Impact of Urbanization on Groundwater Quality of Water Bodies in Cities: Public Perceptions of the Reservoir in the Tigris-Euphrates Basin in Iraq

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Abstract

Groundwater, crucial for nearly half of the global population's drinking water, confronts escalating threats due to urbanization, including pollution from improper waste disposal, industrial activities, and agricultural practices. This is equally so in Iraq. In this context, this study examines the Tigris-Euphrates Basin. It employs a theoretical framework to establish the urbanization-groundwater quality relationship, emphasizing land-use change as the primary contaminant.

The research utilized an assessment form to ascertain public perceptions of diverse urbanization impacts on groundwater quality, of the Tigris-Euphrates Basin. This is a valuable tool for a comprehensive understanding.

The research reveals key factors influencing groundwater quality in the Tigris-Euphrates Basin. They are the land-use change, improper wastewater disposal, industrial activities, and agricultural practices. The paper thus emphasizes the significance of strategic interventions to safeguard groundwater quality. It recommends preserving agricultural and natural lands, implementing sustainable urban development practices, enhancing wastewater management infrastructure, and enforcing regulations on industrial activities. Promoting sustainable agriculture and increasing vegetation cover are highlighted as essential measures.

By addressing these factors and recommending these measures, this study aims to contribute to the protection of groundwater quality in the Tigris-Euphrates Basin, ensuring its availability for current and future generations. The research underscores the critical nexus between urbanization and groundwater quality, urging comprehensive understanding and proactive strategies for sustainable water management.

Keywords: Groundwater, Urbanization, Tigris-Euphrates Basin, Pollution, Land-use

Introduction

Groundwater is a vital natural resource that plays a crucial role in ensuring water security for many communities around the world. It is the primary source of drinking water for

nearly half of the world's population and provides a significant proportion of water used in agriculture and industry. Maintaining the quality of this resource is essential not only for the current needs but also for the future generations.

The pace of urbanization has been relentless, especially in the latter half of the 20th century and into the 21st century. Cities and towns around the world have seen extensive growth. Urban developments bring with them various challenges, including the potential to degrade groundwater quality. Several factors arising from urban development can contaminate groundwater reserves. For example, improper waste disposal can lead to the leaching of pollutants into groundwater. Increased impermeable surfaces can alter natural recharge patterns, which can reduce the amount of water that recharges groundwater aquifers. Various other urban activities can also introduce new contaminants into the groundwater systems. An understanding of these factors is essential for policymakers, urban planners, and environmentalists to make informed decisions and to craft effective strategies that protect the valuable groundwater resources. In this context, this paper examines the intricate dynamics between urbanization and groundwater quality in Iraq. It aims to provide a comprehensive understanding of the challenges posed by rapid urban development there. It intends to unravel the complexities surrounding the impact of urbanization on groundwater in the Tigris-Euphrates Basin in Iraq and delineate the critical factors influencing water quality within the urban areas. Its objectives are as follows.

1. To comprehensively analyze the urbanization impact
    - To identify the multifaceted impact of urbanization on groundwater quality, addressing factors such as land-use change, wastewater disposal, industrial activities, agricultural practices, and climate change.
    - To investigate the interconnected pathways through which urbanization influences groundwater contamination, considering the conversion of land, increased impermeable surfaces, and reduced vegetation cover.
2. To develop Mitigation Strategies
    - To propose evidence-based recommendations and strategies to mitigate the adverse effects of urbanization on groundwater quality in the Tigris-Euphrates Basin.
    - To emphasize the importance of proper wastewater disposal, enforcement of environmental regulations, educational outreach, and the need for ongoing research to develop effective mitigation approaches.

Theoretical Framework

There is a good understanding about this issue among the scholars such as Brindha and Schneider, (2019) and Brammer and Ravenscroft (2009) They offer a clear understanding of the ways in which urbanization affects ground water quality. The equation they suggest goes as follows.

