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Original Research

Assessment of Drinking Water Quality in Derna, Ain Mara, and Al-Quba (Al- Jabal Al- Akhdar Basin) following Storm Daniel

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ABSTRACT:

The city of Derna and the surrounding areas located within the Al- Jabal Al- Akhdar basin, one of the most important water basins in Libya, experienced a severe environmental disaster as a result of Storm Daniel, which struck the region in September 2023. This event led to devastating floods and the collapse of infrastructure, including water supply and sewage networks, raising concerns about the potential contamination of drinking water sources with chemical and microbiological pollutants. This study focuses on evaluating the quality of drinking water in three areas within the Al- Jabal Al- Akhdar basin: Derna, Ain Mara, and Al-Quba. Fieldwork was conducted during different periods following the disaster (from November 2024 to April 2025) to assess the extent to which water quality was affected by environmental factors resulting from the floods. The analyses included physical parameters (such as temperature and turbidity), chemical parameters (such as nitrates and chlorine), and microbiological parameters (such as coliform bacteria). The results were compared with the Libyan Standard Specification No. 82 of 2013, as well as the World Health Organization (WHO) guidelines of 2011. The results showed that all samples complied with the Libyan standards, with no indications of serious or persistent contamination. This suggests that the ecosystem of Al-Jabal Al-Akhdar has the capacity to absorb environmental shocks, as well as the effectiveness of the efforts made by the relevant authorities to contain the negative impacts of natural disasters. The study concluded with several recommendations, including the need for continuous periodic monitoring of water quality, expanding the geographical scope of assessment, and developing an environmental water emergency plan for future disasters.

KEYWORDS: Water Quality, Storm Daniel, Flood Contamination, Al- Jabal Al- Akhdar, Environmental Resilience.

INTRODUCTION

Safe drinking water is one of the most essential requirements for human life, as it plays a vital role in maintaining human health and ensuring the sustainability of social and economic development. At a time when many Libyan cities are facing increasing challenges related to water quality, the city of Derna stands out as a special case due to the major natural disaster it experienced—Storm Daniel—which struck eastern Libya in September 2023. This event caused massive destruction to infrastructure, the collapse of dams, and the loss of thousands of lives.

This natural disaster resulted in wide-ranging environmental impacts, most notably the potential contamination of water sources due to their mixing with sewage and floodwaters. This poses a direct threat to public health and calls for precise field and laboratory studies to assess the current situation. Given the importance of water as a fundamental source of life, ensuring its quality and safety in the aftermath of natural disasters is an urgent priority.

In this context, the present study was conducted to evaluate the quality of drinking water in the city of Derna during the periods from November 2024 and January 2025 to April 2025, i.e., in the phase immediately following the Storm Daniel disaster. The aim is to determine the suitability of water for human consumption in comparison with the Libyan standard for drinking water and the World Health Organization (WHO) guidelines (2011). The study also aims to understand changes in the physical, chemical, and microbiological characteristics of water, analyze the extent of their impact by the disaster, and provide scientific recommendations to improve water monitoring systems after disasters.

The study aims to achieve the following:

-Evaluate the physical, chemical, and microbiological characteristics of drinking water in the targeted areas: (Ain Bou Mansour) in Derna, (Ain Shuaib) in Ain Mara, and (Ain Al-Dabusiyah), located within the Al -Jabal Al-Akhdar basin, during the periods of November 2024, January, and April 2025.

-Analyze the physical, chemical, and microbiological properties of water and compare them with the Libyan Standard Specification No. 82 of 2013 and the World Health Organization (WHO) standards (2011).

-Identify any potential ongoing environmental impacts resulting from Storm Daniel on water sources in the region and monitor any changes in water quality over time after the disaster.

-Propose and provide recommendations to improve water quality monitoring and management under environmental and natural risks, in order to enhance water security in disaster situations.

MATERIALS AND METHODS

Study Design

This study is based on a descriptive analytical approach, carried out through the collection and analysis of laboratory data for drinking water samples from three different sites located within the Al-Jabal Al- Akhdar Basin, one of the most important water basins in Libya. The study aims to evaluate the impact on water quality following Storm Daniel in September 2023.

