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Chemical and Microbiological Analysis of Groundwater After a Major Flood Event in Darna City

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التحليل الكيميائي والميكروبيولوجي للمياه الجوفية بعد وقوع فيضان كبير في مدينة درنة

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Abstract:

This study evaluates the impact of severe flooding caused by Storm Daniel on groundwater quality in Derna city. Groundwater samples from five wells were collected immediately after the flood and analyzed for physical, chemical, and microbiological parameters. Wells 1 and 2 were located within the flooded area, while Wells 3, 4, and 5 were nearby but were not submerged.

The results indicate that the pH values of groundwater samples ranged from 7.17 to 7.61, remaining within the permissible limits set by both national (Libyan standards, 2008) and international (WHO guidelines, 2003) water quality standards.

Total Dissolved Solids (TDS) levels were generally within acceptable limits, except in Wells 1 and 2. The highest TDS concentration was recorded in Well 2 at 1837 mg/L, followed by 1147 mg/L in Well 1.

Electrical Conductivity (EC) values exceeded the permissible limit of 1400 µS/cm in several wells. The highest EC value was recorded in Well 2 at 3675 µS/cm.

The concentrations of cations (Mg^{2+}, Ca^{2+}, and Na^{+}) were mostly within allowable limits. However, sodium levels exceeded the standards in some samples. Among anions, sulfate (SO_4^{2-}) and chloride (Cl^{-}) concentrations were notably elevated, especially in Wells 1 and 2, exceeding both national and international permissible limits.

The total bacterial count per milliliter detected in the well water revealed the presence of bacteria in Wells 1 and 2. Notably, water from these wells was found to be unfit for drinking.

Keywords: Groundwater quality, Total Dissolved Solids, Electrical Conductivity, pH values, microbiological parameters.

الملخص

تقيّم هذه الدراسة تأثير الفيضانات الشديدة التي تسببت بها العاصفة دانيال على جودة المياه الجوفية في مدينة درنة. تم أخذ عينات من المياه الجوفية من خمسة آبار مباشرة بعد حدوث الفيضان، وتحليلها من حيث الخصائص الفيزيائية والكيميائية والميكروبيولوجية. تقع البئران (1) و(2) داخل المنطقة التي غمرتها مياه الفيضان، في حين تقع الآبار (3) و(4) و(5) في مناطق قريبة لكنها لم تُغمر بالمياه.

تشير النتائج إلى أن قيم الأس الهيدروجيني (pH) لعينات المياه الجوفية تراوحت بين 7.17 و7.61، وبقيت ضمن الحدود المسموح بها وفقًا للمعايير الوطنية (المواصفات الليبية لعام 2008) والمعايير الدولية (إرشادات منظمة الصحة العالمية لعام 2003) لجودة مياه الشرب.

كانت مستويات المواد الصلبة الذائبة الكلية (TDS) عمومًا ضمن الحدود المقبولة، باستثناء البئرين رقم (1) و(2)، حيث سُجِّلت أعلى قيمة للمواد الصلبة الذائبة الكلية في البئر رقم (2) بتركيز بلغ 1837 ملغم/لتر، تلتها قيمة 1147 ملغم/لتر في البئر رقم (1).

تجاوزت قيم التوصيلية الكهربائية (EC) الحد المسموح به والبالغ 1400 ميكروسيمنز/سم في عدة آبار، حيث سُجِّلت أعلى قراءة في البئر رقم (2) بقيمة 3675 ميكروسيمنز/سم.
كانت تراكيز الكاتيونات المغنيسيوم (Mg^{2+}) والكالسيوم (Ca^{2+}) والصوديوم (Na^{+}) في معظمها ضمن الحدود المسموح بها، إلا أن تراكيز الصوديوم تجاوزت المعايير المعتمدة في بعض العينات. أما فيما يتعلق بالأنيونات، فقد لوحظ ارتفاع ملحوظ في تراكيز الكبريتات (SO_4^{2-}) والكلوريد(Cl^{-}) ، ولا سيما في البئرين (1) و(2)، حيث تجاوزت هذه التراكيز الحدود المسموح بها وطنيًا ودوليًا.
كما أظهر العدّ الكلي للبكتيريا لكل ملليلتر من مياه الآبار وجود بكتيريا في كلٍّ من البئرين (1) و(2)، وقد تبيَّن أن مياه هذين البئرين غير صالحة للشرب.

