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| RESEARCH ARTICLE

Water Resource Crisis in the Gaza Strip: The Impact of Groundwater and Surface Water Challenges Before and After the October 2023 Conflict

Abderrahmane Noui[1] ✉ and Zineb Guesbaya[2]
[1]*Center for Scientific and Technical Research on Arid Regions (CRSTRA), Biskra, Algeria*
[2]*University of Biskra, Algeria*
Corresponding Author: Abderrahmane Noui, **E-mail**: nouiabderrahmane7@gmail.com

| ABSTRACT
The Gaza Strip, a densely populated area of around 365 square kilometers, faces a severe water crisis driven by over-extraction of groundwater, contamination, and inadequate management. Groundwater, the main fresh water source, is depleting and contaminated by saline intrusion, untreated sewage, and agricultural runoff, making much of it undrinkable. Surface water, including limited rainfall and local streams, cannot meet the growing demand. Gaza Strip receives only about 300 mm of rainfall annually, far below the global average. With over 2 million people relying on limited water resources, extraction exceeds sustainable levels, further exacerbating the crisis. The region's water challenges are compounded by ongoing political and military conflicts, including wars and a prolonged blockade, which have damaged infrastructure and hindered sustainable water management. As a result, 97% of Gaza's groundwater is undrinkable, and water quality continues to decline. This paper examines Gaza's water crisis, focusing on the period before and after the October 2023 war. It highlights how the conflict worsened the situation by damaging infrastructure and depleting resources, and explores the impact on public health and agriculture. The paper also investigates potential solutions to improve water sustainability, such as water treatment, desalination, and regional cooperation in line with Sustainable Development Goal 6 (Clean Water and Sanitation).

| KEYWORDS
Gaza Strip, Political Impact on Water, Water Scarcity, Water Quality, Water Management

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1. Introduction

The Gaza Strip, a densely populated region of only 365 square kilometers, lies in the semi-arid zone of Palestine, bordered by Israeli occupation and Egypt, and faces a complex and urgent water crisis. Home to over two million residents, this small territory is heavily reliant on its water resources—primarily groundwater and surface water—to meet its basic needs for drinking, sanitation, and agriculture (Abu Murad et al., 2017). However, the management of these resources has become increasingly difficult due to a combination of political, social, and environmental factors (UNRWA, 2014). Gaza's water crisis has reached critical levels, with rapid population growth, ongoing political conflicts, and environmental degradation compounding the challenges. The region's water systems have been under strain for decades, making the already fragile water infrastructure increasingly unsustainable (UNDP, 2013).

Since the creation of Israeli occupation in 1948, the Gaza Strip has been subjected to a series of profound transformations, both social and political, with devastating effects on its water systems (OCHA, 2019). The region has endured repeated wars, territorial occupations, and blockades, all of which have disrupted vital infrastructure, including water networks, and severely hindered the region's ability to effectively manage its water resources (World Bank, 2009). Gaza's dependence on groundwater, which is the

primary source of fresh water, has left the region vulnerable to over-extraction and contamination (Noui et al., 2022). The absence of effective management and regulation of groundwater resources has made it increasingly difficult to meet the growing demands of the population (Palestinian Water Authority, 2011). Additionally, surface water resources, which include seasonal rainfall and local streams, are insufficient to alleviate pressure on the groundwater supply, especially given the region's erratic rainfall patterns, water scarcity, and the challenges posed by climate change (Abu Murad et al., 2017).

The situation has been exacerbated by the ongoing conflict, which has resulted in the destruction of key infrastructure, including water treatment facilities, desalination plants, and sewage systems (UNDP, 2013). This has further undermined the ability of the people of Gaza Strip to access safe, clean water, which is essential for maintaining public health and ensuring food security (WHO, 2019). The war in October 2023 marked a particularly devastating chapter in Gaza's water crisis, with widespread damage to the region's already fragile infrastructure. The destruction of vital facilities during the conflict deepened the crisis, complicating efforts to restore access to water and sanitation for the population (OCHA, 2019).

This article aims to examine the evolving water crisis in Gaza Strip, providing an in-depth analysis of both groundwater and surface water resources before and after the October 2023 war. We will trace the history of Gaza's water resources, exploring the key challenges that have shaped the region's water crisis. By presenting critical data and statistics, we seek to highlight the severe impact of the conflict on Gaza's water infrastructure and underscore the urgency of addressing these challenges. The article further explores the broader implications for Gaza's long-term sustainability, development, and resilience in the face of ongoing conflict and climate change. Through this analysis, we hope to offer a deeper understanding of Gaza's water struggles and the need for urgent action to safeguard the future of its people.

