption management systems in industries. Raise public awareness: Educate and create culture about the importance of saving water consumption and protecting groundwater resources. Implement artificial recharge plans:Injecting water into aquifers in areas where it is possible, such as implementing watershed management projects to increase water infiltration into the ground.

Continuous monitoring of water levels and groundwater quality: Closely monitor the status of groundwater to make appropriate management decisions.

Overall, the groundwater situation in the Tabriz plain is very critical and requires urgent and fundamental measures to prevent the crisis from escalating and to restore these valuable resources. This requires cooperation and synergy of all relevant agencies and institutions, as well as active participation of the people.

3. Consequences of the Decrease in Groundwater levels in the Tabriz Plain

Decrease in water quality: Salinity of groundwater due to the infiltration of salt water from the lower layers and the decrease in water quality for agricultural and drinking purposes Negative impact on soil condition: The presence of chemical elements in urban and industrial wastewater causes negative effects on the soil in terms of physical and chemical aspects.

Land subsidence: The decrease in groundwater levels in the Tabriz plain has caused land subsidence in various regions. In addition to economic losses, this subsidence brings environmental and even human risks. Buildings, infrastructure facilities and agricultural lands are at serious risk. Decrease in agricultural production: Reduced access to quality water for agriculture causes a decrease in agricultural production and, as a result, economic problems for farmers.

Threat to biodiversity: The decrease in groundwater levels and changes in water quality have a negative impact on the biodiversity of the region and cause a decrease in the population of various animal and plant species.

4. Strategies to Deal with the Water Crisis in the Tabriz Plain

Optimal water consumption management: implementing pressurized irrigation schemes, modifying the cultivation pattern, using modern irrigation technologies, and increasing water consumption efficiency.

Development of surface water resources: restoring canals, constructing small and medium-sized dams, using greenhouse crops, and using surface water for agricultural and industrial purposes

Wastewater treatment: improving wastewater collection and treatment systems and preventing contaminated wastewater from entering aquifers

Control of water well withdrawal: determining the amount and period of permitted well withdrawal according to seasonal rainfall, blocking unauthorized wells, and installing smart meters

Awareness and education: increasing public awareness about the importance of water and ways to save water.

The water crisis in the Tabriz plain is a serious challenge that requires immediate and coordinated actions by all executive agencies and the public. By implementing appropriate solutions and adhering to the principles of sustainable development, this crisis can be prevented from escalating and a better future can be guaranteed for future generations.

5. Important Studies and Research on Optimal Groundwater Extraction Management in the Tabriz Plain

In recent years, numerous studies and research have been conducted to investigate the groundwater status of the Tabriz plain and provide optimal management solutions. These studies have addressed various aspects of this issue with the help of groundwater resource modeling in the Tabriz plain, including the following:

Hydrological modeling: Many studies have developed numerical models to simulate groundwater flow in the Tabriz plain. These models allow researchers to examine the impact of various factors such as rainfall, well withdrawals, and land use changes on groundwater levels.

Water quality modeling: In addition to quantitative modeling, qualitative models have also been developed to predict changes in groundwater quality and identify factors affecting it.

6. Assessing Sustainable Harvesting Potential

Determining the permissible withdrawal rate: Several studies have determined the permissible withdrawal rate of groundwater in the Tabriz Plain to prevent further reduction of groundwater levels and salinization of the waters.Assessing the stability of aquifers: Researchers have assessed the stability of aquifers in the Tabriz Plain using various indicators and identified critical areas. Analyzing the impact of various factors on the status of groundwater

Impact of climate change: Some studies have examined the impact of climate change on the reduction of rainfall and, as a result, the reduction of groundwater levels.

Impact of human activities: The impact of agricultural, industrial, and urban activities on the status of groundwater has been another topic examined in various studies.

7. Providing Optimal Management Solutions

Demand management: Several studies have presented solutions for managing water demand, including modifying cropping patterns, using low-energy irrigation methods, and improving productivity in the industrial sector.

Supply management: Other studies have examined solutions for increasing water supply, including rehabilitating canals, constructing small and medium-sized dams, and reusing wastewater.

Groundwater resource protection: Several studies have examined solutions for protecting groundwater quality, including controlling industrial and agricultural pollution. The most important results of these studies show that:

Excessive groundwater extraction, reduced rainfall, and land use change are among the most important factors in reducing groundwater levels in the Tabriz plain. For optimal management of groundwater resources, a comprehensive and integrated approach is needed that includes demand management, supply management, and groundwater resource protection.

7.1. Methods of Extraction from Groundwater Resources

Deep Wells: These wells are dug deep to extract water from aquifers. Qanats:

Qanats are ancient water structures that use gravity to transport water from aquifers to the surface of the earth. Hand Wells:

These wells are shallower than deep wells and water is extracted from them using hand tools.