الكلمات المفتاحية :جودة المياه الجوفية، المواد الصلبة الذائبة الكلية، التوصيلية الكهربائية، قيم الأس الهيدروجيني(pH) ، المعايير الميكروبيولوجية.

1. Introduction

Unquestionably, climate change in recent years has increased the frequency and intensity of high-rainfall events in many parts of the world. Prolonged rainfall preceding high-intensity events raises the groundwater table and saturates the vadose zone, significantly increasing the risk of flooding. Notable flash floods linked to such conditions include the Rye River in North Yorkshire (June 2005), the Kosi River in Nepal and India (June 2013), Mumbai, India (June 2015), and the Mississippi River in the USA (December 2015). (Tan et al.,2015).

Floods are a severe and common cause of epidemics in low-income countries across Asia and Africa. They facilitate the spread of water-borne diseases such as typhoid fever, cholera, leptospirosis, and hepatitisa , as well as vector-borne diseases, including malaria, dengue hemorrhagic fever, yellow fever, and West Nile fever. Contamination of water sources by pathogenic microorganisms and the resulting diseases remain major public health concerns worldwide, particularly in developing countries. People living in or visiting affected areas, especially those consuming water from contaminated wells, are at significant risk of gastrointestinal illnesses caused by these infectious agents.The impact of flooding on groundwater quality in these regions can therefore have far-reaching consequences for human health (Czajkowski,et al.,2015).

Flooding is one of the most widespread natural disasters, with far-reaching consequences for human health, infrastructure, and the environment. One of its critical impacts is the contamination of domestic water sources, which can lead to the spread of waterborne diseases. (Oyebode, 2021).

Between 1980 and 2013, floods affected the drinking water of approximately 2.8 billion people through multiple pathways, including the migration of pathogens from surface water and groundwater into household water supplies (Doocy et al,2013) (Alderman et al.,2012). Flooding can overwhelm or damage water supply infrastructure, forcing affected populations to rely on unsafe alternatives. Additionally, displacement caused by flooding often leads to the use of unprotected water sources. Even after floodwaters recede, the threat of pathogen contamination can persist, posing long-term public health risks. (Levy et al., 2008; McCluskey, 2001).

Floods have a significant negative impact on water quality. In Bangladesh, testing of drinking water supplies during and after flooding revealed contamination with total coliforms, fecal coliforms, and *Vibrio cholerae*, Similarly, during floods in Thailand, drinking water was deemed unfit for consumption due to similar microbial contamination. (Islam et al., 2007).

In many low-income Asian and African nations, floods are a serious and frequent cause of epidemics. These natural disasters accelerate the spread of waterborne and vector-borne diseases, including malaria,dengue hemorrhagic fever, yellow fever, West Nile virus, cholera, leptospirosis, hepatitis A, and typhoid fever. Globally, waterborne pathogen pollution and related illnesses remain pressing public health concerns (UNICEF, 2023).

Derna is situated at the mouth of a wadi—a narrow valley characterized by a typically dry riverbed that only carries water during periods of intense rainfall. The region's arid climate, steep topography, and sparse vegetation make it highly susceptible to flash flooding. Because the Wadi Derna remains dry for most of the year, the city of Derna is particularly vulnerable to sudden and extreme flood events. The Wadi Derna watershed covers approximately 560 km² and is located in eastern Libya, east of the Jebel El Akhdar area. It extends for nearly 70 km from its upper catchment to the Mediterranean coast, where it discharges through the city of Derna.(Yee et al .,2023) (Petley et al .,2023).

On September 11, 2023, one of the most devastating floods in the region's history occurred when Storm Daniel brought unprecedented rainfall to the Wadi Derna watershed. In less than 48 hours, the Libyan coast opposite Derna received approximately 414 mm of rainfall—an extraordinary amount for a semi-arid region where the average annual precipitation typically ranges between 200 and 250 mm. In effect, nearly two years' worth of rainfall fell within a two-day period, triggering catastrophic flooding across a landscape dominated by valleys and drainage channels. (Argüeso et al.,2024) (Ashoor et al.,2024).