Sampling Periods

Water samples were collected at different intervals after the disaster: The first period: 04/11/2024 (approximately one year after the event). The second period: 16/02/2025. The third period: 26/04/2025.

Sample Type and Analysis Method:

Samples were collected according to protocols approved by health authorities, using pre-sterilized containers. The samples were preserved under appropriate conditions until they reached the laboratory.

The analyses included:

1-Physical Parameters:

Temperature, turbidity (NTU), total dissolved solids (TDS), electrical conductivity (EC), and pH.

2-Chemical Parameters:

Free residual chlorine (Free Cl), nitrate (NO_3^-), nitrite (NO_2^-), and ammonia (NH_3).

3-Microbiological Parameters:

Total bacterial count at 37°C and coliform bacteria (E. coli).

Standards Used for Comparison:

The results were compared with the Libyan Standard Specifications No. (82) of 2013 and the World Health Organization (WHO) guidelines for drinking water quality (2011), which define the maximum permissible limits for various contaminants to ensure public health safety.

Analysis:

The samples were transported to Al-Karbal Laboratory for Chemical Works and Water Analysis (Derna), and to Qimat Libya First Company for laboratory supply, consulting, training, and biochemical analysis, where chemical and microbiological tests were conducted.

Microbiological samples were collected in sterilized glass bottles with a capacity of 1 liter and prepared under strict aseptic conditions. The samples were transported to the laboratory under appropriate conditions and analyzed within no more than 6 hours after collection to ensure result accuracy.

The following parameters were determined:

1-pH:

The pH of the studied water samples was measured according to the methods described by Mckeague (1978) and Mclean (1982), using a JENWAY pH meter (Model 3310) by direct measurement.

2-Total Dissolved Solids(TDS):

TDS was measured using a conductivity meter (HANNA Hi 9635 A, B).

3-Total Hardness(as $CaCO_3$):

Total hardness is defined as the sum of calcium and magnesium ions expressed as calcium carbonate in parts per million (ppm). It is also considered an indicator of soap solubility efficiency in natural water.

4-Sodium Ion(Na^+):

Sodium concentration was determined according to Franson et al. (1995) by direct instrument measurement using a flame spectrophotometer.

5-Iron(Fe):

Iron concentration was measured using the phenanthroline method with a Philips UV-Vis spectrophotometer (Model PU 8625) at a wavelength of 508 nm.

6-Ammonia(NH_4^+):

Ammonia was measured spectrophotometrically at 425 nm using Nessler's reagent, forming a colored complex under alkaline conditions. Water hardness may significantly interfere with this method.

7-Nitrate(NO_3^-):

Nitrate was measured using a Philips UV-Vis spectrophotometer (Model PU 8625) via the ultraviolet method as described in Standard Methods (1978).

8-Chlorides(Cl^-):

Chloride concentration was determined by titration according to Standard Methods (1978), Method No. (408), using 0.0141 N silver nitrate solution with potassium chromate as an indicator.

9-Sulfates(SO_4^{2-}):

Sulfate concentration was determined using a spectrophotometer with appropriate measurement cells.

Geographical Locations of the Study:

Three sites were selected, extending geographically from the coastal city of Derna, passing through Ain Mara area, to the city of Al-Quba. This transect covers approximately 40 km within the Al-Jabal Al- Akhdar Basin and represents a gradient of environmental and population impacts. All these areas rely directly on groundwater sources or local distribution networks as the main source of drinking water.

Ain Bou Mansour:

Location: Situated in the Al- Jabal Al- Akhdar region in Libya, near the city of Derna.

Coordinates: 32.75° N, 21.75° E

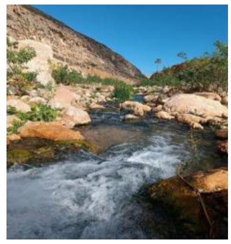

Figure (1): Study area of Ain Bou Mansour
Figure (2): Recent image of Ain Bou Mansour

Ain Shuaib:

Location: Located in the Al-Jabal Al- Akhdar region, in the village of Ain Mara near the city of Derna.