7.2. Modern Methods of Extraction

Seawater Distillation

In this method, salty seawater is heated to evaporate, and then the water vapor is distilled and converted into fresh water.

Reverse Osmosis: In this method, salty water is passed through a semi-permeable membrane under pressure, and salt and other solids remain on the other side of the membrane. Rainwater Harvesting: Collecting rainwater through roofs and tanks is one of the old and effective methods of providing water. Fog collection:

In mountainous and coastal areas, using special nets, the moisture in the air (fog) is collected and converted into fresh water.

7.3. Factors affecting the selection of water harvesting method

Amount of water required: Depending on the amount of water required, different methods are selected.

Required water quality: Different qualities of water are required for different uses such as agriculture, industry and drinking.

Economic costs: The costs of drilling wells, building dams, water treatment, etc. are effective in selecting the water harvesting method.

Climatic and geological conditions: The climatic and geological conditions of the region are also effective in selecting the water harvesting method.

Environmental considerations: The selection of the water harvesting method should be done by considering its environmental impacts.

Selecting the appropriate water harvesting method requires careful and comprehensive studies. Water engineers and hydrologists choose the best method for each region and specific conditions, taking into account various factors.

7.4. Advantages and disadvantages of different methods of groundwater extraction

Water extraction from underground sources is one of the main methods of providing water for various uses, including agriculture, industry, and drinking. Each of the methods of groundwater extraction has its own advantages and disadvantages, and the selection of the most appropriate method depends on various factors such as the type of aquifer, the depth of the aquifer, water quality, the amount of extraction required, and the geological conditions of the region.

7.5. Main methods of groundwater extraction

Deep wells

Advantages: Access to water at great depths, the possibility of extracting large volumes of water in a short time, better control over the amount of extraction. Disadvantages: Drop in groundwater level, salinization of water, land subsidence, high cost of drilling and equipment, need for electrical energy to pump water.

Qanats

Advantages: Traditional and sustainable method, using gravity to transport water, low cost, environmentally friendly.

Disadvantages: Limited capacity, drought sensitivity, need for constant maintenance, reduced water flow in dry years.

Hand wells

Advantages: Simple and low cost, suitable for domestic and livestock use in rural areas.

Disadvantages: Limited capacity, need for manpower to extract water, possibility of water contamination.

7.6. Factors affecting the selection of the appropriate method

Aquifer type: The type of aquifer (free or pressurized) is effective in selecting the extraction method.
Aquifer depth: The depth of the aquifer determines the type of well and the equipment required.

Water quality: The quality of groundwater affects its uses.

Required extraction rate: The amount of water required for different uses determines the type and number of wells.

Geological conditions of the region: The geological conditions of the region affect the possibility of drilling a well and its performance.

Economic costs: The costs of drilling, equipping, and maintaining wells are influential in choosing the extraction method.

Challenges of groundwater extraction

Declining groundwater levels: Excessive extraction of groundwater causes the water level to drop and wells to dry up.

Water salinization: The intrusion of saltwater into freshwater aquifers and increased water salinity are common problems in arid and semi-arid regions.

Land subsidence: Excessive extraction of water from aquifers creates voids and, as a result, land subsidence.

Groundwater pollution: The entry of industrial and agricultural pollutants into aquifers reduces water quality.

8. Sustainable Groundwater Management

For sustainable management of groundwater, the following measures should be taken:

Determining the permissible withdrawal rate: Using hydrological studies, the permissible withdrawal rate from each aquifer should be determined.

Water quality control: Water quality should be periodically controlled and pollutants should be prevented from entering the aquifer.

Using low-consumption irrigation methods: In the agricultural sector, low-consumption irrigation methods such as drip and sprinkler irrigation should be used.

Water recycling: Treated wastewater should be used for non-potable purposes.

Raising public awareness: Informing people about the importance of water and the need to save its consumption.

By adopting these measures, groundwater resources can be used sustainably and water crises can be prevented.

8.1. Strategies for improving the situation

Optimal withdrawal management: Determining the permissible withdrawal rate from each well, controlling water quality, and preventing the drilling of unauthorized wells. Development of low-consumption irrigation methods: Using drip and sprinkler irrigation methods to reduce water consumption in the agricultural sector. Water recycling: Using treated wastewater for non-potable purposes. Raising public awareness: Informing people about the importance of water and the need to save its consumption. Protection of groundwater resources: Preventing pollutants from entering aquifers. The groundwater situation in the Tabriz plain is very critical and requires urgent and coordinated measures for the sustainable management of these resources. Given the importance of water in human life and sustainable development, all capacities should be used to preserve and restore these valuable resources.

