Analysis of Urbanisation, Industrialization, Irrigation Activities, and Ground Water Quality in Indonesia

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There is a growing need to address groundwater quality on a global scale, particularly in countries that heavily rely on urbanisation and industrialization. This has led to an increased focus on dedicated research efforts. This study aims to examine the impact of urbanisation, industrialization, and irrigation activities on groundwater quality in Rengel District, Tuban Regency, Indonesia. Additionally, the research explores the moderating influence of government support in the context of urbanization, industrialization, irrigation activities, and groundwater quality in Indonesia. Primary data were gathered through surveys conducted with officials from the Ministry of National Development Planning in Indonesia, and the reliability of the data and interrelationships among variables were assessed using SPSS-AMOS. The results suggest that there is a link between urbanisation and irrigation activities and groundwater quality in Indonesia. On the other hand, industrialization seems to have a negative impact on groundwater quality. Furthermore, the study highlights the important role of government support in influencing the connections between urbanisation, industrialization, irrigation activities, and groundwater quality in Indonesia.

Keywords: Urbanization, Industrialization, Irrigation Activities, Government Support, Groundwater Quality.

1. Introduction

Human desires are influenced by different factors, but the basic needs like food, water, and air, remain consistent, along with the importance of their quality. Water is an essential element for the human body, playing a crucial role in sustaining life. The availability of water alone is not enough. The quality of water is crucial in determining its impact on the human body, whether it is positive or negative. Groundwater is a crucial source of water that plays a vital role in meeting human water needs. Approximately half of the world's population depends on groundwater for their drinking water, and it also plays a significant role in meeting 43% of the water demands for agriculture (Verma et al., 2020). Groundwater reservoirs are crucial for meeting the daily water needs of a significant portion of the world's population, which amounts to 2.5 billion people. According to projections, it is expected that the Earth's population, which is currently around 8 billion, will increase to 11 billion by the year 2100 (Li et al., 2021). The importance of ensuring a sufficient food supply while also safeguarding climate stability, water resources, and land integrity is crucial for the sustenance of humanity. Regarded as a formidable obstacle that humanity must overcome, lies in effectively managing groundwater in a sustainable manner. The quality of groundwater is crucial for ensuring optimal health outcomes for the global population (Latchmore et al., 2020; Li et al., 2021).

Indonesia, a country with a population of approximately 275 million people, boasts the largest economy in Southeast Asia. However, a considerable segment of the population encounters difficulties in obtaining affordable and secure water, as around 192 million individuals lack access. The limited availability of resources greatly contributes to health issues in the country (Putranto et al., 2018). Fortunately, there is an increasing sense of importance, fueled by national objectives to attain widespread availability of clean water and sanitation by 2024. Both the public and private sectors acknowledge the growing importance of funding for home sanitation and water solutions. In Indonesia, the water quality index in 2022 was 53.88, consistently falling below ideal levels, indicating compromised water quality. Despite the availability of sufficient water supply in most regions, more than 40 million Indonesians continue to face challenges in accessing improved water sources (Rusydi et al., 2021).

Indonesia uses a classification system consisting of 421 "groundwater basins" that are defined by hydrogeological boundaries. The country implements this system to effectively manage and regulate its groundwater resources. With a total groundwater potential of 457,400 million cubic metres per year (MCM/year), the safe yield is conservatively estimated at 137,200 MCM/year due to significant groundwater recharge flowing into rivers (Fitriani et al., 2020). When it comes to safe yield estimates, there are some regions that stand out. Bali, Nusa Tenggara, Java, and Sulawesi have lower estimates, ranging from 400 to 7,700 MCM per year. On the other hand, Kalimantan, Sumatra, and Papua have higher estimations, ranging from 26,000 to 59,000 MCM/year (Wijayanti et al., 2021). Aquifer yields are prominent in the northern plains of Java, South and West Papua, South Kalimantan, East Sumatra, and South Sulawesi. The aquifers in Java play a vital role as sources of potable water (Amanah et al., 2019). A range of global factors, which vary depending on specific circumstances in different locations, influence water quality. The groundwater quality of each country is influenced by various factors, including industrialization, urbanisation, chemical usage in industries and agriculture, irrigation activities, and

government policies (Akhtar et al., 2021; Lopes et al., 2021; Santore et al., 2021). This study focuses on three key factors: urbanisation, industrialization, and irrigation activities. The study also examines the moderating effect of government support. Figure 1 displays the water quality index for Indonesia.