- Urbanization → Land-use change → Water flow → Groundwater recharge → Pollutant transport → Groundwater quality

This model suggests that urbanization can lead to groundwater contamination through a variety of pathways. Land-use change, in particular, is a major driver of groundwater contamination. The conversion of land from agricultural or natural areas to urban areas can lead to changes in the way that water flows through the landscape. This can affect the recharge of groundwater aquifers and the transport of pollutants to groundwater.

The specific factors that are included in the model are based on the existing knowledge from the literature. These factors include:

- Land-use change: The conversion of land from agricultural or natural areas to urban areas can lead to the following changes in the way that water flows through the landscape:
    - Increased impermeable surfaces such as roads and buildings, can reduce infiltration and increase runoff. This can lead to the transport of pollutants from the surface to groundwater (Brindha and Schneider, 2019).

    - Reduced vegetation cover can also reduce infiltration and increase runoff (Brammer and Ravenscroft, 2009).
- Wastewater disposal: Improper wastewater disposal is a major source of groundwater contamination. Wastewater can contain a variety of pollutants, including pathogens, nutrients, and heavy metals. These pollutants can leach into groundwater and contaminate drinking water supplies (Brindha and Schneider, 2019).
    - Industrial activities: Industrial activities can also release pollutants into the environment that can contaminate groundwater. These pollutants can include heavy metals, organic solvents, and other hazardous substances (Han et al., 2014).
    - Agricultural practices: Agricultural practices, such as the use of fertilizers and pesticides, can also contaminate groundwater. Fertilizers can leach into groundwater and contribute to nutrient pollution. Pesticides can break down into harmful chemicals that can also contaminate groundwater (Han et al., 2014).
- Climate change: Climate change is expected to have a significant impact on groundwater quality. Rising temperatures can increase the evaporation of water from soil and groundwater, which can lead to lower groundwater levels. Changes in precipitation patterns can also affect groundwater recharge (Brindha and Schneider, 2019).

This research employs a groundwater quality assessment form based on this theoretical framework that explains the conceptual model of the relationship between urbanization and groundwater quality

Review of Literature

A diverse range of studies highlights the multifaceted nature of urbanization's impact on groundwater quality, drawing attention to various contributing factors and their interconnections. Among them, Wu et al. (2018) and Chen et al. (2022), (Wu et al. 2018; Zhang, Geng, and Wei (2022) as well as Brindha and Schneider (2019) and Brammer and Ravenscroft (2009) stand out. This literature review critically synthesizes existing research on the impact of urbanization on groundwater quality, with a focus on the Tigris-Euphrates Basin.

Wu et al. (2018) and Chen et al. (2022) examine Urbanization and Groundwater Contamination**.** They have extensively discussed how improper wastewater disposal significantly contributes to groundwater contamination by introducing pathogens, nutrients, and heavy metals. They underline the urgent need for improved wastewater management in urban areas (Wu et al. 2018; Zhang, Geng, and Wei 2022). Similarly, Brindha and Schneider (2019) examine the agricultural practices and groundwater relationship. They focus on the role of agriculture in exacerbating groundwater pollution is another critical aspect. Brindha and Schneider (2019) in fact, emphasize that the use of fertilizers and pesticides in agriculture leads to nutrient pollution and the release of harmful chemicals into groundwater systems. This suggests a pressing need for sustainable agricultural practices to mitigate this form of pollution.

At the same time, Brammer and Ravenscroft (2009) examine the Land-Use Change and Water Flow. They point out that the transition from natural or agricultural landscapes to urban areas profoundly affects water flow and groundwater recharge. Moreover, Brammer and Ravenscroft (2009) show that such land-use changes facilitate the transport of pollutants into groundwater, highlighting the need for careful urban planning and land management. On the contrary, Brindha et al. (2014) examine climate change and groundwater quality and thereby bring to light how climate change, through rising temperatures and altered precipitation patterns, can lower groundwater levels and impact recharge. They point out that this evolving challenge requires adaptive strategies to safeguard groundwater resources against climate change impacts (Brindha et al. 2014).