Coordinates: 32.70° N, 22.65° E

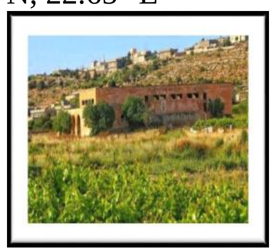

Figure (3): Study area of Ain Shuaib
Figure (4): Image of the Ain Shuaib study area

Ain Al-Dabusiyah:

Location: Located south of Wadi Al-Dabusiyah, a valley extending from the small rural town of Al-Dabusiyah north of the city of Al-Quba, reaching the coastal area of Latheron.

Coordinates: 32.65° N, 21.60° E

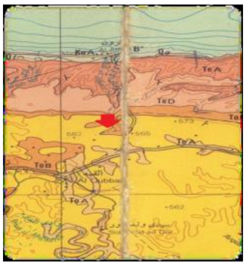

Figure (5): Study area of Ain Al-Dabusiyah

Figure (6): Image of the Ain Al-Dabusiyah study area

RESULTS AND DISCUSSION

The results of the analyzed samples (see Table 1), collected from Ain Bou Mansour (Derna), Ain Shuaib (Ain Mara), and Ain Al-Dabusiyah (Al-Quba) over three different time periods, were evaluated. The measured values of physical, chemical, and biological parameters were compared with the Libyan Standard Specifications No. (82) of 2013, as well as the World Health Organization guidelines (WHO, 2011) for drinking water.

The pH values ranged between **7.20 and 7.90**, indicating that all samples were within the ranged from **285 to 474 mg/L**, while total hardness ranged from **185 to 318 mg/L**. Sodium (Na^+) concentrations varied between **20 and 64 mg/L**, and the highest recorded iron (Fe) concentration was **0.113 mg/L**. All these values were within the permissible limits.

Ammonia (NH_4^+) concentrations ranged from **0.00 to 0.06 mg/L**, and chloride (Cl^-) levels ranged from **15.2 to 69 mg/L**, both within acceptable standards.

However, nitrate (NO_3^-) concentrations during the first sampling period (November 4, 2024) showed elevated values in Ain Al-Dabusiyah (**24 mg/L**) and Ain Bou Mansour (**16 mg/L**), exceeding the Libyan standard limits but still remaining within the acceptable limits set by the World Health Organization (WHO).

Sulfate (SO_4^{2-}) concentrations ranged from **3 to 45 mg/L**, remaining within safe limits.

Regarding microbiological analysis, the results for coliform bacteria and *E. coli*...

Table (1): Results obtained after conducting chemical and biological analyses on the selected water samples mentioned previously in the section *Sample Type and Analysis Method*, along with their comparison to the Libyan Standard Specifications for Drinking Water No. (82) and the World Health Organization (WHO) drinking water standards.

Parameter	Period 1 4 Nov 2024			Period2 16Feb 2025			Period 3 26 Apr 2025			Libyan Standards No. (82) 2013	WHO Standards (2011)
	Ain Bou Mansour	Ain Shuaib	Ain Al-Dabusiyah	Ain Bou Mansour	Ain Shuaib	Ain Al-Dabusiyah	Ain Bou Mansour	Ain Shuaib	Ain Al-Dabusiyah		
pH	7.30	7.21	7.40	7.90	7.35	7.35	7.88	7.20	7.30	6.5-8.5	6.5-8.5
TDS	386	285	409	474	420	450	470	418	438	500	500-100
Total Hardness	229	185	284	300	300	315	3.04	298	318	200	500
Na^+	20	28	24	25.6	63.0	59.0	25.1	64.0	60.4	100	200-400
Fe^{+2}	-	-	-	0.012	0.010	0.113	0.011	0.008	0.108	0.3	0.3
NH_4^+	-	-	-	0.06	0.0	0.0	0.05	0.0	0.0	0.5	1.5
Cl^-	69	60	60	66.01	20	15.2	65.2	17.9	16.3	150	200-600
NO_3^-	16	9	24	0.71	0.04	9.58	0.95	0.02	5.34	10	10-45
SO_4^{2-}	45	3	15	11.98	18.0	9.58	10.50	16.3	10.0	150	200-400
Total Coliform	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	0	0
(E. coli)	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	0	0