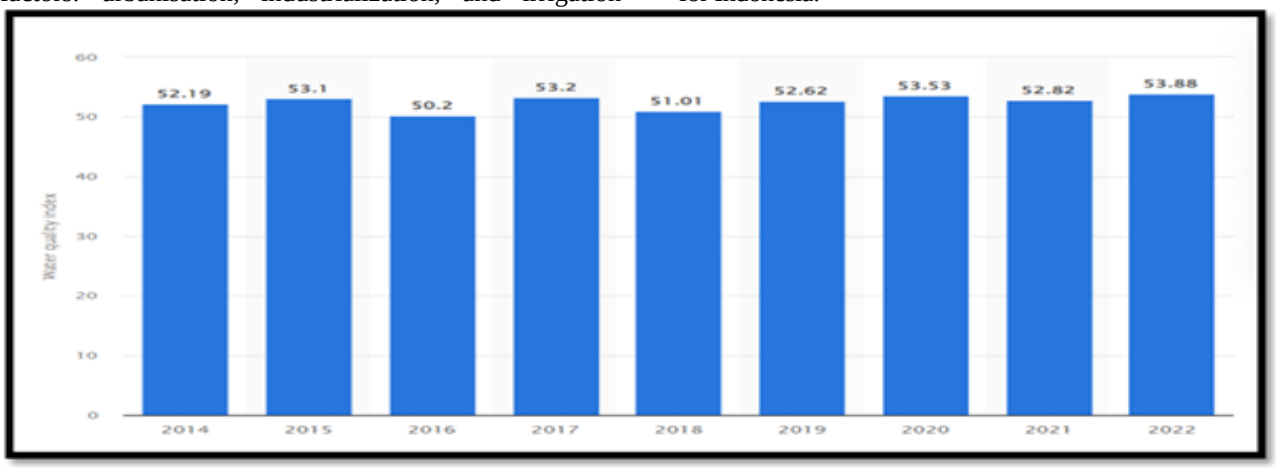

Figure 1: Water Quality Index in Indonesia.
Source: Statista.

This study aims to fill gaps in the literature by investigating a model that includes urbanisation, industrialization, irrigation activities, and groundwater quality, while also considering the moderating effect of government support, specifically in the context of Indonesia. Prior studies have examined the correlation between urbanisation and groundwater quality (Cerqueira et al., 2020; Chelsea Nagy et al., 2012), as well as the influence of industrialization on groundwater quality (Kamal Patel et al., 2014; Rahmana et al., 2021). Studies have examined the relationship between irrigation activities and groundwater quality (Balamurugan et al., 2020; Bouimouass et al., 2022). This study expands upon existing perspectives by considering additional factors and examining the moderating effect of government support. This study extends previous research by examining the role of government support in different relationships. Specifically, it investigates the impact of government support on the relationship between urbanisation, industrialization, irrigation activities, and groundwater quality. The study's significance lies in three key contributions. Firstly, it highlights the importance of clean groundwater for global health. Secondly, it adds to the existing literature on groundwater quality, focusing specifically on Indonesia. Lastly, it enhances the understanding of professionals involved in natural resource management regarding the crucial role of clean water in promoting human well-being.