The extreme floodwaters caused the collapse of two dams located upstream of Derna, releasing massive volumes of water that surged through the city. These torrents resulted in widespread destruction of residential areas, infrastructure, and critical public services. Damage to Derna's coastal and waterfront infrastructure further intensified the disaster, allowing seawater to overflow into urban areas and mix with floodwaters, significantly increasing the scale of destruction. (WMO, 2023).

As a result of this compound flooding event, Derna suffered severe humanitarian impacts. The destruction of water supply networks and sanitation systems left many residents without access to safe drinking water, making water scarcity and public health risks among the most urgent challenges in the aftermath of the disaster. (Petley et al.,2023).

Even before the 2023 floods, Libya faced significant water scarcity. The country is heavily dependent on groundwater, with over 95% of its water supply sourced from aquifers (Abdudayem & Scott, 2014).

Given Libya's dependence on groundwater and the recent flood damage, the importance of assessing groundwater quality in Derna has become increasingly urgent. This research aims to evaluate the chemical and microbial quality of groundwater to determine its suitability for various uses, including drinking and irrigation. Particular attention is paid to bacterial contamination and pathogenicity.

The study provides reliable data on the physical, chemical, and microbiological properties of groundwater, assessing its compliance with both Libyan and international standards. The findings form a scientific basis for informed decision-making in water resource management and highlight key challenges such as high salinity, elevated electrical conductivity, and microbial pollution. Ultimately, the research supports the development of policies and strategies to improve water quality and promote sustainable water management practices in flood-prone areas.

Water Quality Parameters

The physical, biological, and chemical properties of drinking water are critically important, as even minor fluctuations in these parameters can significantly affect human health. Among these**, pH** is a crucial factor influencing water quality and pollution levels in water bodies Although pH does not directly impact human health, it can have indirect effects by altering **metal solubility** and creating favorable conditions for **pathogenic microorganisms.** Elevated pH levels may also impart an unpleasant, acidic taste to drinking water(jonnalagadda et at 2001) .

2. Methods

2.1. Chemical Analysis

Water samples were collected from five wells (Wells 1 to 5) located within the study area figure 1. Each sample was stored in a **500 ml plastic bottle**, thoroughly cleaned with distilled water and securely sealed to prevent contamination. Each bottles were clearly labeled with the corresponding well number and sampling,as present in Table (1). for proper identification.

A comprehensive suite of **chemical and ionic tests** was performed on each sample, including:

- **pH Measurement**
- **Electrical Conductivity (EC)** — measured in microsiemens per centimeter (µS/cm)
- **Total Dissolved Solids (TDS)** — measured in mg/L
- **Total Hardness (TH)** — measured in mg/L
- **Anion and Cation Analysis** (Na^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-)

The chemical analysis adhered to the Libyan Standard Specifications (2005) and the World Health Organization (WHO, 2003) guidelines. These standards served as benchmarks for evaluating the water quality. Table 1 presents the standard limits for various indicators according to both Libyan and WHO guidelines.

Figure1: locations where groundwater is collected.

Table 1: groundwater well sample.

S. no.	Well Sites	Wells Depth (m)	Coordinates	
			N	E
1	Al-Fakhakhry Mosque	100	32.762852	22.639224
2	Al-sarwahi	100	32.763067	22.643485
3	Shiha El-Sharqia	150	32.756635	22.633945
4	Bab -Tubraq1	200	32.755225	22.637521
5	Bab -Tubraq2	200	32.754634	22.636624

Table 2: The standard limits for the various water quality indicators based on both the Libyan and WHO guidelines.

Parameters	units	Standard values	
		Libyan Standards	WHO standards
pH	-	6.5 - 8	6.5 - 8
EC	(µS/cm)	1400	1400
TDS	(mg/L)	1000	1000
TH	(mg/L)	500	500
TOC	(mg/L)	100	100
Ca^{2+}	(mg/L)	200	200
Na^{+}	(mg/L)	200	200
NO_3^{-}	(mg/L)	45	50
Cl^{-}	(mg/L)	250	250
Mg^{+2}	(mg/L)	150	30-150
SO_4^{-2}	(mg/L)	250	250

2.2 Microbiological Analysis

The total bacterial count was estimated using the pour plate method, following the procedures described by the American Public Health Association (APHA, 2005). To ensure sample homogeneity, each water sample was shaken 25 times prior to analysis, 1 ml aliquot from a series of decimal (tenfold) dilutions was aseptically transferred into sterile Petri dishes. Sterile Plate Count Agar (PCA), previously cooled to 45–50°C, was poured into the Petri dishes containing the sample.

