Opportunities and challenges of utilizing well water for aquaculture in Basrah government, Southern Iraq

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Abstract

The current study aimed to assess the environmental and economic feasibility of using well water in fish farming in Basrah Governorate. It reviewed the global importance of aquaculture and its vital role in providing food and income, emphasizing that water quality is a fundamental factor in the success of aquaculture projects. The study discussed the current status of fish farming projects in Basrah and the problems they face due to the deterioration of water quality in the Shatt al-Arab. It also evaluated the possibility of using well water as an alternative, referring to some studies that showed contamination of well water in the governorate. The study relied on the quantitative and spatial distribution of groundwater in Basrah Governorate using satellite imagery processed with Geographic Information System (GIS) software. The current study proposed some modern technologies for treating and purifying well water for reuse in fish farming, with the necessity of establishing environmental, social, and economic controls to ensure sustainability. The study concluded that adopting a comprehensive approach that considers all aspects will contribute to achieving a balance between developmental needs and the preservation of natural resources.

Keywords: Fish farming, Shatt Al-Arab water, Well water, Water pollution, Water treatment, GIS.

The Importance of Aquaculture Globally

Aquaculture projects play a significant role in providing food, income, and livelihoods for millions worldwide. The aquaculture experts ensure that this industry can bridge the gap between available natural protein sources and the growing needs of growing communities (FAO, 2010; Naylor *et al.*, 2000). Over the past years, aquaculture has played a fundamental role in supporting food security at local, regional and global levels. Many studies indicate that over 50% of the fish, crustaceans and molluscs consumed globally are products of aquaculture (FAO, 2020). This confirms the ability of aquaculture to address significant challenges in supporting food security worldwide. Aquaculture contributes to preserving the natural stocks of aquatic organisms and their natural habitats directly or indirectly, as well as protecting species facing the threat of overfishing (Lorenzen *et al.*, 2010; Naylor *et al.*, 2000). Annual reports from the Food and Agriculture Organization (FAO) indicate that fish farming provides employment opportunities for millions of people globally and significantly supports economic development.

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This development and the available job opportunities are not limited to the fish farming sector but extend to other related fields (FAO, 2020).

Water Quality as a Determinant of Success

Different fish species have varied requirements related to water quality, which helps them grow and survive. Suitable water for farming is determined based on temperature, pH, oxygen concentration, turbidity, salinity, and other important factors (Table 1) (Woynarovich *et al.*, 2011). There are ideal ranges for these factors, within which the highest levels of fish growth are achieved. Degraded water quality can lead to decreased oxygen levels in the aquatic environment, causing rapid fish mortality (Diaz and Breitburg, 2009). Continuous accumulation of waste in farming water can negatively affect the delicate gill structure, leading to increased concentrations of harmful elements in the bloodstream, reducing growth and threatening the overall fish health (Matey *et al.*, 2008). Moreover, the deterioration of water quality in the farming area can gradually degrade the surrounding environment, resulting in eutrophication and increased algae growth, ultimately leading to death of farmed fish. Thus, it is evident that high-quality water is essential to support successful and sustainable fish farming projects. Shatt Al-Arab has provided numerous services that have long been a source of community well-being in Basrah, including fishing and fish farming projects along its banks. Fishing is an ancient practice for rural residents in the governorate and a favourite hobby for many city dwellers, while fish farming is a relatively modern practice dating back to the end of the twentieth century (Ahmed *et al.*, 2020). Aquaculture flourished during that period due to increased demand resulting from population growth and government policies that encouraged fish farming by providing loans to farmers and supporting the import of manufactured feeds with high nutritional value. The abundance and suitability of Shatt Al-Arab water for fish farming at that time were also critical factors in the success of farming projects, offering attractive profits that encouraged investment (Ahmed *et al.*, 2020). Common carp (*Cyprinus carpio*) is the primary species farmed in Iraq. Carp can tolerate a wide range of temperatures, pH levels and salinity (Woynarovich *et al.*, 2011).