2. Literature Review

In recent years, there has been a global trend of individuals from rural areas migrating to urban areas in search of modern amenities. The significant increase in urbanisation is associated with higher rates of waste disposal, improper land use, and a lack of concern for the conservation of natural resources. These factors directly affect groundwater quality. Cerqueira et al. (2020) investigated the relationship between urbanisation and water quality in a river in Northeast Brazil, with a specific emphasis on changes in land use. The sampling was conducted twice a year at 16 locations within the basin over a period of 1^2 months, focusing on the analysis of physical and chemical parameters. Significantly higher concentrations of NO3, PO^4, NH^4, NO^2, and NH^3 were found in densely urbanised areas. The results indicate that urbanisation has a notable effect on the levels of dissolved inorganic nutrients in the Cachoeira River Basin. Among the different factors, land use type has the most pronounced negative influence on water quality. This study emphasises the need to prioritise urbanisation considerations in order to protect groundwater quality. It specifically highlights the significance of coastal factors in influencing groundwater dynamics. The coastal areas experience significant urbanisation, which has a considerable impact on water quality in these regions.

In their study, Chelsea Nagy et al. (2012) examined the relationship between urbanisation, stream hydrology, and water quality in the Coastal area of the Gulf Coast. The study collected data on hydrological and microbial aspects in watersheds, focusing on surface gradients ranging from 0 to 15%. The results revealed a significant association between urbanisation and water quality, with noticeable deterioration observed in areas with high levels of urbanisation. Rivers are important water resources worldwide, leading nations to increase conservation efforts for future generations. Increased urbanisation near rivers, aimed at ensuring water availability, has a negative impact on water quality. Luo et al. (2020) investigated the relationship between land use, urbanisation, and water quality, finding a significant correlation between urbanisation and river water quality.

H1: Urbanization has an association with Groundwater Quality in Indonesia.

Globalisation has led to increased global business interactions by creating a closely interconnected world. The increased global business activity has led to a rise in industrialization, causing the release of chemically

polluted water that contaminates groundwater. Kamal Patel et al. (2014) examined the connections between industrialization, urbanisation, and water quality in Gujrat, India. Sampling was conducted at four sites (Causeway, Chowpati, Navadi, and Chowk) over a two-week period. The results showed high levels of pollution in the Tapi River at Chowk, Navadi, and Chowpati, exceeding the established standards. This is likely due to the rapid industrialization and urbanisation in the area. Although pollutants generally disperse and degrade faster in flowing water, many rivers and streams worldwide still suffer from significant contamination. One important factor that affects water quality, especially in developing countries, is the significant release of household waste, which contributes significantly to the negative effects of industrialization on water quality. This highlights the worldwide environmental advocacy position opposing industrialization. Rahmana et al. (2021) examined the relationship between industrialization, urbanisation, and water quality in the Sumara River, Bangladesh. The findings suggest that the overall quality is average, with one-third rated as severe and the remaining two-thirds classified as medium quality. The increased severity is linked to urbanisation and industrialization, requiring control measures to protect water quality and prevent river contamination. Groundwater quality in Nigeria is negatively affected by industrialization. Zacchaeus et al. (2020) conducted a study on 80 samples from different industrial units in Nigeria, which were analysed using SPSS. The findings suggest that industrialization has a negative impact on groundwater quality in Nigeria, with the use of chemicals in industries identified as a major contributing factor.

H2: Industrialization has an association with Groundwater Quality in Indonesia.

Hunger is a significant global challenge that has led to various initiatives being implemented worldwide. In order to tackle this issue, there is a focused endeavour to optimise irrigation techniques in order to improve agricultural productivity. The widespread adoption of artificial irrigation, which involves the use of hazardous chemicals for early and increased food production, poses risks to both land and groundwater quality. Irrigation methods contribute to groundwater impact. The study conducted by Bouimouass et al. (2022) examined the correlation between climate change and groundwater quality in the Attur region of Tamilnadu, India. The investigation specifically analysed 43 bore wells. The study revealed a significant correlation between climate change and groundwater quality in the area. Human activities, synthetic fertilisers, agricultural waste, and the weathering of host rocks and minerals were identified as key factors affecting water quality. The study suggests that prompt primary treatment is necessary prior to consumption. Mora et al. (2022) conducted a study examining the relationship between wastewater irrigation (WWI) and groundwater quality. The study found a connection between the use of wastewater for irrigation and the quality of groundwater. This resulted in higher levels of salinity, ammonium, and nitrates in groundwater resources as a result of wastewater irrigation. The increased salinity of the soil can affect the leaching of heavy metals into groundwater, leading to contamination by pharmaceuticals, phthalates, and sweeteners. Microbiological contamination is most prevalent in shallow or fractured aquifers.