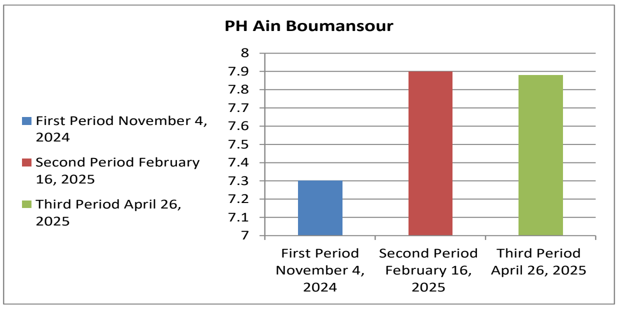

Figure (7): pH values for all sampling periods at Ain Bou Mansour.

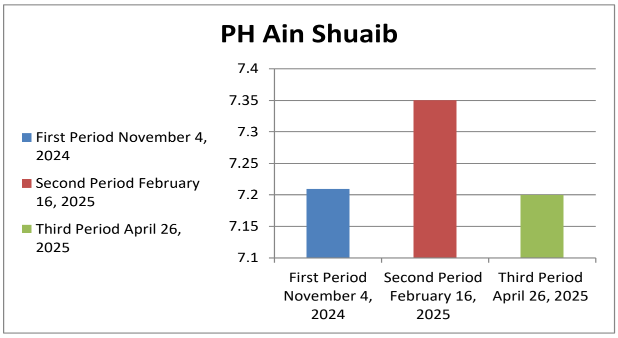

Figure (8): pH values for all sampling periods at Ain Shuaib.

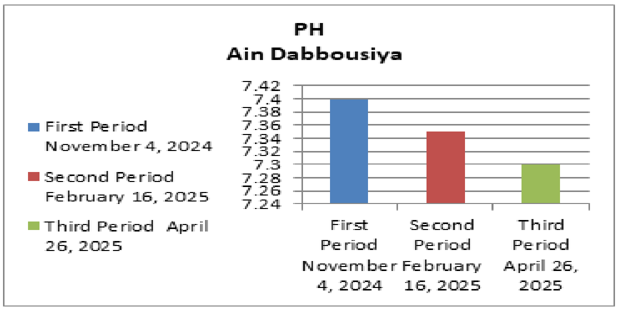

Figure (9): pH values for all sampling periods at Ain Dabusiyah.

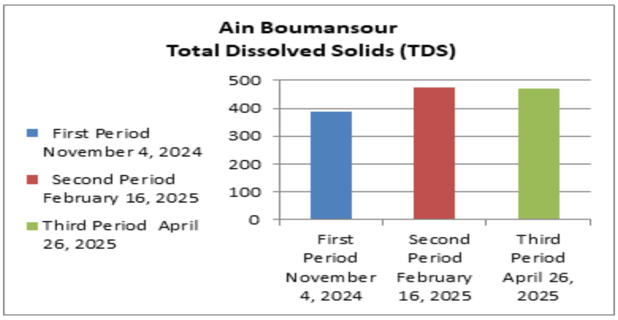

Figure (10) shows the values of all total dissolved salts (TDS) results for all periods for Ain Bou Mansour

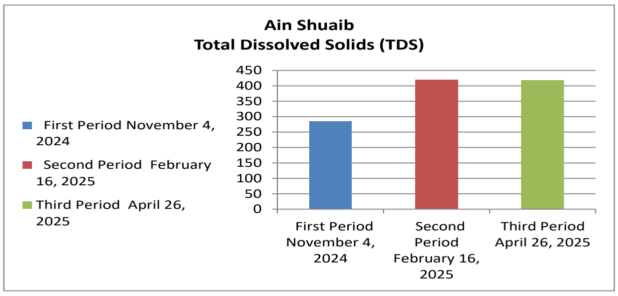

Figure (11) shows the values of all total dissolved salts (TDS) results for all periods for Ain Shuaib.