A recent study by Ahmed (2020) mentioned two main methods of fish farming in the governorate: floating cages and earthen ponds, with cages being the preferred system in Basrah due to their easy construction from locally available materials at a relatively low cost However, most cage farms in the governorate have failed and had their licenses revoked in recent years due to changes in the quantity and quality of water in Shatt Al-Arab and its tributaries. Dams and irrigation projects on the Tigris and Euphrates rivers have diverted much of the water flow heading to the Shatt Al-Arab. Wastewater from both Iraq's and Iran's industry and households flows into the rivers untreated, further contaminating the water supply (UN, 2020). The quality of the river's water has also deteriorated due to the direct discharge of domestic, agricultural and industrial waste into Shatt Al-Arab and its tributaries, originating from upstream countries and within Basrah Governorate. These factors have negatively impacted fish farming projects, as high salinity

affects feeding, feed conversion rates and fish growth rates (Habib *et al.*, 2024). Additionally, significantly increased salinity weakens the immune system of fish, making them more susceptible to diseases (Sun *et al.*, 2023). The rise in salinity levels in Shatt Al-Arab water has led to massive losses in the farming sector, estimated at billions of dollars (Ahmed and Al-Zewar, 2020; Ahmed and Hameed, 2021). Consequently, farmers have been seeking alternative water sources that are more suitable in terms of quantity and quality to sustain fish farming projects in the governorate.

Important Environmental Factors for Aquaculture and the Tolerable Ranges for Carp.

Table 1 environmental factors suitable for the growth of carp and the lethal levels.

Quality/parameters	Minimum	Optimal/ Desired range	Maximum	Lethal
Temperature (°C)	4	25-20	30	35.8-35
Turbidity (mg/L)		<25		
pH	6.5	7-8	8.5	<4.7->10.8
Salinity (part per million)		0.5-1.5	5.0	
Relative conductivity at 20°C (µS/cm)		800	1600	
Dissolved oxygen (mg/L)	4	>6		
Hardness (ppm)	100	120-180	300	
Ammonium ion (mg/L) (pH dependent)		<1.0000	2.50	
Free ammonia (mg/L)			0.02	
Nitrite ion (mg/L)		<0.1000	0.30	
Nitrate Ion (mg/L)		<20	40	
Hydrogen sulphide (mg/L)			0.002	
Orthophosphate ion (mg/L)		0.3000	2.00	
Arsenic (mg/L)		0.0500	0.10	
Zine (mg/L)		0.2000	0.70	1.0000
Mercury (mg/L)		0.0005	0.001	
Cadmium (mg/L)		0.0030	0.004	0.0050
Chrome-total (mg/L)		0.0100	0.020	0.1000
Nickel mg/L)		0.0200	0.100	
Lead (mg/L)		0.0100	0.05	0.1000
Iron (mg/L)		<0.5000	0.90	
Copper (mg/L)		0.2000	0.022	1.0000
Cyanide (mg/L)		0.0100	0.10	
Total suspended material (mg/L)		1000	1500	
Petroleum (mg/L)				0.3000
Diesel (mg/L)				0.0400
Petrol (mg/L)				0.0050

*Source: Woynarovich *et al.* (2011).

Well Water as a Valuable Source for Fish Farming

Well water is a valuable resource for fish farming projects because its quantity and quality tend to be relatively stable in specific locations. Additionally, groundwater is free from wild fish and predators (Shahmohammadi-Kalalagh *et al*., 2017). The suitability of well water for fish farming primarily depends on the requirements of the species intended for farming. In general, well water can be a good alternative to surface water in aquaculture projects if it is free from pollutants such as bacteria, viruses and chemicals, and has appropriate temperature, salinity and pH levels for the types of fish or crustaceans to be farmed.

Well Water in Basrah Governorate

The Dibdibba layer is an important source of groundwater in Basrah Governorate, characterised by its sandstone composition. It provides water for various purposes, including agriculture and grazing. However, studies have shown that groundwater in the Dibdibba layer faces significant challenges due to increased salinity and pollution from various sources, making it unsuitable for human consumption in most areas (Al-Mallah *et al*., 2022). In this context, 37 groundwater samples were collected from wells in the confined Dibdibba aquifer between Safwan and Al-Zubair in Basrah Governorate to assess the groundwater quality.

The analysis of physical and chemical factors revealed that all samples were unfit for drinking due to high levels of total dissolved solids (TDS) and unsuitable for irrigation purposes due to high sodium absorption ratio (SAR), sodium percentage, permeability index, magnesium concentration and residual sodium bicarbonate (Abdulameer and Al-mallah, 2018). In a study by Younus and Al–Khafaji (2016), the concentrations of polycyclic aromatic hydrocarbons (PAH) in groundwater were estimated for eight wells located at different distances from the Shuaiba oil refinery in Basrah. The study identified 16 PAH compounds in the water samples, suggesting that the high PAH levels were likely due to dissolved/suspended hydrocarbons transported by rainfall through the soil to the groundwater, with oil refineries being the primary source of PAH pollution in nearby wells. A study by Mohammed *et al*. (2023) aimed to assess the groundwater quality in southern Basrah Governorate in three selected areas (Zubair, Safwan and Umm Qasr). Fifty groundwater samples were collected, and their physical and chemical characteristics were analysed to calculate the Water Quality Index (WQI) using 12 indicators. The results showed that groundwater quality was generally poor, with high salinity and TDS, and it was unfit for human consumption according to World Health Organization standards.