In fact, there are Regional Implications of this process if viewed from the Global Perspectives. In this connection, Wu et al. (2018) and Gomez et al. (2020) argue that urbanization poses a global threat to groundwater quality, necessitating a comprehensive

approach to mitigation. In fact, Jassam (2021) underscores the importance of holistic strategies that encompass proper waste disposal, strict enforcement of environmental regulations, and proactive educational outreach. Wu et al. (2018) Al-Jaberi et al. (2021) and Colclough et al. (2021) agree with this position.

However, studies focusing specifically on the Tigris-Euphrates Basin in Iraq are rare. Various research studies however examine the interplay of natural and anthropogenic factors that profoundly affect groundwater quality. Al-Ansari et al. (2020) for example, highlighting a critical concern underlined across the Tigris and Euphrates Rivers, points out that the primary water sources in Iraq are increasingly impacted by factors such as dam constructions in upstream countries and extensive irrigation usage. They argue that these lead to reduced flow rates and heightened salinity issues. Nadhir Al-Ansari and Sven Knutsson (2011) affirm this when they say that this reduction has further implications on groundwater reserves, which have been declining significantly over the past decades, severely impacting the agricultural sector and domestic water supply.

André Mueller et al. (2021) also show that urbanization, industrialization, and traditional farming methods compound these challenges by increasing water demand and contributing to water quality deterioration through pollutants such as pesticides and untreated sewage. The situation is exacerbated by climate change, manifesting as reduced precipitation and temperature increases, which further strain the already precarious water resources (Alessandro Tinti 2017).

The necessity to understand and manage these complex hydro-geochemical dynamics have led to the development of the Iraqi Water Quality Index (Iraq WQI), which integrates various water quality parameters to provide a comprehensive assessment of water suitability for different uses (Abdullah et al. 2019). This index is crucial for effective water resource management, especially in urban settings where the impact of human activities is more pronounced.

The hydrogeochemical studies conducted in the region, such as those by Tinti and others, emphasize the importance of integrated water resources management (IWRM) in addressing these challenges, considering the interconnected nature of surface and groundwater systems in the Tigris-Euphrates Basin (Awad et al. 2022). This approach is vital for sustainable water management, ensuring that both the quantity and quality of water resources are maintained for future generations.

In summary, the Tigris-Euphrates Basin in Iraq faces multifaceted challenges regarding groundwater quality, influenced by a combination of natural processes and human activities. Effective management strategies, underpinned by comprehensive research and tools like the Iraq WQI, are crucial to mitigate these challenges and sustainably manage this vital resource.

Research Methods

This study examines a case study: Tigris-Euphrates Basin. Within the case study, it uses a mixed-methods approach to collect and analyze data. Qualitative data is collected through interviews with stakeholders and focus groups with residents of the Tigris-Euphrates Basin. It also uses the groundwater quality assessment form developed to collect data on the presence and extent of the factors that are identified in the theoretical framework. This form was distributed to 150 people via Google Forms (Table 2, Fig.1). The data collected from this form is used to provide a more comprehensive understanding of the impact of urbanization on groundwater quality.

Groundwater Quality Assessment Form

Based on the theoretical ideas discussed above, a groundwater quality assessment form is designed to collect data on the presence and extent of the factors that are identified in the theoretical framework. Data collected from this form is then used to assess the overall impact of urbanization on groundwater quality.

The form is designed to be user-friendly and can be completed by a variety of stakeholders, including researchers, policymakers, and community members. The form is also flexible and can be adapted to different settings and contexts (Table 1).
In fact, the data collected from this form is used to:

- Identify areas that are most at risk of groundwater contamination due to urbanization.
- Develop and implement strategies to mitigate the impact of urbanization on groundwater quality.
- Monitor the effectiveness of these strategies over time.

This groundwater quality assessment form is a valuable tool for improving our understanding of the impact of urbanization on groundwater quality. By collecting data on the presence and extent of the factors that are identified in the theoretical framework, this form engages this important resource.