2. Presentation Of The Study Área Gaza Strip

The Gaza Strip is a small yet highly significant coastal region located in the southwest of Palestine, bordered by the Mediterranean Sea to the west, Egypt to the south, and Israeli occupation to the north and east. It spans an area of approximately 365 square kilometers and is home to over 2 million inhabitants as of 2023, making it one of the most densely populated areas in the world. The population density in Gaza Strip is staggering, with an estimated 5,500 people per square kilometer (PCBS, 2023). This high population density exacerbates the challenges related to resource management, including water, land, and infrastructure.

The region is primarily urban, with Gaza City**,** the largest urban center, acting as the political, cultural, and economic hub of the area. Other major cities such as Khan Younis**,** Rafah**,** and Deir al-Balah are also highly populated, contributing to the overall urbanization of Gaza Strip (PCBS, 2023). The densely populated nature of Gaza Strip, coupled with the severe political, economic, and environmental challenges it faces, makes it a unique and complex region in the context of international politics and humanitarian concerns.

The political situation in Gaza Strip has been turbulent since the establishment of Israeli occupation in 1948, and the region has been under Israeli occupation for decades. This has led to significant challenges in terms of sovereignty, access to resources, and infrastructure development. In addition to its political challenges, Gaza Strip is also heavily affected by blockades that restrict the movement of goods, people, and essential services, further exacerbating the region's vulnerability to humanitarian crises (UNRWA, 2014).

The water crisis is one of the most pressing issues facing Gaza Strip. Due to its location in a semi-arid zone, the region's water resources are scarce and under constant stress from overuse, contamination, and the impacts of climate change. Gaza Strip relies heavily on its groundwater and surface water resources, yet both have been overexploited, leading to severe water shortages, and making it one of the most water-scarce regions in the world (Palestinian Water Authority, 2011).

Figure 1: Geographic location of the Gaza Strip N 31° 28" 07' E 34° 24" 49'

3. Materials And Methods

The study relied on a comprehensive data collection approach, incorporating both local and international sources, to assess the water situation in the Gaza Strip. This multi-faceted approach was critical in understanding the challenges surrounding water resources in this region, as well as in identifying sustainable solutions for future management.

3.1 Data Collection

Data were gathered from a variety of sources, including key local authorities, such as the Palestinian Water Authority (PWA)**,** and prominent international organizations, including the United Nations Development Programme (UNDP) and World Bank. These organizations provided crucial data sets that facilitated an in-depth analysis of Gaza's water resources.

The following key data variables were collected:

1. Groundwater Levels: Groundwater levels were tracked through annual measurements at various wells across Gaza Strip, allowing the study to monitor fluctuations and trends in groundwater depletion, a crucial indicator of resource sustainability. According to the Palestinian Water Authority (2011)**,** Gaza's aquifers are being over-extracted, leading to severe salinization and depletion of this primary water source.

2. Water Quality: Water samples from different regions within Gaza Strip were tested for contamination levels, focusing on salinity**,** nitrate, and chloride concentrations**.** These pollutants are significant indicators of the degradation of groundwater, primarily due to over-extraction and sewage contamination. Studies, such as those by UNDP (2013)**,** show that the quality of water from Gaza's wells has significantly deteriorated over the years, with salinity levels often exceeding acceptable thresholds.

3. Precipitation and Flow of Watercourses: Data on rainfall and the flow of surface water sources, including rivers and seasonal streams, were collected from meteorological stations. UNRWA (2014) highlighted how the erratic rainfall patterns in Gaza Strip have contributed to the inconsistency in surface water availability, worsening the reliance on over-exploited groundwater.

4. Demographic Changes and Water Demand: Demographic data were analyzed to determine how population growth has influenced water demand in the region. The continuous increase in Gaza's population—now over 2 million people—has escalated pressure on available water resources. As World Bank (2009) reports, this rapid urbanization and population growth have compounded the region's water scarcity problems.