3. Results and Discussion

Table 3 shows the results obtained from the analysis of the characteristics of water samples collected from the wells. The findings are summarized as follows:

Table 3: The chemical and physical properties of groundwater.

Well number	pH	E.C µs\cm	T.D.S ppm	TH ppm
1	7.08	2292	1147	300
2	7.71	3675	1837	328
3	7.69	1624	769	245
4	7.74	1312	677	200
5	7.35	1007	503	174
Max	7.71	3675	1837	328
average	7.51	1982	986.6	249.4
SD	0.29	1059	530	65

Acidity (pH) The results presented in Table (3) and Figure (2) show that the pH values range from 7.08 to 7.74. These values fall within the permissible limits set by the World Health Organization (WHO) guidelines for drinking water, as well as the Libyan Standard Specifications of 2008.

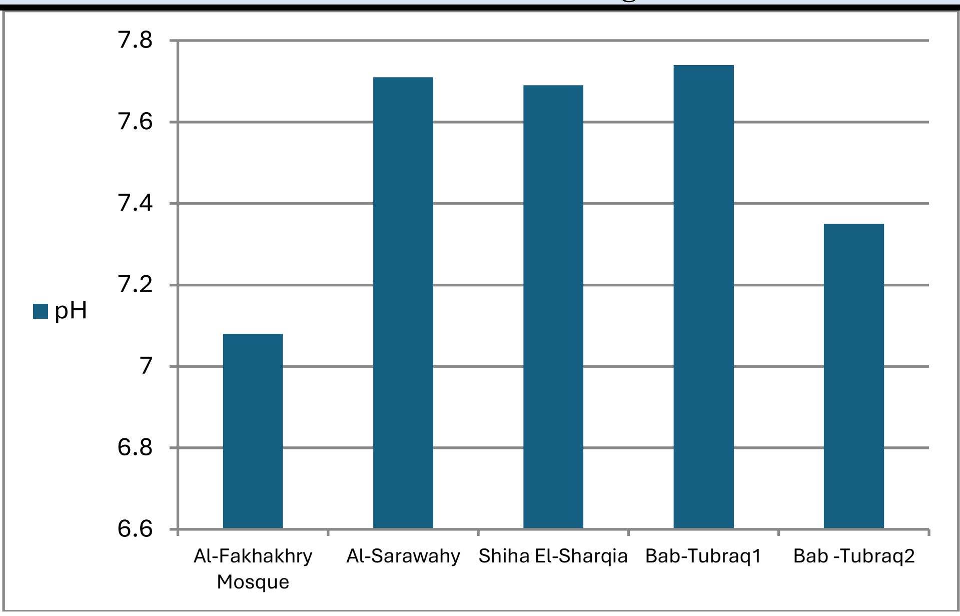

Figure 2: pH values of groundwater.

Total Dissolved Salts (TDS) refer to the total concentration of dissolved ions in water, including positively charged ions such as calcium, magnesium, and sodium, as well as negatively charged ions such as chlorides and sulfates. The data presented in Table (3) and Figure (3) indicate elevated TDS levels in most wells, exceeding the permissible limits set by both the World Health Organization (WHO) and Libyan drinking water standards. The highest recorded TDS value was 1837 mg/L in Well No. 2, while the lowest value was 503 mg/L in Well No. 5.
The increase in TDS levels in some wells can be attributed to the infiltration of surface water into the groundwater system during flooding events. Floodwater may carry a variety of dissolved solids, including salts, minerals, and organic matter from the surrounding environment. These materials can contribute to increased TDS levels in groundwater, particularly in wells affected by flooding, where the wells become submerged by floodwater.
In this study, Electrical Conductivity (EC) values, which serve as an indicator of TDS, varied significantly among the wells. The highest EC value was recorded in Well No. 2 at 3675 µS/cm, while the lowest value was recorded in Well No. 5 at 1007 µS/cm, as shown in Figure (3).