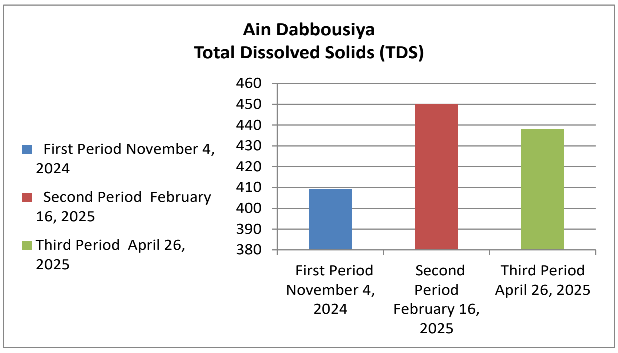

Figure (12) shows the values of all total dissolved salts (TDS) results for all periods for Ain Dabusiyah.

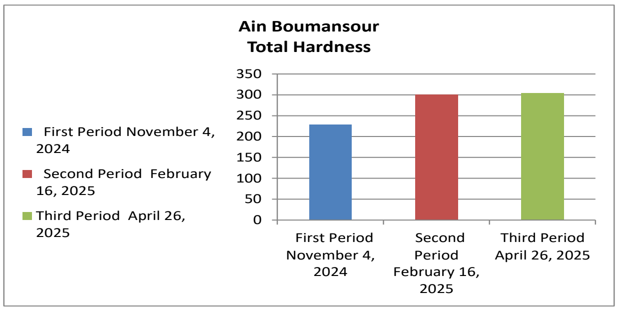

Figure (13) shows the values of all total hardness results for all periods for Ain Bou Mansour.

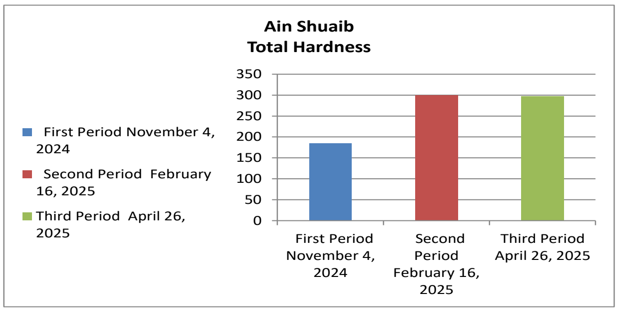

Figure (14) shows the values of all total hardness results for all periods for Ain Shuaib.

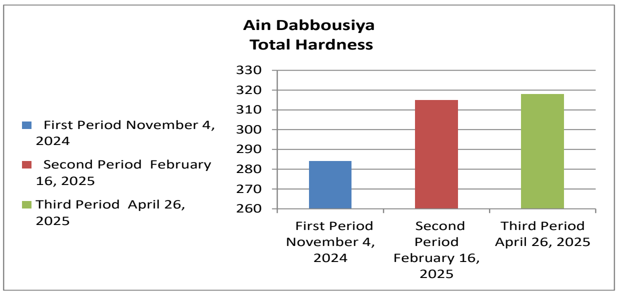

Figure (15) shows the values of all total hardness results for all periods for Ain Dabbousiya.

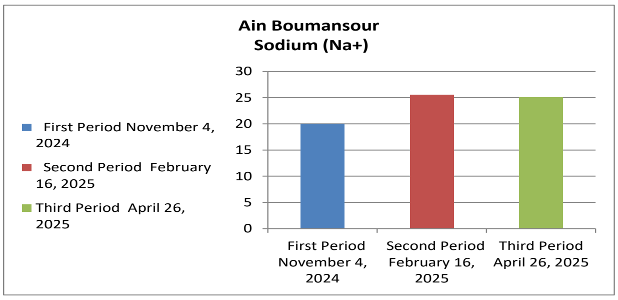

Figure (16) shows the values of all Sodium results for all periods for Ain Bou Mansour.