H3: Irrigation Activities have an association with Groundwater Quality in Indonesia.

The rapid pace of urbanisation is causing the depletion of natural resources. The significant level of urbanisation presents challenges for governments in terms of resource provision and management. The adverse impact of urbanisation on natural resources, especially water, requires government intervention to ensure effective resource control through proper management of urbanisation. Saberi and Hamdan (2019) examine the relationship between entrepreneurship and economic growth in GCC economies within the context of modernization. The study uses a 10-year dataset from the Global Entrepreneurship Monitor covering the years 2006 to 2015. The analysis of the data is conducted using the Generalised Method of Moments (GMM) approach. The findings indicate a noteworthy correlation between entrepreneurship and economic growth, which is further influenced by active government support.

H4: Government support moderates the nexus amid urbanization and Groundwater Quality in Indonesia.

Every global economy aims to enhance its business activities to promote a strong economic environment. Government support for industrialization is often driven by the goal of economic growth, but this comes with significant ecological and natural resource consequences. Governments intervene to regulate and control industrial processes when industrialization negatively affects natural resources, specifically groundwater contamination. This intervention aims to safeguard resources like water and air. Anwar et al. (2020) examine the correlation between entrepreneurial finance and venture success in Pakistan within the framework of moderation. The study uses a sample of 182 new ventures selected through simple random sampling and applies the Smart PLS approach for data analysis. The results indicate a notable correlation between entrepreneurial finance and the success of ventures, which is influenced by the presence of government support.

H5: Government support moderates the nexus amid industrialization and Groundwater Quality in Indonesia.

Agriculture plays a crucial role worldwide, not only in providing food but also in creating jobs and making significant contributions to economic revenues. The increasing need for food places significant strain on the agricultural sector, resulting in the implementation of different irrigation techniques, such as the use of harmful chemicals to achieve early and large-scale crop yields. The use of these chemicals has negative effects on the land, groundwater, and environment. As a response, governments intervene through policy formulation and the

imposition of fines to protect natural resources. Xia et al. (2020) examine the correlation between research intensity and diversified performance in current developments. The study employs the SPSS approach for data analysis, utilising two datasets from 2009 to 2017 and later from 2018 to 2019. The results indicate a strong link between the level of research activity and the extent of performance diversification. Additionally, this relationship is influenced by the presence of active government support.

H6: Government support moderates the nexus amid irrigation activities and Groundwater Quality in Indonesia.

3. Research Methodology

This study examines the impact of urbanisation, industrialization, and irrigation on groundwater quality in Indonesia, with a focus on the role of government support as a moderating factor. The collection of primary data involved conducting surveys with officials from Indonesia's Ministry of National Development Planning. The measurement constructs consist of four questions for urbanisation (Lapointe et al., 2020), six questions for industrialization (Lekan et al., 2020), five questions for irrigation activities (Leroy, 2023), three questions for government support (Zulu-Chisanga et al., 2021), and five questions for groundwater quality (Mooney et al., 2021).

The respondents in this study are officials from the Ministry of National Development Planning in Indonesia, selected through purposive sampling. A total of 501 surveys were distributed to the participants' respective institutions through personal visits and official mails. After two months, 291 valid responses were received, resulting in a response rate of 58.08 percent. The reliability of data and relationships among variables were assessed using SPSS-AMOS, a widely recognised statistical tool known for its efficacy in analysing primary data and producing optimal results (Hair et al., 2014). This tool excels in generating precise outcomes when working with extensive datasets and complex models (Hair et al., 2017). The article includes groundwater quality (GWQ) as a predictive variable, government support (GS) as a moderating variable, and three predictors: urbanisation (UR), industrialization (IN), and irrigation activities (IA)—as illustrated in Figure 2.