Table 1: Groundwater quality assessment form
Source: Author

Factor	Description	Score (1-5, with 5 being the best)
Land-use change	The extent to which land has been converted from agricultural or natural areas to urban areas.	
Increased impermeable surfaces	The quantity of impervious surfaces, such as roads and buildings, in the area.	
Reduced vegetation cover	The amount of vegetation cover in the area.	
Improper wastewater disposal	The extent to which wastewater is disposed of improperly, such as in septic tanks or on the ground.	
Industrial activities	The extent to which industrial activities take place in the area.	
Agricultural practices	The extent to which agricultural practices, such as the use of fertilizers and pesticides, take place in the area.	
Climate change	The extent to which climate change is affecting the area, such as through increased evaporation or changes in precipitation patterns.	

The Case Study: Tigris-Euphrates Basin

The Tigris-Euphrates Basin is a major source of water for the Middle East (Fig. 1). The basin is home to a large and growing population, and urbanization is a major challenge. Urbanization in the basin is characterized by the following trends:

- Rapid population growth: Population of the Tigris-Euphrates Basin is growing at a rate of 2.5% per year. This growth is being driven by natural population growth and migration (Makki et al., 2021).
- Increased economic development: Tigris-Euphrates Basin is a major center for economic development. This development is leading to increased urbanization and industrialization (Khayyun and Sharif, 2021).
- Changing land use: Urbanization is leading to changes in land use in the Tigris-Euphrates Basin. Forests and agricultural lands are being converted to urban and industrial uses (Makki et al., 2021).

These trends are likely to lead to increased groundwater contamination in the Tigris-Euphrates Basin. The specific factors that are most likely to be important in this region include:

- Land-use change: The conversion of land from agricultural or natural areas to urban areas is likely to be a major driver of groundwater contamination in the Tigris-Euphrates Basin. This is because the basin is a semi-arid region with limited natural recharge. The conversion of agricultural or natural lands to urban areas will reduce

infiltration and increase runoff, which can lead to the transport of pollutants from the surface to groundwater (Wadhah M. Shakir Al-Khafaji, 2014).

- Wastewater disposal: Improper wastewater disposal is also likely to be a major source of groundwater contamination in the Tigris-Euphrates Basin. This is because the basin is home to a large and growing population, and wastewater treatment infrastructure is often inadequate (Makki et al., 2021; Al–Basrawi, Awad and Hussain, 2015).
- Climate change: Climate change is expected to have a significant impact on groundwater quality in the Tigris-Euphrates Basin. Rising temperatures are expected to increase the evaporation of water from soil and groundwater, which can lead to lower groundwater levels. Changes in precipitation patterns can also affect groundwater recharge (Khayyun and Sharif, 2021).

The specific impact of urbanization on groundwater quality in the Tigris-Euphrates Basin will depend on a number of factors, including the rate of urbanization, the specific land-use changes that occur, and the management of wastewater and other pollutants.