Dawood *et al*. (2016) evaluated the quality of groundwater taken from 29 wells in southern Basrah (Safwan, Zubair and Umm Qasr) and its suitability for industrial, construction and agricultural uses. The pH, electrical conductivity (EC), total dissolved solids (TDS) and major ions were measured. The results indicated that, according to global standards, groundwater was unfit for industrial use and unsuitable for irrigation except for salt-tolerant plants, and it might require treatment before being used in agriculture.

When 37 groundwater samples were collected from the shallow Dibdibba aquifer during wet and dry periods, the physical and chemical parameters showed spatial and temporal variations across the studied areas (Al-Mallah *et al*., 2022).

There is no study assessing the suitability of well water for fish farming in Basrah Governorate. However, Ahmed (2021) evaluated the concentration of heavy metals (copper, zinc, chromium, nickel, mercury, lead and cadmium) in the muscle tissue of common carp farmed in groundwater in Khor Al-Zubair, Basrah Governorate. The X-ray fluorescence (XRF) analysis revealed that the average concentrations in edible fish parts exceeded the maximum safe levels for human consumption set by the FAO, WHO, European Commission and FDA regarding chromium, nickel, mercury, lead and cadmium. The results indicated that the fish muscle tissue was unfit for human consumption, and the groundwater was likely contaminated with heavy metals, mainly due to industrial activities in the Khor Al-Zubair area.

Overall, the groundwater in Basrah is generally polluted and cannot be directly utilized for fish farming. Figures 1 and 2 show the quantitative and spatial Distribution of groundwater in Basrah governorate Using Satellite Imagery Processed with GIS Software.

Modern Techniques for Treating Salty and Polluted Water and Reusing It for Fish Farming

Different pollutants require different treatment methods. A study by Hashim *et al*. (2011) reviewed 35 significant methods for removing trace elements from groundwater, classifying them into three main categories: chemical, biochemical and physicochemical. The study focused on the advantages of each method while considering environmental sustainability and economic viability issues.

To address salinity, Yasin *et al*. (2020) mentioned various water purification methods, such as desalination using polymeric, ceramic and composite membranes with nanofibres/nanomaterials to filter groundwater. The nanofibres and nanomaterials are incorporated into these membranes to enhance their performance.

A study by Meiramkulova *et al*. (2022) compared the effectiveness of natural and synthetic zeolite in groundwater purification and concluded that both types of zeolite were effective in treating groundwater, with synthetic zeolite showing higher performance in removing heavy metal ions due to its larger pore size advantage. Moussavi and Bagheri (2012) noted the effectiveness of the combined adsorption technique on beryllium powder followed by exposure to $O_3H_2O_2$ in removing petroleum hydrocarbons from contaminated groundwater. Moreover, a study by Demenev *et al*. (2021) evaluated the effectiveness of biological degradation of total petroleum hydrocarbons (TPH) using stimulation and bioaugmentation methods. The results showed a significant decrease in TPH concentration and water quality improvement. Purifying and reusing groundwater for fish farming can be a crucial step towards achieving food security and sustainable development. However, strict regulations must be implemented to ensure responsible water resource utilisation. This can be achieved by adhering to environmental policies and

regulations, adopting best practices in water and aquaculture management, providing training and raising awareness among farmers and consumers, and coordinating with all stakeholders to ensure water resource sustainability.