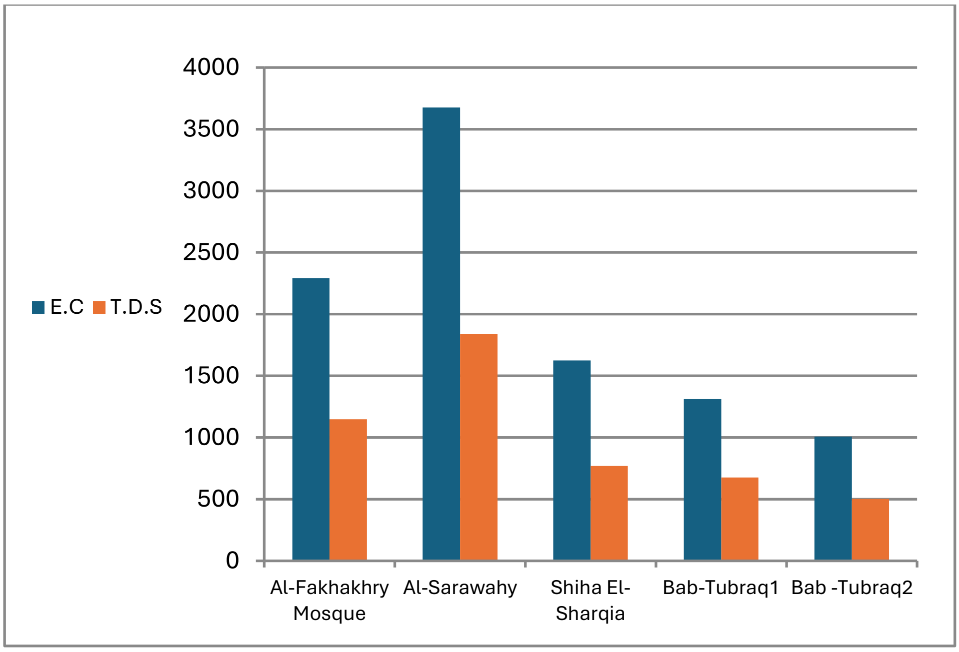

Figure 3: electrical conductivity (EC) and total dissolved solids (TDS).

Libyan Open University Journal of Applied Sciences (LOUJAS)
Volume 2 - Issue 1 - 2026 - Pages 24-34

Table 4: concentration of anions and cations.

Number of wells	$SO4^{-2}$ ppm	Mg^{+2} ppm	Ca^{+2} ppm	Na^{+} ppm	NO_3^{-} ppm	Cl^{-} ppm
1	224	29	72	100	47	400
2	400	34	76	300	48	734
3	50	20	65	124	33	300
4	100	11	62	75	24	200
5	95	17	42	48	38	100
Max	400	34	76	300	48	734
average	137	22.5	63.4	129.4	38	346.8
SD	142	9.6	13.18	99.5	10	243.1

Table (4) and Figure (4) present the concentrations of cations in groundwater. The concentrations of calcium and magnesium ions generally fell within the Libyan standard specifications for drinking water. In contrast, sodium concentrations were within the limits set by the Libyan standard specifications (2008), except for samples from Well No. 2, which showed elevated sodium levels exceeding both Libyan and World Health Organization (WHO) standards.