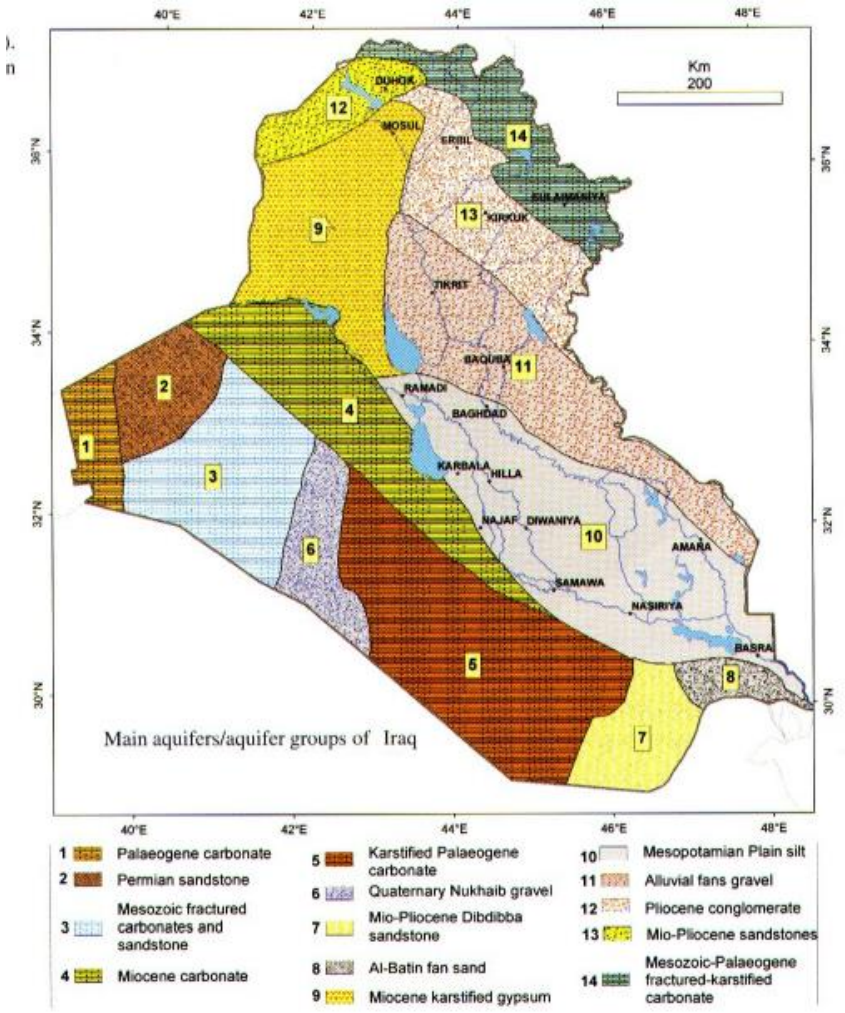

Fig. 1: The main aquifer (Groundwater) groups of Iraq
Source: Jassim and Goff, 2006

Table 2: Groundwater quality assessment of groundwater reservoir in the Tigris-Euphrates Basin
Source: Author

Factor	Description	Score (1-5, with 5 being the best)					Average score
		1	2	3	4	5	
Land-use change	The extent to which land has been converted from agricultural or natural areas to urban areas.	0.22	0.6	0.1	0.05	0.03	2.4
Increased impermeable surfaces	The amount of impervious surfaces, such as roads and buildings, in the area.	0.09	0.25	0.33	0.23	0.1	2.2
Reduced vegetation cover	The amount of vegetation cover in the area.	0.23	0.37	0.26	0.09	0.05	3.7
Improper wastewater disposal	The extent to which wastewater is disposed of improperly, such as in septic tanks or on the ground.	0.12	0.13	0.23	0.3	0.22	2.2
Industrial activities	The extent to which industrial activities take place in the area.	0.18	0.32	0.2	0.27	0.03	2.1
Agricultural practices	The extent to which agricultural practices, such as the use of fertilizers and pesticides, take place in the area.	0.11	0.39	0.25	0.13	0.12	2
Climate change	The extent to which climate change is affecting the area, such as through increased evaporation or changes in precipitation patterns.	0.25	0.3	0.22	0.19	0.04	3.4

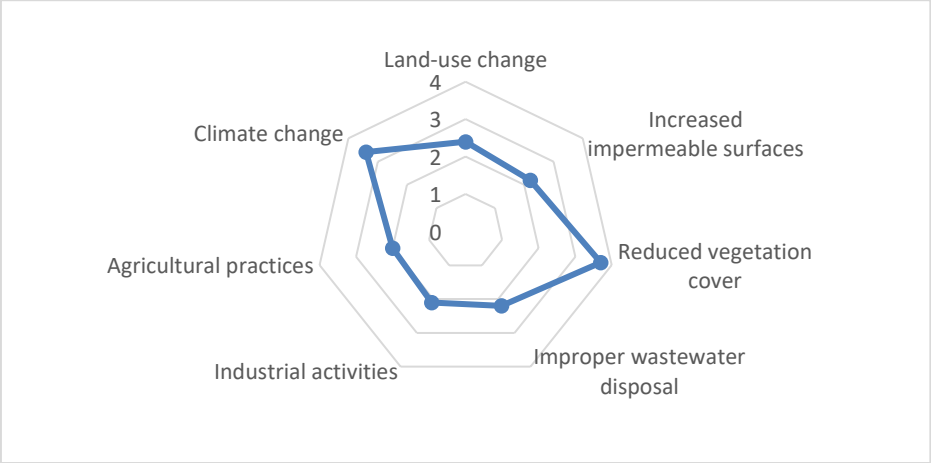

Fig. 2: Assessment of Groundwater Reservoir in the Tigris-Euphrates Basin
Source: Author