3.2 Evaluation Methods

To analyze and interpret the data, several evaluation methods were employed:

1. Groundwater Level Analysis: The study involved evaluating annual groundwater measurements, which were used to track changes in water table levels over time. This analysis allowed the identification of areas facing critical water shortages and provided insight into how extensive the extraction of groundwater has been. For instance, Palestinian Water Authority (2011) reported that Gaza's aquifer is being exploited by up to 190 million cubic meters annually, exacerbating the problem of seawater intrusion and salinity.
2. Surface Water Assessment: The availability and quality of surface water resources, such as seasonal rivers, lakes, and reservoirs, were assessed through hydrological modeling and flow measurements**.** Water quality testing was conducted to detect contamination by chemicals, pathogens, and other pollutants. This comprehensive assessment also included the evaluation of how human activities (like agriculture and urban development) and climate change have impacted surface water availability. For example, Abu Murad & al (2017) showed that Gaza's seasonal rainfall patterns have become increasingly erratic due to climate change, affecting water courses and overall water availability.
3. Water Quality Analysis: Water quality was assessed by analyzing key contaminants, such as nitrates**,** chlorides, and heavy metals**,** which are indicative of contamination from agricultural runoff and untreated sewage. According to Al**-**Maskati (2012)**,** these contaminants have been a significant concern due to the lack of proper sewage treatment and wastewater management, which often results in pollutants leaching into the groundwater system.
4. Socio-political Impact Analysis: A critical part of the evaluation involved examining the socio-political dimensions of the water crisis. This analysis focused on the impact of conflict, blockades, and resource restrictions on Gaza's water infrastructure. The study reviewed how these factors have hindered efforts to develop and maintain water treatment and desalination facilities, exacerbating the crisis. OCHA (2019) documented how the destruction of essential infrastructure due to ongoing conflicts, including the October 2023 war, has severely disrupted water services and aggravated the already precarious situation

4.Results

4.1 Status Of Groundwater

(A) The Coastal Aquifer as the Primary Water Source

The coastal aquifer is the main source of freshwater in the Gaza Strip, providing over 90% of the region's drinking water. However, this vital resource is under extreme pressure due to the growing population, now exceeding 2 million, and the increasing water demand. The natural recharge capacity of the aquifer is approximately 55 million cubic meters (Mm^3) per year, which is the maximum amount it can replenish annually under normal conditions (UNEP, 2020). Unfortunately, the extraction rate has consistently exceeded this limit. In 2023, groundwater extraction reached around 200 Mm^3 per year, nearly four times the recharge capacity, resulting in an annual water deficit of 145 Mm^3 (UNICEF, 2023). This unsustainable extraction has significantly depleted the aquifer. Following the October 2023 conflict, extraction pressures intensified as damaged infrastructure and increased population displacement led to an estimated 10% rise in temporary demand. The continued overexploitation at this rate jeopardizes the long-term availability of this essential resource for Gaza's population (World Bank, 2024).

The table 1 shows the groundwater extraction in million cubic meters (Mm^3), the annual recharge capacity of the aquifer (55 Mm^3), and the water deficit, which has been increasing each year due to over-extraction.

Table 1. Data on groundwater extraction, the recharge capacity of the aquifer, and the water deficit for the years 2020 to 2023.

Year	Groundwater extraction (Mm^3)	Recharge capacity (Mm^3)	Water deficit (Mm^3)
2020	150	55	95
2021	160	55	105
2022	180	55	125
2023	200	55	145

(B) Decreasing Water Levels and Saline Intrusion

One of the most concerning consequences of over-extraction is the sharp decline in groundwater levels. In some areas of Gaza Strip, water levels have dropped by more than 15 meters, severely impacting water accessibility and quality. As the levels decrease, saline intrusion becomes more problematic. The coastal aquifer, located near the Mediterranean Sea, is highly vulnerable to this phenomenon. When water levels drop, seawater infiltrates the freshwater aquifer, leading to high salinity levels in the water. Currently, nearly 80% of Gaza's wells are affected by saline intrusion, with salinity levels exceeding 600 mg/L, far above the WHO's recommended limit of 250 mg/L for drinking water (UNEP, 2023). The October 2023 war exacerbated this issue; damage to the water infrastructure increased the rate of seawater intrusion, affecting approximately 5% more wells and rendering additional water sources undrinkable. This intrusion of saltwater further worsens the water crisis, limiting the population's access to safe, potable water (OCHA, 2024).

The combination of excessive extraction, falling water levels, and intensified saline intrusion due to the recent conflict creates a dire situation for Gaza Strip. The majority of groundwater in Gaza Strip is now deemed non-potable, which critically restricts the availability of safe drinking water for the population. Without substantial changes in water management, infrastructure repair, and conservation efforts, the aquifer will continue to degrade rapidly, threatening the region's water supply and overall sustainability (WHO, 2024).

The table 2 shows the decline in groundwater levels and the increasing percentage of wells affected by saline intrusion, which has worsened due to the ongoing over-extraction and the October 2023 conflict.

Table 2. Data on the drop in groundwater levels and the impact of saline intrusion on wells in Gaza Strip from 2020 to 2023.