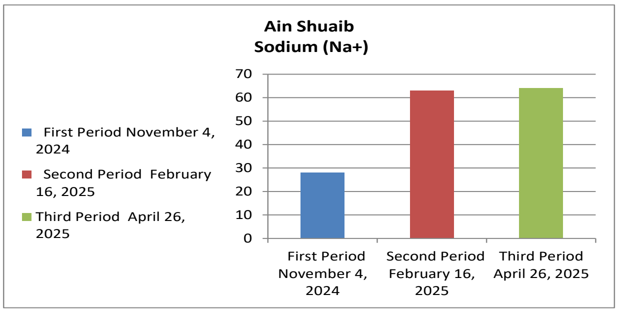

Figure (17) shows the values of all Sodium results for all periods for Ain Shuaib.

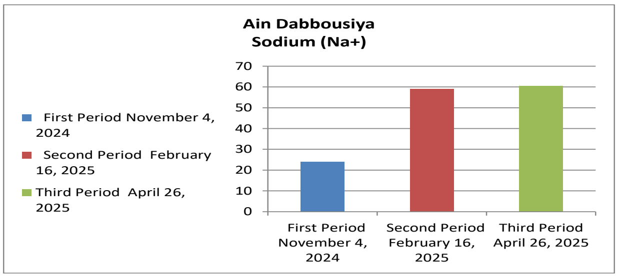

Figure (18) shows the values of all Sodium results for all periods for Ain Dabusiyah

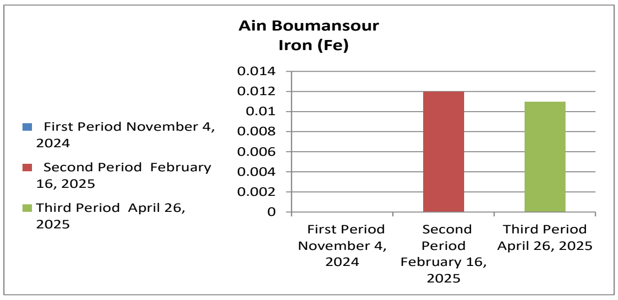

Figure (19) shows the values of all Iron (Fe) results for all periods of the Ain Abu Mansour.

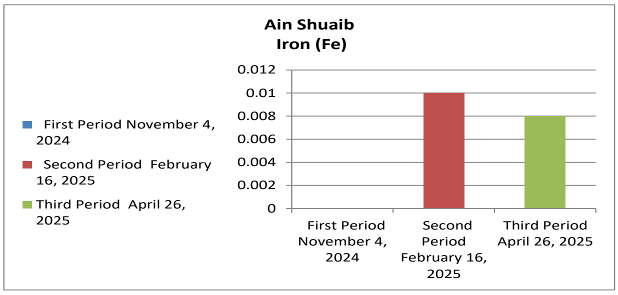

Figure (20) shows the values of all Iron (Fe) results for all periods of the Ain Shuaib.

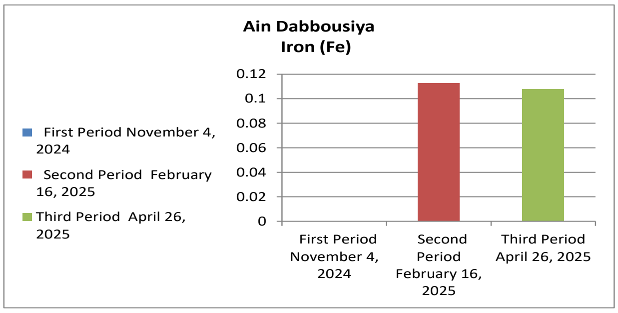

Figure (21) shows the values of all Iron (Fe) results for all periods of the Ain Dabbousiya.