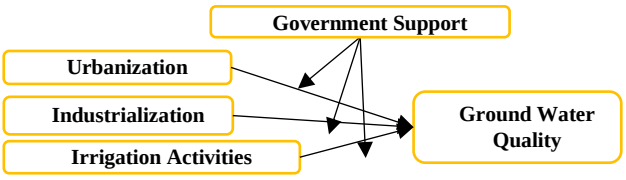

Figure 2: Theoretical Model

4. Research Findings

The investigation examines the relationship between items, known as convergent validity, using multiple criteria. The study examines CR values above 0.70, factor loadings above 0.50, and AVE values greater than 0.50. The study also validates the findings using MSV and ASV values, which should be lower than the AVE. The satisfaction of these criteria suggests valid convergent validity, indicating a strong correlation between items. The findings are outlined in Table 1.

Table 1: Convergent Validity.

Constructs	Items			Loadings	CR	AVE	MSV	ASV
Urbanization	UR1	<---	UR	0.796	0.885	0.657	0.432	0.313
	UR2	<---	UR	0.804				
	UR3	<---	UR	0.824				
	UR4	<---	UR	0.819				
Irrigation Activities	IA1	<---	IA	0.855	0.912	0.722	0.324	0.280
	IA2	<---	IA	0.937				
	IA4	<---	IA	0.867				
	IA5	<---	IA	0.726				
Industrialization	IN1	<---	IN	0.910	0.839	0.523	0.483	0.323
	IN2	<---	IN	0.879				
	IN3	<---	IN	0.601				
	IN5	<---	IN	0.509				
	IN6	<---	IN	0.627				
Ground Water Quality	GWQ1	<---	GWQ	0.770				
	GWQ2	<---	GWQ	0.801	0.792	0.693	0.419	0.488
	GWQ3	<---	GWQ	0.617				
	GWQ4	<---	GWQ	0.596				
Government Support	GS1	<---	GS	0.852	0.786	0.648	0.419	0.349
	GS2	<---	GS	0.755				

The study examines the relationship between variables, known as discriminant validity, using the Fornell-Larcker criteria. This criterion requires that the values indicating connections with the construct itself should be higher than the values indicating connections with other constructs. The satisfaction of this criterion demonstrates the presence of valid discriminant validity, indicating a strong correlation between variables. Table 2 delineates these findings.

Table 2: Discriminant Validity.

	GWQ	UR	IN	IA	GS
GWQ	0.702				
UR	0.657	0.811			
IN	0.695	0.526	0.723		
IA	0.564	0.569	0.527	0.850	
GS	0.348	0.469	0.504	0.449	0.805

The study evaluates the model's goodness of fit using multiple fit indices. The Tucker-Lewis Index (TLI) and

Comparative Fit Index (CFI) must both have values above 0.90, indicating an acceptable model fit. The study also evaluates the Root Mean Square Error of Approximation (RMSEA), with values below 0.05 indicating a well-fitting model. The criteria collectively indicate good fit of the model. The results are presented in Table 3.

Table 3: Model Good Fitness.

Selected Indices	Result	Acceptable level of fit
TLI	0.965	TLI > 0.90
CFI	0.976	CFI > 0.90
RMSEA	0.000	RMSEA < 0.05 good; 0.05 to 0.10 acceptable