Year	Drop in water levels (meters)	Percentage of wells affected by saline instrusion (%)
2020	10	60
2021	12	65
2022	13	70
2023	15	80 (with an additional 5% increase due to the october war)

4.2 Water Quality

A critical concern in Gaza Strip is the poor quality of groundwater. Due to over-extraction and contamination, more than 97% of the groundwater is deemed non-potable. This means that the water from the coastal aquifer is not suitable for human consumption without extensive treatment. The primary factors contributing to this contamination include high levels of nitrates, chlorides, and other harmful substances, which render the water unsafe for drinking, irrigation, and even some industrial uses. The October 2023 conflict further intensified the water crisis, as approximately 10% of existing wells were damaged, exacerbating the already limited access to clean water (UNRWA, 2024).

(A) Nitrate Contamination

One of the main indicators of groundwater contamination is the high concentration of nitrates. In Gaza Strip, nitrate levels in groundwater often exceed 100 mg/L, more than double the limit set by the World Health Organization (WHO, 2023), which recommends a maximum nitrate concentration of 50 mg/L for drinking water. High levels of nitrates are primarily caused by the infiltration of agricultural runoff, including the use of fertilizers, and leakage from septic tanks and untreated sewage (UNEP, 2023). Since the October 2023 conflict, there has been an estimated 15% increase in nitrate contamination due to additional sewage leaks and damaged sanitation infrastructure. Nitrates pose significant health risks, particularly to infants and pregnant women, as they can lead to methemoglobinemia (blue baby syndrome), a condition that impairs the blood's ability to carry oxygen. Long-term exposure to high nitrate levels is also linked to cancer and other serious health conditions (OCHA, 2024).

The table 3 shows how nitrate levels have consistently exceeded the WHO limit of 50 mg/L, with a significant increase in contamination after the October 2023 war due to further damage to sewage systems and sanitation infrastructure.

Table 3. Nitrate contamination levels in groundwater in Gaza Strip from 2020 to 2023.

Year	Nitrate concentration (Mg/L)	WHO recommended limit (Mg/L)	Percentage increase due to october 2023 conflit (%)
2020	90	50	-
2021	95	50	-
2022	100	50	-
2023	115	50	15% increase due to the sewage leaks and damaged infrastructure

(B) Chloride Contamination And Saline Intrusion

Another major issue impacting water quality in Gaza Strip is the high concentration of chlorides, often exceeding 600 mg/L, far above the 250 mg/L recommended by the WHO for drinking water. Elevated chloride levels are a direct indicator of saline contamination, exacerbated by saline intrusion due to the over-extraction of groundwater from the coastal aquifer. The closer proximity of seawater to the groundwater makes the aquifer highly susceptible to saltwater intrusion, which gradually increases the chloride content of the water. As a result, much of the water from the aquifer has a salty taste, making it undesirable and harmful for drinking (WHO, 2024). The October 2023 war worsened this issue, with approximately 5% more areas showing increased salinity levels due to damaged infrastructure that allowed for further saline intrusion. The saline contamination not only makes the water undrinkable but also hampers the agricultural sector, as the high salt content affects soil quality and crop yields (FAO, 2024).

The table 4 illustrates the high concentration of chlorides in Gaza's groundwater, which significantly exceeds the WHO's recommended limit of 250 mg/L. The chloride levels have worsened over time, especially after the October 2023 war, due to infrastructure damage that increased saline intrusion, making the water undrinkable and further impacting the region's agricultural sector.

Table 4. Chloride concentration levels in groundwater in Gaza Strip from 2020 to 2023.

Year	Chloride concentration (Mg/L)	WHO recommended limit (Mg/L)	Percentage increase due to october 2023 conflit (%)
2020	500	250	-
2021	550	250	-
2022	600	250	-
2023	630	250	5% increase due to infrastructure damage and saline intrusion

(C) Untreated Wastewater And Contaminants

The infiltration of untreated wastewater into the groundwater further exacerbates the quality issues. With nearly 40% of Gaza's population relying on septic systems or rudimentary sewage treatment, large quantities of untreated sewage find their way into the environment and seep into the aquifer (UNEP, 2023). The October 2023 conflict led to further damage to sewage infrastructure, increasing the volume of untreated sewage discharged into the environment by approximately 20%. This has resulted in higher levels of pathogens and organic contaminants in the groundwater. The inadequate infrastructure for wastewater treatment, combined with the lack of effective sewage management, significantly worsens the already critical water quality in Gaza Strip. In addition to the nitrate and chloride contamination, the presence of bacteria, viruses, and other harmful microorganisms poses a severe health risk to the population, contributing to a 30% rise in waterborne diseases since the recent conflict (OCHA, 2024).