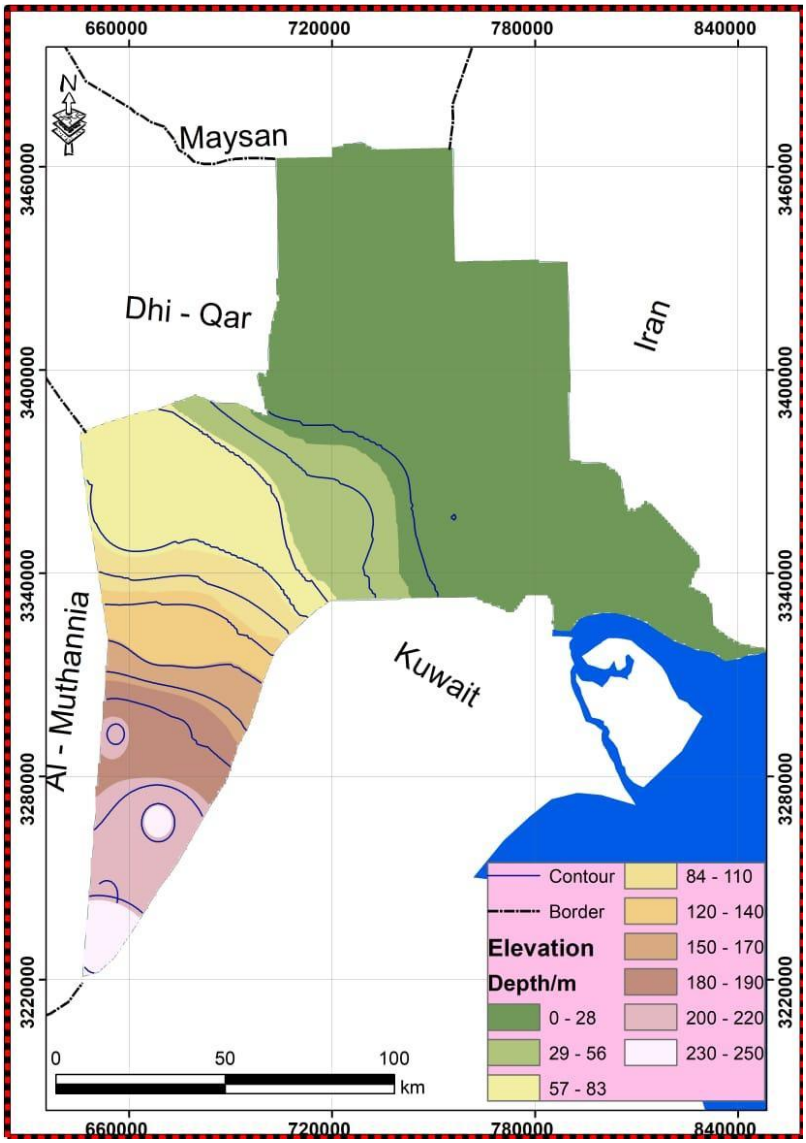

Figure 1. Quantitative Distribution of Groundwater in Basrah Governorate Using Satellite Imagery Processed with GIS Software.

Conclusions and Recommendations

Several important conclusions can be drawn from the current review:

1. Most studies emphasise the importance of fish farming in meeting the growing demand for fish and supporting food security, with the quality of farming water being the critical factor in the success and sustainability of fish farming projects.
2. There are significant challenges related to the sustainability of fish farming projects in Basrah due to the deterioration of water quality in Shatt Al-Arab.

3. Some studies have found high levels of salinity and pollution in well water in Basrah, limiting its direct use for fish farming.
4. Several promising modern techniques can treat and purify well water for sustainable use in fish farming.