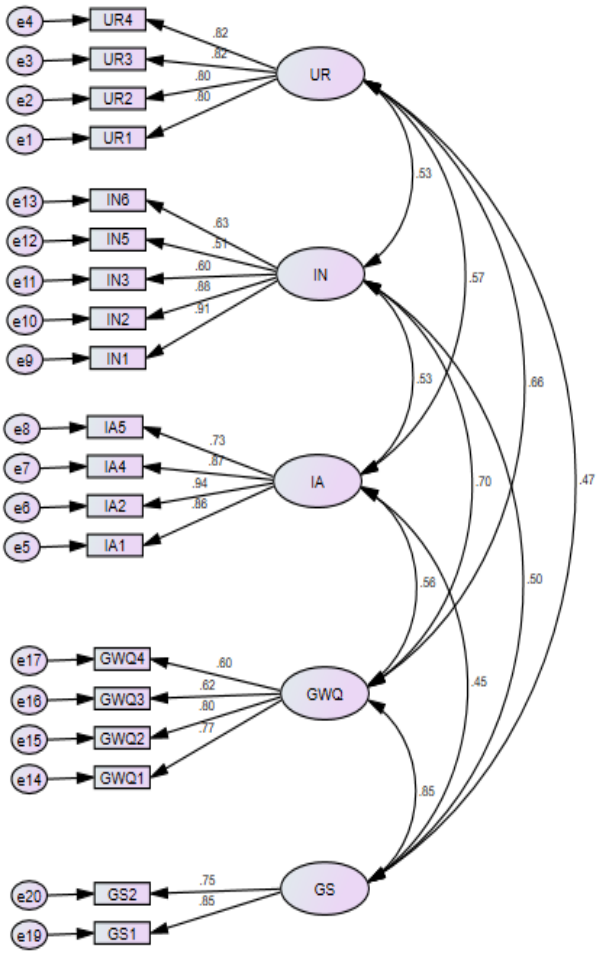

Figure 3: Measurement Assessment Model.

The present study employs path analysis to reveal the relationships between variables. The findings demonstrate a positive relationship between urbanisation and irrigation activities, as well as groundwater quality in Indonesia. Conversely, industrialization shows a negative correlation with groundwater quality, supporting hypotheses H1, H2, and H3. The study's results indicate that government support has a notable impact on the connections between urbanisation, industrialization, irrigation activities, and groundwater quality in Indonesia. This supports the acceptance of hypotheses H4, H5, and H6. The results are presented in Table 4.

Table 4: Path Analysis.

Relationships			Beta	S.E.	C.R.	P
Ground Water Quality	<---	Urbanization	0.201	0.032	6.296	0.000
Ground Water Quality	<---	UR x GS	0.007	0.002	3.500	0.002
Ground Water Quality	<---	Industrialization	-0.043	0.019	-2.263	0.021
Ground Water Quality	<---	Irrigation Activities	0.307	0.032	9.498	0.000
Ground Water Quality	<---	Government Support	0.120	0.030	3.996	0.000
Ground Water Quality	<---	IA x GS	0.061	0.005	11.241	0.000
Ground Water Quality	<---	IN x GS	0.065	0.005	12.545	0.000

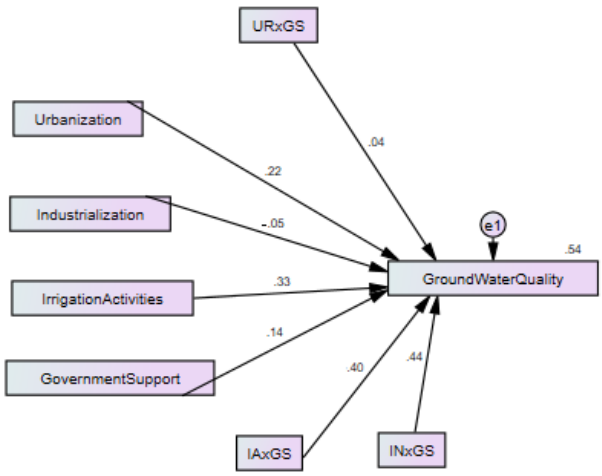

Figure 4: Structural Assessment Model.

5. Discussions

The research suggests a positive link between urbanisation and groundwater quality, as supported by Khan et al. (2020). According to these authors, as urbanisation expands, there is a rise in environmental awareness among the population, leading to a greater focus on activities that could affect groundwater quality. This supports the findings of ul Haq et al. (2021), who suggest that the increase in urbanisation results in the adoption of eco-friendly initiatives, which help protect the quality of groundwater. Conversely, the findings indicate a correlation between industrialization and a decline in groundwater quality. This supports the viewpoint put forth by Karmakar et al. (2023), who argue that an increase in industrial sites results in more chemical processes and manufacturing operations, leading to higher pollution emissions and a decline in groundwater quality. Sarker et al. (2021) highlights the impact of increased industrial practices on groundwater quality. They emphasise that the release of polluting waste emissions from these practices contributes to its deterioration.