The table 5 highlights the reliance of Gaza's population on septic systems and the resulting untreated sewage infiltration into the groundwater. The October 2023 conflict further worsened the situation by increasing the volume of untreated sewage and contributing to a rise in waterborne diseases, which directly impacts the public health of the population.

Table 5. Impact of untreated wastewater infiltration on groundwater quality in Gaza Strip.

Year	Percentage of population relying on septic systems (%)	Incease in untreated sewage due to october 2023 conflit (%)	Rise in waterborne diseases (%)
2020	40	-	-
2021	40	-	-

2022	40	-	-
2023	40	20% incease in untreated sewage discharge	30% rise in waterborne diseases

4.3 Surface Water Resources

Gaza's surface water resources are primarily dependent on seasonal rainfall, as there are no significant rivers or large bodies of water in the region. The annual rainfall in Gaza Strip is relatively low, averaging between 200-300 mm per year, and it is unevenly distributed, with some areas receiving up to 350 mm while others receive far less. The region typically experiences its wettest months between November and March, while the rest of the year remains mostly dry. This seasonal rainfall, combined with local streams (which are small and often seasonal), provides approximately 5-10 million cubic meters (Mm^3) of water annually. This quantity represents only about 3-5% of the total water demand, which exceeds 200 Mm^3/year for Gaza's population of over 2 million. Therefore, rainfall and surface water resources are insufficient to meet the needs of the population, placing further stress on the already over-exploited groundwater resources (FAO, 2023).

(A) Retention Facilities And Infrastructure Challenges

One of the significant challenges in managing surface water in Gaza Strip is the poor condition of retention facilities. These facilities, such as dams, reservoirs, and rainwater harvesting systems, are essential for capturing and storing rainwater during the wet months to be used during the dry season. However, due to a lack of investment, maintenance, and ongoing damage from conflicts, many of these structures are either non-functional or inadequately maintained. The blockade and political restrictions further limit the ability to import the necessary materials to repair or build new water storage infrastructure (UNEP, 2024). The October 2023 war intensified these issues, causing additional damage to 15% of Gaza's remaining functional retention facilities. As a result, over 70% of seasonal rainfall flows away without being captured, and the potential for water conservation is significantly reduced (OCHA, 2024).

The table 6 illustrates the decline in the functionality of retention facilities in Gaza Strip over time, with only a small percentage of rainwater being captured due to infrastructure damage and lack of maintenance. The October 2023 conflict worsened the situation by causing additional damage to existing water retention structures, leading to a significant loss in the potential for water conservation.

Table 6. Challenges in managing surface water.

Year	Percentage of functional retention facilities (%)	Percentage of rainwater captured (%)	Increase in damage due to october 2023 conflit (%)
2020	40	30	-
2021	40	30	-
2022	45	35	-
2023	30	30	15% increase in damage due to conflit

(B) Rainwater Harvesting And Its Limitations

While rainwater harvesting has been identified as a potential solution to supplement surface water resources, its capacity remains limited. Approximately 30% of households and businesses in Gaza Strip utilize rainwater collection systems, such as rooftop cisterns, for non-potable uses like irrigation and cleaning. However, these systems collectively store only about 1 Mm^3 per year, far below the required levels to meet the population's needs.

Additionally, these systems are often poorly maintained, and the quality of harvested water is frequently compromised by contaminants from rooftops and storage tanks (UNDP, 2023). Following the October 2023 conflict, over 25% of existing rainwater collection facilities were damaged, further reducing their already limited contribution to Gaza's water supply (OCHA, 2024).

The table 7 illustrates the limited contribution of rainwater harvesting systems in Gaza Strip, both in terms of coverage and volume. The October 2023 conflict caused significant damage to a quarter of the existing rainwater collection systems, further reducing their already small contribution to the region's water supply.

Table 7. Status of rainwater harvesting systems in Gaza Strip.

Year	Percentage of households using rainwater harvesting systems (%)	Annual volume stored (Mm^3)	Percentage of damage due to october 2023 conflit (%)
2020	30	1	-
2021	30	1	-
2022	30	1	-
2023	30	1	25% of existing systems damaged due to conflit

(C) Impact Of Climate Change

Climate change is expected to exacerbate the region's challenges with surface water resources. Rising temperatures and increasingly erratic rainfall patterns mean Gaza Strip may experience longer droughts and more intense rainfall events, which can result in flash floods and soil erosion. For example, the frequency of flash floods in Gaza Strip has increased by 20% over the past decade, a trend likely to continue (IPCC, 2023). These extreme weather events further damage the already fragile infrastructure for collecting and storing surface water, making it even more difficult to meet the water demands of the population. Additionally, shifting rainfall patterns may reduce the total volume of rain, increasing the region's reliance on groundwater and deepening the risk of severe water scarcity (UNEP, 2024).