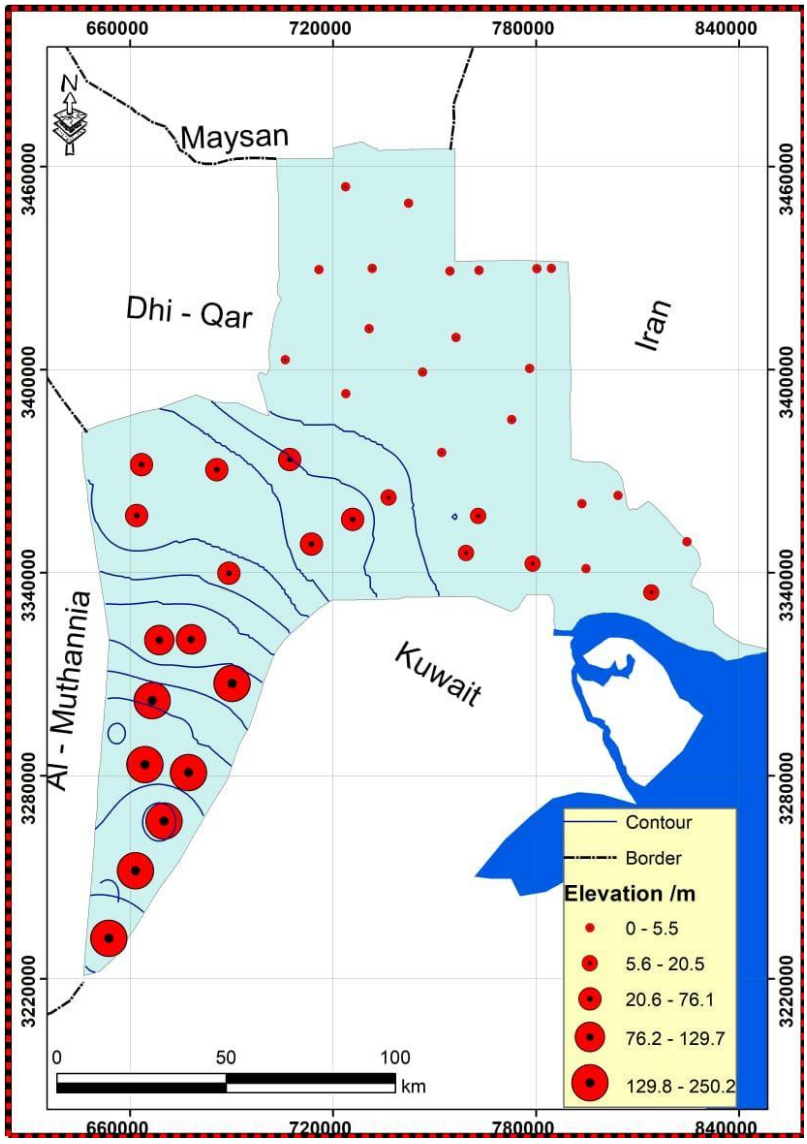

Figure 2. Spatial Distribution of Groundwater in Basrah Governorate Using Satellite Imagery Processed with GIS Software.

Based on these findings, the current study concludes that using well water for fish farming in Basrah is a promising option but requires further research to develop well water treatment techniques and ensure the sustainability of this valuable water resource. It also necessitates establishing regulations and legislation to optimize and sustainably manage well water utilisation in fish farming operations.

Practical Recommendations for Future Research in Using Well Water for Fish Farming:

1. Conduct field studies to assess water quality in specific areas of Basrah and its suitability for fish farming.
2. Perform practical experiments to test the effectiveness of selected water treatment and purification techniques in improving the quality of salty and polluted well water.
3. Undertake economic studies to estimate the costs and expected returns of using well water compared to surface water sources.
4. Carry out environmental impact assessments to evaluate the ecological consequences of using well water for fish farming on soil and groundwater quality.
5. Perform social impact assessments to gauge local communities' acceptance of using well water for fish farming.
6. Conduct legislative and regulatory studies to determine the necessary controls and laws for sustainably using well water.

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فرص وتحديات الاستفادة من مياه الآبار في تربية الأحياء المائية في محافظة البصرة جنوب العراق

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المستخلص

هدفت الدراسة الحالية إلى تقييم الجدوى البيئية والاقتصادية لاستخدام مياه الآبار في الاستزراع السمكي في محافظة البصرة واستعرضت أهمية الاستزراع المائي عالمياً ودوره الحيوي في توفير الغذاء والدخل، مع التأكيد على أن نوعية المياه عامل أساسي في نجاح مشاريع الاستزراع. ناقشت الدراسة الوضع الراهن لمشاريع الاستزراع في محافظة البصرة والمشكلات التي تواجهها بسبب تدهور نوعية مياه شط العرب كما قيّمت إمكانية استخدام مياه الآبار كبديل، مع الإشارة إلى بعض الدراسات التي أظهرت تلوث مياه الآبار في المحافظة. اعتمدت الدراسة على التوزيع الكمي والمكاني للمياه الجوفية في محافظة البصرة باستخدام صور الأقمار الصناعية المعالجة ببرنامج نظم المعلومات الجغرافية (GIS). اقترحت الدراسة الحالية بعض التقنيات الحديثة لمعالجة وتنقية مياه الآبار لإعادة استخدامها في الاستزراع السمكي مع ضرورة وضع ضوابط بيئية واجتماعية واقتصادية لضمان الاستدامة. خلصت الدراسة إلى أن اعتماد نهج شامل يراعي جميع الجوانب، سيسهم في تحقيق التوازن بين الاحتياجات التنموية والحفاظ على الموارد الطبيعية.

الكلمات المفتاحية: الاستزراع السمكي، مياه شط العرب، مياه الابار، تلوث المياه، معالجة مياه، نظم المعلومات الجغرافية