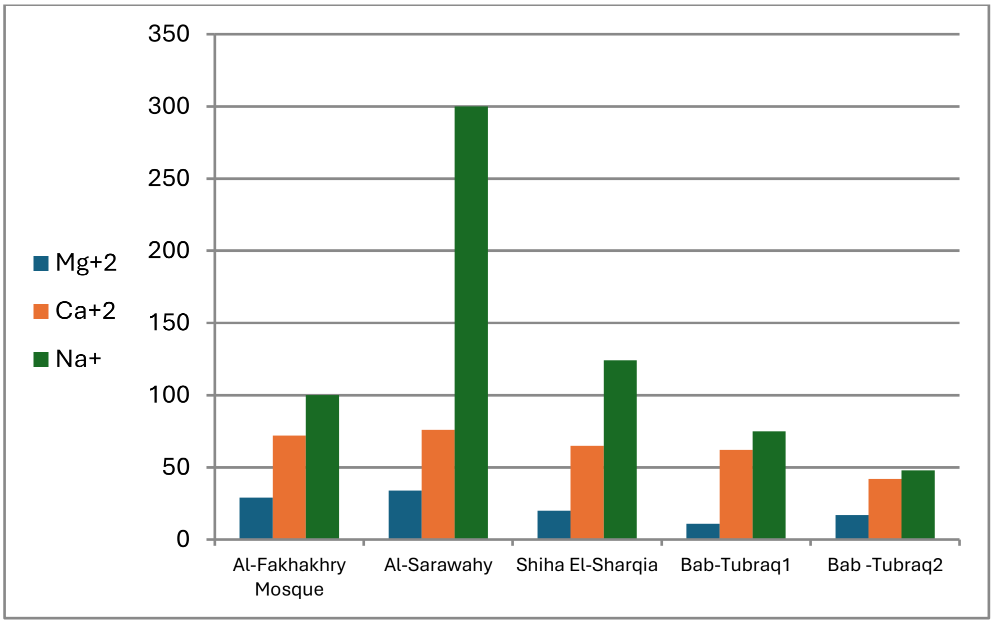

Figure 4: ion concentration values of Mg^{++}, Ca^{++}, Na^{+}

Table (4) and Figure (5) also show the concentrations of anions in groundwater. Nitrate levels did not exceed local specifications, while sulfate concentrations exceeded the local standard in Well No. 2. Additionally, chloride levels reached very high concentrations compared to both local and international standards in Wells No. 1 and 2.

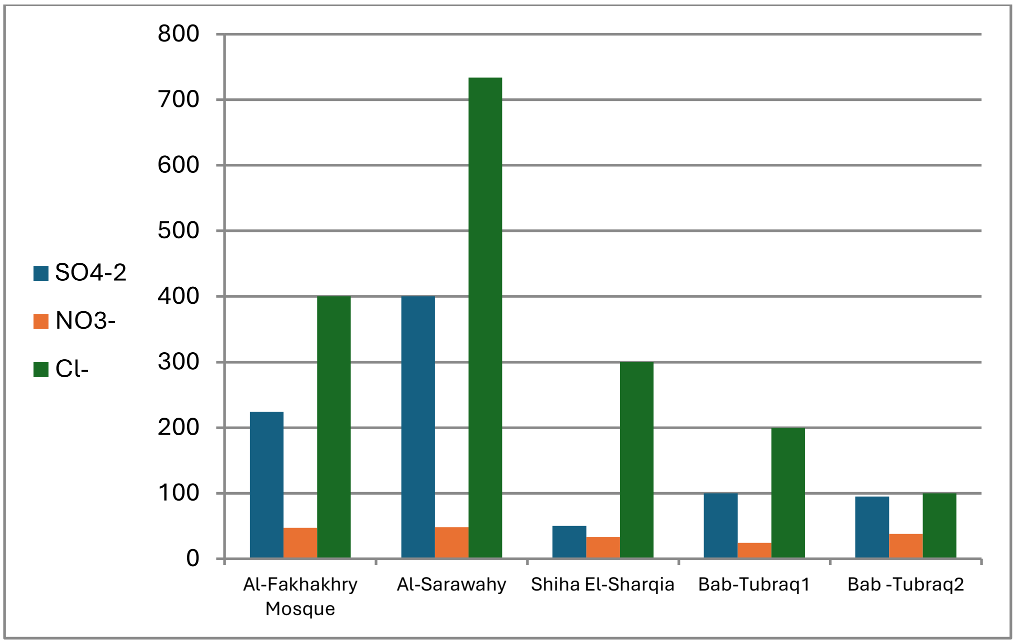

Figure 5: ion concentration values of CL^-, NO_3^- and SO_4^-

Total Hardness (TH) and elevated levels of magnesium salts in water beyond permissible limits contribute to water hardness. Total hardness is commonly categorized into four groups: soft water, moderately hard water, hard water, and very hard water.
Based on the results obtained from the study wells, as shown in Table (3) and Figure (6), TH values ranged from 174 mg/L in Well No. 5 to 300 mg/L in Well No. 1. According to the Libyan Standard Specifications (2008) for drinking and irrigation water, these values indicate that the water in this region falls under the category of moderately hard water.