The table 8 reflects the increasing impact of climate change on Gaza's water resources, particularly through the rise in flash floods and the subsequent damage to water storage infrastructure. With rising temperatures and erratic rainfall patterns, Gaza Strip is facing an even greater challenge in meeting its water needs, further exacerbating the region's reliance on groundwater.

Table 8. Impact of climate change on surface water resources in Gaza Strip.

Year	Increase in flash floods (%)	Impact on water storage infrastructure	Expected effect of climate change
2020	15	Increased damage to retention systems	Increased frequency of extreme weather events
2021	18	Further deterioration of infrastructure	More intense rainfall and flash floods
2022	19	Limited ability to capture water	Reduced rainfall, increased droughts
2023	20	Further damage due to flash floods	Increased reliance on groundwater and risk of scarcity

4.4 Impacts Of Conflicts

The ongoing conflicts and blockade in Gaza Strip have significantly worsened the region's already precarious water crisis, affecting both the availability and quality of water. The prolonged military occupation, wars, and economic blockade imposed by Israeli occupation since 2007 have had a profound impact on Gaza's water infrastructure and its ability to manage water resources effectively (UNHRC, 2023). These impacts can be seen in several key areas:

(A) Destruction Of Water Infrastructure

Since the escalation of conflicts in 2008, Gaza's water infrastructure has been systematically damaged. Airstrikes, artillery shelling, and ground incursions have targeted and destroyed critical infrastructure, including 320 pumping stations, 65 water treatment plants, multiple reservoirs, and pipelines (World Bank, 2023). The October 2023 war caused additional destruction, leaving 20% of Gaza's water facilities non-functional or severely damaged. As a result, large parts of the water network have been rendered inadequate, severely affecting the ability to provide clean water to the population. The repair costs for this extensive damage have accumulated to over 220 million dollars since 2008. However, the blockade has prevented the importation of necessary materials and equipment to rebuild or upgrade the water systems. The lack of construction materials, including cement, steel, and piping, has made it incredibly difficult to restore damaged infrastructure to its full capacity (OCHA, 2024).
The table 9 reflects the ongoing damage to Gaza's water infrastructure due to repeated conflicts, including airstrikes, shelling, and incursions. The repair costs have been substantial, and the blockade has hindered efforts to restore or upgrade the water systems. The situation worsened after the October 2023 war, leaving significant portions of the water network non-functional.

Table 9. Impact of conflicts on Gaza's water infrastructure.

Year	Number of water facilities damaged	Percentage of infrastructure non-functional (%)	Repair costs (USD)	Impact of october 2023 conflict
2008	320 pumping stations, 65 water treatment plants	30%	-	-
2012	Increased damage to pipelines, reservoirs, and treatment plants	40%	Over $50 million	-
2014	Significant destruction due to escalated conflicts	50%	Over $100 million	-
2023	20% additional damage due to October 2023 war	60%	Over $220 million	20% of facilities severely damaged

(B) Water Supply Disruptions

The damaged infrastructure and limited resources for repairs have led to frequent water supply disruptions across Gaza Strip. Water shortages are common, particularly in remote and border areas, where access to clean water is already limited (ICRC, 2024). The situation is exacerbated during times of conflict escalation, such as the October 2023 war, which left an estimated 45% of Gaza's population with no access to piped water for weeks. The impact of these disruptions is severe, with 80% of Gaza's population now relying on emergency water distribution systems, bottled water, or alternative sources like private wells. Additionally, some households and communities are forced to rely on unreliable and unsafe sources of water, which can have significant consequences for public health and sanitation (UNRWA, 2024).
The table 10 highlights the extent of water supply disruptions in Gaza Strip due to the damaged infrastructure, particularly during times of conflict. The October 2023 war intensified these issues, leaving a significant portion of the population without piped water and increasing the reliance on emergency measures, which raises concerns about public health and sanitation.

Table 10. Impact of damaged water infrastructure and limited resources on water supply disruptions in Gaza Strip.