8.2. Quantitative optimization of water withdrawal with a comprehensive approach

Quantitative optimization of water withdrawal means reducing the volume of water that is withdrawn from various sources, especially groundwater. This is necessary not only to preserve water resources but also to improve productivity and reduce costs. A comprehensive approach to optimizing this process includes a combination of the following measures:

8.2.1. Creating culture for the general public:

Public education: Raising awareness about the importance of water, the challenges of water scarcity, and ways to save water.

Encouraging responsible behavior: Encouraging people to use water optimally in homes, gardens, and other places.

Conducting information campaigns: Using various media to promote a culture of saving water.

8.2.2. Using modern agricultural methods:

Drip and sprinkler irrigation: These methods reduce evaporation and increase irrigation efficiency.

Cultivating of low-consumption crops:Replacing high-consumption crops with low-consumption crops.

Using new technologies: Using soil moisture sensors, smart irrigation systems, and water management software.

8.2.3. Optimal methods for industries:

Water recycling: Reusing treated water for industrial purposes.

Utilization of new technologies: Use of industrial equipment and processes with less water consumption.

Optimization of production processes: Reduce water consumption in different stages of production.

Benefits of quantitative optimization of water withdrawal:

Conservation of groundwater resources: Reduce pressure on aquifers and prevent water level drop.

Increase water productivity: Optimal use of water and reduce its waste.

Reduce production costs: Reduce costs related to pumping and water treatment.

Increase environmental sustainability: Reduce water pollution and improve environmental quality.

Challenges and solutions:

Resistance to behavioral change: Changing people's consumption habits requires time and continuous effort.

Initial investment cost: Using new methods and new technologies requires initial investment.

Lack of information and knowledge: Many farmers and industries are not sufficiently aware of new irrigation and water management methods.

Solutions to address challenges:

Financial facilities: Provide low-interest facilities and loans to purchase new equipment and technologies.

Education and promotion: Conducting training courses for farmers and industrialists.

Encouragement and motivation: Providing financial and non-financial incentives for farmers and industries that use optimal methods.

Formulation of laws and regulations: Establishing appropriate laws and regulations to manage water consumption and encourage the use of optimal methods.

Quantitative optimization of water withdrawal is an inevitable necessity. By adopting a comprehensive approach and cooperation of all sectors of society, desirable results can be achieved in this field.

8.3. Quality optimization of water withdrawal with a comprehensive approach

Quality optimization of water withdrawal means improving the quality of water withdrawn from various sources, especially groundwater. This is essential to ensure human health, environmental protection and productivity in industries. A comprehensive approach to optimizing this process includes a combination of the following measures:

8.3.1.Identification and control of pollution sources:

Point sources: Identification and control of pollution from industries, wastewater treatment plants and agricultural effluents.

Non-point sources: Control of pollution from surface runoff, chemical fertilizers and agricultural pesticides.

8.3.2.Improvement of wastewater collection and treatment systems:

Development and modernization of treatment plants: Improving treatment technology and increasing the efficiency of pollutant removal.

Separation of industrial and domestic wastewater: Preventing the mixing of industrial wastewater with domestic wastewater and improving the quality of treatment.

8.3.3.Proper management of industrial wastewater:

Advanced treatment: Using advanced treatment methods to remove specific and persistent pollutants.

Wastewater recycling: Reusing treated wastewater in industries and agriculture.

8.3.4.Protection of groundwater resources:

Establishing protection zones: Designating protection zones around groundwater resources and preventing polluting activities in these areas.

Water quality monitoring: Conducting periodic tests to monitor groundwater quality and identify possible changes.

8.3.5.Education and information:

Public awareness: Educating people about the importance of water quality and their role in preserving this valuable resource.

Farmer education: Educating farmers about the correct methods of using fertilizers and agricultural pesticides.

8.3.6.Formulation of laws and regulations:

Strengthening environmental laws: Formulating strict laws to control water pollution and punish violators.

Monitoring the implementation of laws: Strengthening the supervisory system to ensure the proper implementation of laws and regulations.

8.3.7.Benefits of optimizing the quality of water withdrawal:

Maintaining public health: Reducing the risk of diseases caused by the consumption of contaminated water.

Environmental protection: Improving the quality of surface and groundwater and protecting biodiversity.

Sustainable development: Providing quality water for various uses and supporting sustainable development.

Increasing the added value of agricultural products: Producing higher quality agricultural products and increasing export capacity.

9. Conclusion

This article examined the water crisis in the Tabriz plain and the problems caused by the lack of optimal use of water resources. This article provided diverse and comprehensive solutions for the optimal management of water resources. By increasing public awareness and how to optimally use this divine blessing, residents of the Tabriz plain can reduce many of the problems caused by water shortages despite droughts. The results of this research show that in order to deal with this major challenge, in addition to the government, the people also need a comprehensive and inclusive approach. All sectors of society should participate in this work with the right perspective.

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