The results suggest a positive relationship between irrigation activities and groundwater quality. Adimalla et al. (2020) highlight the importance of utilising high-quality water for crops in irrigation systems to ensure the preservation of good groundwater quality. Batarseh et al. (2021) provides additional evidence for the assertion that increased irrigation practices, beyond dependence on rainwater alone, promote the preservation of groundwater quality. In addition, the study finds that government support plays a significant role in moderating the relationship between urbanisation and groundwater quality. According to Wafa et al. (2020), government support promotes urbanisation and reduces environmental pollution, which helps protect groundwater quality. Ijioma (2021) argues that government support promotes. Urbanisation contributes to the sustainability of groundwater quality. The study demonstrates that government support significantly influences the connection between industrialization and groundwater quality. Zacchaeus et al. (2020) argue that a government that supports economic prosperity and health protection can facilitate responsible industrialization while minimising environmental impacts, thereby maintaining groundwater quality. The findings of Hasan et al. (2022) provide additional support for the argument that government assistance mitigates the negative impacts of industrialization on groundwater quality. The study highlights the important role of government support in moderating the relationship between irrigation activities and groundwater quality. The provision of government support allows farmers to afford efficient irrigation systems, which helps preserve groundwater quality (Gugulothu et al., 2022). Singh et al. (2020) assert that government support is instrumental in improving irrigation systems and preserving groundwater quality.

6. Implications

The current study has important empirical implications, especially in emerging economies where environmental pollution is a pressing issue. This article provides relevant recommendations for regulatory bodies involved in environmental management, highlighting the importance of implementing a well-organized urbanisation approach to improve groundwater quality. The study supports the implementation of environmentally friendly measures during industrialization expansion to reduce pollution and improve groundwater quality. The research highlights the significance of implementing an efficient irrigation system to preserve groundwater quality. The text emphasises the importance of government support and suggests that public endorsement of such support could promote urbanisation, leading to improved groundwater quality. The study suggests that accessible government support should be provided to address the environmental aspects related to industrialization and maintain the quality of groundwater. The research highlights the importance of government support in addressing environmental challenges associated with industrialization and maintaining groundwater quality through supported irrigation systems.

7. Conclusion

This study aimed to investigate the effects of urbanisation, industrialization, and irrigation on groundwater quality, considering the moderating influence of government support. Quantitative data were collected from government officials through the use of questionnaires. The results showed a positive correlation between urbanisation, irrigation activities, and groundwater quality. The process of urban development resulting from rural-to-urban migration has a positive impact on groundwater quality as it helps to mitigate environmental pollution. On the other hand, the increase in industrialization has a detrimental effect on groundwater quality as a result of excessive resource consumption and pollution emissions. The installation of an irrigation system improves groundwater quality by ensuring a consistent water supply. Government support has played a crucial role in facilitating urbanisation, improving industrial administration, and enhancing groundwater quality through improved irrigation systems.

8. Limitations

The study has a few limitations, but these can be overcome with more academic focus. Firstly, the study focuses on examining the effects of urbanisation, industrialization, and irrigation activities on groundwater quality. Unfortunately, the study fails to address important factors like green financial inclusion, social and environmental responsibilities, and energy consumption patterns. As a result, readers may find the guidance provided to be limited in scope. Therefore, it is important for future research efforts to consider these significant factors when analysing groundwater quality. Furthermore, the study's heavy reliance on a questionnaire survey and the sole use of respondents' opinions for hypothesis testing highlight a limitation. A more thorough approach, supported by well-documented and validated information, should be utilised in future studies to strengthen the reliability of the findings.

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