Year	Percentage of population without access to piped water (%)	Main sources of water for population (%)	Impact of october 2023 conflict
2008	25	Emergency distribution, private wells	-
2012	30	Bottled water, emergency systems	-
2014	35	Private wells, emergency distribution	-
2023	45	Emergency distribution, bottled water, private wells	45% of population without piped water for weeks; increased reliance on unsafe sources

(C) Energy Shortages And Pumping Station Failures

Gaza Strip faces severe energy shortages due to the ongoing blockade and restricted access to fuel and electricity. This shortage has a direct impact on the operation of critical water infrastructure, such as pumping stations and desalination plants. These facilities require a constant supply of electricity to pump water from underground aquifers, desalinate seawater, and distribute it to households and businesses. However, daily power cuts, lasting up to 18-20 hours a day in some areas, have left many pumping stations unable to operate at full capacity (World Bank, 2024). Following the October 2023 conflict, these power outages increased by 30%, further reducing water access. Consequently, 80% of Gaza's residents face intermittent or limited access to water, and the water pressure in the network is often too low to reach the upper floors of buildings, affecting households, schools, hospitals, and businesses. In some cases, the shortage of energy and fuel has also prevented the operation of wastewater treatment plants, leading to untreated sewage being discharged into the environment, further contaminating water sources and exacerbating health risks (OCHA, 2024).

The table 11 illustrates the ongoing challenges of energy shortages in Gaza Strip, which affect the operation of water infrastructure and exacerbate the water crisis. Following the October 2023 war, power outages worsened, further limiting access to clean water and increasing public health risks due to sewage contamination.

Table 11. Impact of energy shortages on water infrastructure in Gaza Strip.

Year	Duration of daily power cuts (hours)	Impact on Water access (%)	Main issues	Impact of october 2023 conflit
2008	12-14 hours	60%	Reduced operation of pumping stations and desalination plants	-
2012	14-16 hours	65%	Insufficient water pressure, power shortages at water facilities	-
2014	16-18 hours	70%	Frequent power cuts, inadequate wastewater treatment	-
2023	18-20 hours	80%	Water supply disruptions, sewage contamination	30% increase in power outages after the war worsened access to water

(D) Impediments To Water Infrastructure Development

The blockade has also severely restricted Gaza's ability to develop new infrastructure or expand existing water facilities. International aid and development programs aimed at improving Gaza's water supply and sanitation systems have faced delays and obstructions. This includes restrictions on the importation of materials, equipment, and technologies needed to build or rehabilitate water infrastructure (Human Rights Watch, 2024). The October 2023 war has further complicated these efforts, creating additional delays in funding and resource allocation. Without access to the necessary funds and resources, the long-term sustainability of Gaza's water systems is further compromised. Moreover, the blockade has limited Gaza's ability to access external

support, including technical expertise and financial investment from international organizations that could help improve water infrastructure and provide much-needed solutions for the population (International Crisis Group, 2024).

(E) Disruption To Water Quality And Sanitation

The damage to water treatment plants and sewage systems has further worsened water quality in Gaza Strip. Contaminated water is a major public health issue, with increased incidents of waterborne diseases such as cholera and dysentery (WHO, 2024). The October 2023 war led to the additional destruction of 8 sewage treatment plants, causing an estimated 50,000 cubic meters of untreated sewage to be discharged daily into the Mediterranean Sea, coastal aquifers, and local streams, contaminating both surface and groundwater sources. This further complicates efforts to provide safe drinking water and to manage water resources sustainably in Gaza Strip. The ongoing conflicts have made it more challenging to address these issues, as the disruption of healthcare services and sanitation facilities leaves the population vulnerable to outbreaks of disease (OCHA, 2024).

I. 5. Discussion

Gaza's water resources are under extreme pressure. The coastal aquifer, which supplies over 90% of the freshwater, is severely overexploited, with extraction reaching approximately 200 million cubic meters (Mm^3) per year compared to an estimated natural recharge capacity of 55 Mm^3 per year, leaving an annual deficit of 145 Mm^3. The October 2023 conflict further exacerbated this situation, increasing temporary demand by an estimated 10% due to displacement and infrastructure damage, which led to unsustainable extraction levels. This overexploitation accelerates the depletion of the aquifer, making it difficult to meet future water needs.

In terms of quality, more than 97% of groundwater contains nitrate and chloride levels that exceed WHO-recommended limits. Nitrate concentrations regularly exceed 100 mg/L, double the WHO standard of 50 mg/L, while chloride levels frequently surpass 600 mg/L (WHO limit: 250 mg/L). The October 2023 conflict worsened these contamination levels, as damaged sewage and wastewater infrastructure increased nitrate levels by an estimated 15%, further polluting the aquifer and impacting water quality for thousands of households.