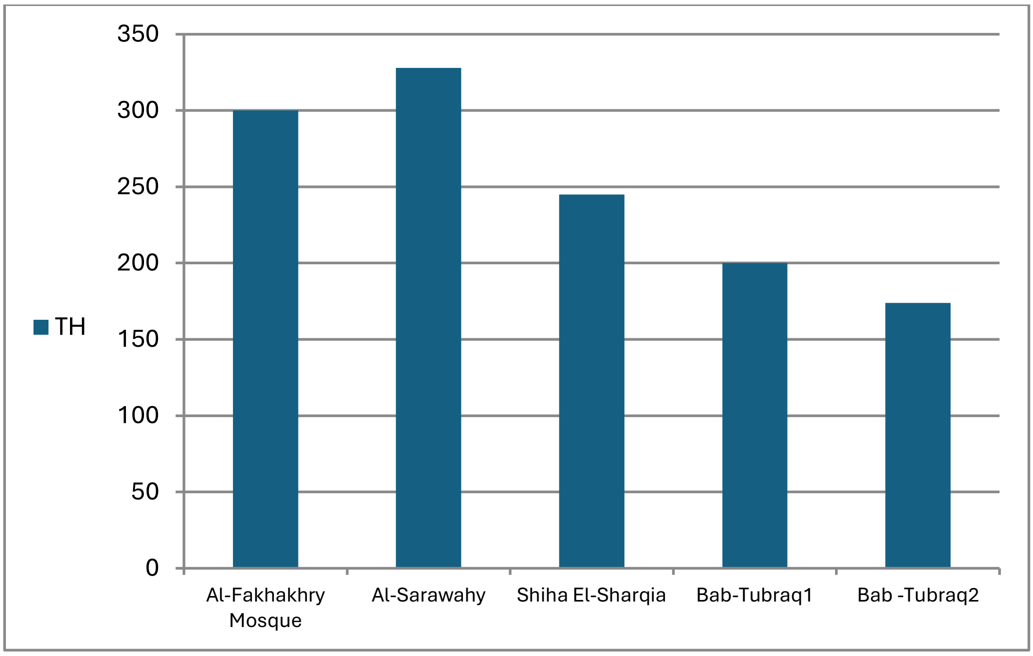

Figure 6: Total hardness of groundwater.

Table 5: Total count of bacteria in groundwater.

Test	unit	Result
Total count of bacteria per ml of sample in well No 1	Colony	300
Total count of bacteria per ml of sample in well No 2	Colony	400
Total count of bacteria per ml of sample in well No 3	Colony	34
Total count of bacteria per ml of sample in well No 4	Colony	24
Total count of bacteria per ml of sample in well No 5	Colony	86

Table 6: coliform bacteria in groundwater.

Test	unit	Result
Colifroms per100 ml	Colony	124
Colifroms per100 ml	Colony	200
Colifroms per100 ml	Colony	Negative
Colifroms per100 ml	Colony	Negative
Colifroms per100 ml	Colony	Negative

In this study, microbial analyses and total bacterial count assessments of well water samples, as presented in Table (5), revealed varying levels of bacterial contamination. The bacterial counts in Wells No. 3, 4, and 5 remained within the acceptable range of 50 to 100 colony-forming units (CFU) per milliliter. However, the bacterial counts in Wells No. 1 and 2 exceeded the permissible limits established by both the World Health Organization (WHO) and the Libyan standards, indicating potential public health risks associated with their use.

Table (6) indicates that fecal coliform bacteria were not detected in Wells No. 3, 4, and 5. However, Wells No. 1 and 2 showed high levels of coliform bacteria, recorded at 300 and 400 calls per 100 mL, respectively. These values exceed the permissible limits set by both the World Health Organization (WHO) and the Libyan standards for drinking water.

4. Conclusion

The findings indicate that floodwaters, likely contaminated with sewage, infiltrated the groundwater system. As a result, most wells within the affected region exhibited elevated levels of bacterial and chemical contaminants, exceeding the limits established by the Libyan Standards Bureau.
Flooding represents a significant global threat to environmental sustainability, socioeconomic stability, and public health. This review highlights the association between floods and outbreaks of waterborne diseases. Urgent measures are required to reinforce infrastructure, strengthen public health interventions, and implement climate change adaptation strategies. The deployment of early warning systems, comprehensive disease surveillance, and community-based recovery programs is essential to mitigate both immediate and long-term health consequences.