Findings

The table provides a good overview of the factors that affect groundwater quality in the area. The factors were rated on a scale of 1 to 5, with 5 being the best. A score of 1 indicates that the factor has a highly negative impact on groundwater quality, while a score of 5 indicates that the factor has a highly positive impact.

The factors with the greatest negative impact on groundwater quality are as follows.

- Land use change: The average score of 2.4 indicates a large negative impact. This is because the conversion of land from agricultural or natural areas to urban areas leads to an increase in impervious surfaces, such as roads and buildings. This prevents rainwater from seeping into the ground and replenishing groundwater supplies.

- Improper wastewater disposal: The average score of 2.2 also indicates a large negative impact. This is because the disposal of wastewater in septic tanks or on the ground contaminates groundwater with harmful bacteria and pollutants.
- Industrial activities: The average score of 2.1 also indicates a large negative impact. This is because industrial activities release pollutants into the air and water, which also contaminate groundwater.
- Agricultural practices: The average score of 2.0 also indicates a large negative impact. This is because the use of fertilizers and pesticides in agriculture also contaminates groundwater.

The factors with the greatest positive impact on groundwater quality are as follows.

- Reduced vegetation cover: The average score of 3.7 indicates a large positive impact. This is because vegetation helps to absorb rainwater and prevent it from running off into streams and rivers. This helps to recharge groundwater supplies.
- Climate change: The average score of 3.4 also indicates a large positive impact. This is because climate change leads to more extreme weather events, such as droughts and floods. These events can increase the amount of rainwater that seeps into the ground and replenishes groundwater supplies.

It is important to note that the impact of each factor on groundwater quality varies depending on the specific location and the other factors that are present. For example, the impact of land use change will be greater in an area with a lot of impervious surfaces than in an area with a lot of vegetation cover.

Conclusions

Based on the comprehensive analysis of the impact of urbanization on groundwater quality in the Tigris-Euphrates Basin, this study concludes with several key insights and recommendations specific to this region:

1. **Significant Negative Impacts:** The primary factors negatively affecting groundwater quality in the Tigris-Euphrates Basin include land use change, improper wastewater disposal, industrial activities, and agricultural practices. These factors significantly contribute to the degradation of groundwater quality, making it imperative to address them with targeted strategies.
2. P**ositive Influences:** The study also identifies factors that have a potential positive impact on groundwater quality, such as increased vegetation cover. This underscores the importance of ecological conservation and reforestation in urban planning to enhance groundwater recharge and quality.
3. **Strategic Recommendations for the Tigris-Euphrates Basin:**
    - **Land Use Management:** Implement policies to minimize land use change by preserving agricultural and natural lands. Urban development should be strategically planned to minimize its impact on groundwater quality.
    - **Wastewater Management Enhancement:** Develop and improve wastewater treatment infrastructure in the basin to ensure safe disposal and treatment of wastewater, thereby reducing groundwater contamination.
    - **Regulation of Industrial Activities:** Enforce strict regulations to control industrial pollution and ensure safe disposal of industrial waste, thereby mitigating its impact on groundwater.
    - **Agricultural Practice Reform:** Promote sustainable agricultural practices, including the judicious use of fertilizers and pesticides, to prevent groundwater contamination.
    - **Vegetation and Green Cover Expansion:** Encourage the expansion of green spaces and vegetation cover in urban and peri-urban areas to enhance natural groundwater recharge and improve water quality.
4. **Future Focus:** This study highlights the urgent need for integrated water resource management and sustainable urban planning in the Tigris-Euphrates Basin. It is

crucial to consider these specific factors and recommendations in policy-making and planning to protect and sustain groundwater resources for future generations.

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