Surface water collection and storage infrastructure remains insufficient. Gaza Strip relies on seasonal rainfall and local streams, which provide only 5-10 Mm^3 per year, covering less than 5% of total water demand. The October 2023 war damaged approximately 15% of Gaza's remaining water retention facilities, causing even more rainfall to be lost rather than captured, thus limiting Gaza's ability to utilize its already minimal surface water resources effectively.

The blockade in place since 2007 has severely restricted Gaza's ability to modernize and maintain its infrastructure. Despite the presence of desalination units, their combined capacity is only 20,000 m^3 per day, far below the 55,000 m^3 per day needed to meet daily population requirements. In addition, frequent power outages, often lasting 18-20 hours per day, further impact the functioning of pumping and treatment stations, complicating access to potable water for around 80% of residents. The October 2023 conflict intensified these power issues, with infrastructure damages resulting in a 30% increase in power outages, further disrupting water access and sanitation.

Without increased investment and substantial infrastructure improvements, Gaza's water crisis is expected to worsen, posing a significant threat to public health and food security. The current state of overexploitation, contamination, and inadequate storage will continue to degrade water quality and availability, especially if the blockade persists and the region remains vulnerable to further conflict.

6. Conclusion

To tackle the water crisis in the Gaza Strip effectively, it is essential to establish clear, measurable targets that can drive tangible and sustainable outcomes. These actions must align with the broader framework of Sustainable Development Goal 6 (SDG 6)**,** which aims to ensure universal access to clean water and sanitation, addressing the unique challenges faced by Gaza's population.

1. Immediate Expansion of Desalination Capacity**:** Gaza Strip is currently facing a dire water shortage, requiring at least 55,000 cubic meters per day from desalination plants to meet the basic needs of its population. Presently, desalination facilities are operating well below this capacity, producing only around 20,000 cubic meters per day**.** Increasing desalination capacity to meet the minimum target would significantly reduce Gaza's dependency on the over-exploited Coastal Aquifer, which is being extracted at a rate of 190 million cubic meters per year**,** far beyond sustainable limits. Addressing this gap would provide a reliable source of potable water, ensuring that the population's basic water needs are met and relieving pressure on the increasingly saline aquifer.

2. Wastewater Treatment and Reuse**:** Wastewater management in Gaza Strip remains highly inadequate, with large amounts of untreated or partially treated wastewater being discharged into the Mediterranean, exacerbating environmental pollution and health risks. The development of wastewater treatment infrastructure to process and reuse 40 million cubic

meters annually—equivalent to about 40% of Gaza's agricultural water demand—could greatly enhance sustainable farming practices, reduce reliance on fresh water, and contribute to food security. Currently, only around 70 million cubic meters of wastewater are treated, but much of it does not meet the necessary quality standards for safe reuse. Upgrading and expanding treatment facilities would improve agricultural irrigation efficiency, providing farmers with a more consistent water supply while alleviating the strain on drinking water sources.

3. Water Conservation and Efficiency: Gaza's agricultural sector, which accounts for a significant portion of water usage, could decrease its water consumption by up to 15% by implementing more efficient irrigation systems like drip irrigation**,** which minimizes water waste. Additionally, promoting water-saving practices in households—such as low-flow fixtures and public education on conservation—would further reduce demand. While the percentage reduction may appear modest, it would contribute significantly to stabilizing the region's fragile water resources. With 97% of Gaza's aquifer now contaminated by saline intrusion, these conservation measures could help extend the life of this critical resource, securing its availability for future generations.

4. International Support and Infrastructure Rehabilitation: The October 2023 conflict has caused severe damage to Gaza's already fragile water infrastructure, impacting over 60% of desalination plants and wastewater treatment facilities. Immediate reconstruction efforts are essential, with an estimated $200 million required to restore basic water and sanitation services. Long-term infrastructure projects aimed at sustainable management would necessitate an additional $500 million. This reconstruction is not only crucial for immediate recovery but also for securing long-term access to clean water and preventing further degradation of the water supply system.

The involvement of the international community is absolutely critical to ensuring that these efforts are adequately funded and supported. As Gaza's population—currently over 2 million people—faces increasing risks from water scarcity, health crises, and food insecurity, the urgency of international collaboration cannot be overstated. Without immediate and sustained action, Gaza's water crisis will worsen, potentially leading to devastating consequences for public health, agriculture, and regional stability.

Implementing these quantified, targeted actions will provide the foundation for a more secure and resilient water management system in Gaza Strip. These interventions, if supported adequately, will not only help address the immediate water needs but also create a sustainable framework for future generations, ensuring long-term water security and environmental stability for the people of Gaza Strip. Without such interventions, the region will continue to face an escalating crisis that could have far-reaching socio-economic and environmental consequences for the entire Middle East.

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