References

1. Abdudayem, A., & Scott, A. H. S. (2014). Water infrastructure in Libya and the water situation in agriculture in the Jefara region of Libya. *African Journal of Economic and Sustainable Development*, *3*(1), 33–46. https://doi.org/10.1504/AJESD.2014.061634
2. Alderman, K., Turner, L. R., & Tong, S. (2012). Floods and human health: A systematic review. *Environment International*, *47*, 37–47. https://doi.org/10.1016/j.envint.2012.06.003

3. American Public Health Association. (2005). *Public health code of ethics*. https://www.apha.org/-/media/Files/PDF/membergroups/ethics/code_of_ethics.ashx
4. Argüeso, D., Marcos, M., & Amores, A. (2024). Storm Daniel fueled by anomalously high sea surface temperatures in the Mediterranean. *NPJ Climate and Atmospheric Science*, *7*, Article 307. https://doi.org/10.1038/s41612-024-00307-0
5. Ashoor, A., & Eladawy, A. (2024). Navigating catastrophe: Lessons from Derna amid intensified flash floods in the Anthropocene. *Euro-Mediterranean Journal for Environmental Integration*, *9*, 1125–1140. https://doi.org/10.1007/s41207-024-00438-1
6. Czajkowski, J., Kunreuther, H., Montgomery, M., & Simmons, K. (2015). *Economic impacts of urban flooding in South Florida: Potential consequences of managing groundwater to prevent saltwater intrusion* (Working Paper No. 2015-10). Risk Management and Decision Processes Center, University of Pennsylvania.
7. Doocy, S., Daniels, A., Murray, S., & Kirsch, T. D. (2013). The human impact of floods: A historical review of events 1980–2009 and systematic literature review. *PLOS Currents: Disasters*. https://doi.org/10.1371/currents.dis.f4deb457904936b07c09daa98ee8171
8. Gazzini, C. (2023, September 14). *When the dams in Libya burst: A natural or preventable disaster?* International Crisis Group. https://www.crisisgroup.org/middle-east-north-africa/north-africa/libya/when-dams-libya-burst-natural-or-preventable-disaster
9. Islam, M. S., Mahmoud, Z. H., Ghorami, T. K., Nazim Uddin, K. M., Islam, A., Yunus, M., & Sack, D. A. (2007). Faecal contamination of drinking water sources of Dhaka city during the 2004 flood in Bangladesh and use of disinfectants for water treatment. *Journal of Applied Microbiology*, *103*(1), 80–87. https://doi.org/10.1111/j.1365-2672.2006.03268.x
10. Jonnalagadda, S. B., & Mhere, G. (2001). Water quality of the Odzi River in the Eastern Highlands of Zimbabwe. *Water Research*, *35*(10), 2371–2376. https://doi.org/10.1016/S0043-1354(00)00533-9
11. Levy, K., Nelson, K. L., Hubbard, A., & Eisenberg, J. N. S. (2008). Following the water: A controlled study of drinking water storage in northern coastal Ecuador. *Environmental Health Perspectives*, *116*(11), 1533–1540. https://doi.org/10.1289/ehp.11296
12. McCluskey, J. (2001). Water supply, health and vulnerability in floods. *Waterlines*, *19*(3), 14–17.
13. Oyebode, O. J. (2021). Hazard assessment and implementation strategies for mitigating flood and erosion in Nigeria. *IOP Conference Series: Materials Science and Engineering*, *1036*(1), 012066. https://doi.org/10.1088/1757-899X/1036/1/012066
14. Petley, D. (2023, September 13). Further information about the Wadi Derna dams. *The Landslide Blog*. https://eos.org/thelandslideblog/further-information-about-the-wadi-derna-dams
15. Tan, I., Jakob, C., Rossow, W. B., & Tselioudis, G. (2015). Increases in tropical rainfall driven by changes in frequency of organized deep convection. *Nature*, *519*(7544), 451–454. https://doi.org/10.1038/nature14339

16. World Health Organization. (2003). *Flooding and communicable diseases: Risk assessment and preventive measures*.
17. World Meteorological Organization. (2023, September 12). *Storm Daniel leads to extreme rain and floods in the Mediterranean, heavy loss of life in Libya*. https://wmo.int/media/news/storm-daniel-leads-extreme-rain-and-floods-mediterranean-heavy-loss-of-life-libya