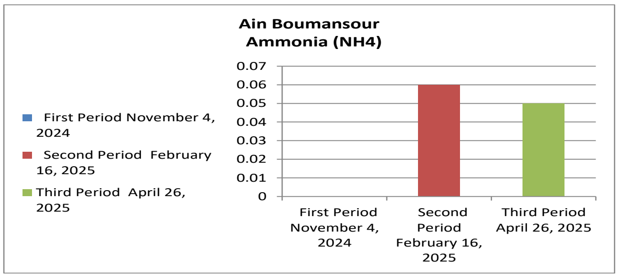

Figure (22) shows the values of all Ammonia (NH_4) results for all periods of the Ain Abu Mansour.

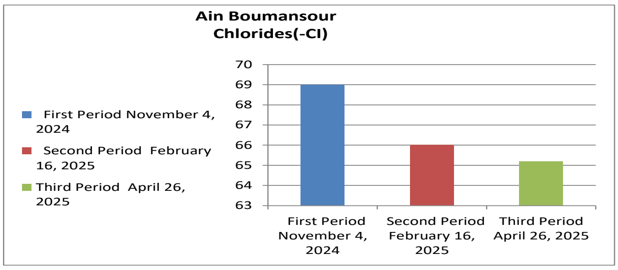

Figure (23) shows the values of all Chloride (Cl^-) results for all periods of the Ain Abo Mansour.

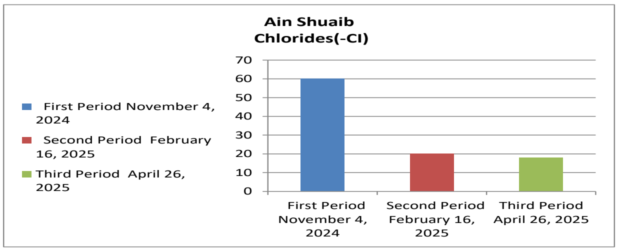

Figure (24) shows the values of all Chloride (Cl^-) results for all periods of the Ain Shaib.

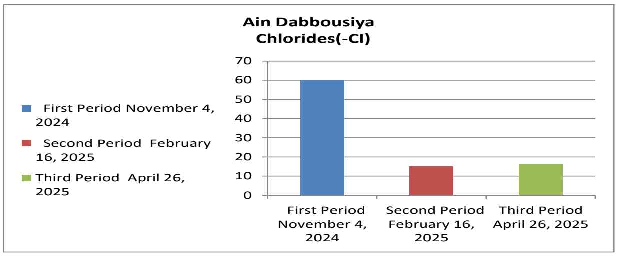

Figure (25) shows the values of all Chloride (Cl^-) results for all periods of the Ain Dabbousiya.

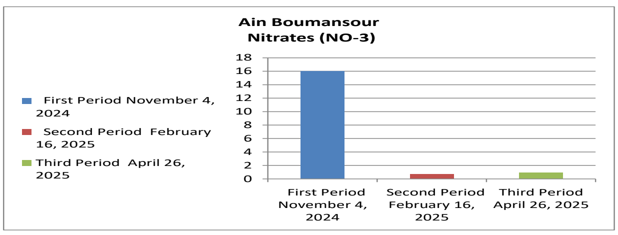

Figure (26) shows the values of all Nitrate (No_3^-) results for all periods of the Ain Bo Mansour.

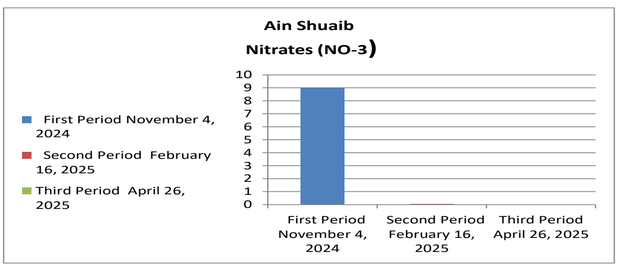

Figure (27) shows the values of all Nitrate (No_3^-) results for all periods of the Ain Shuaib.

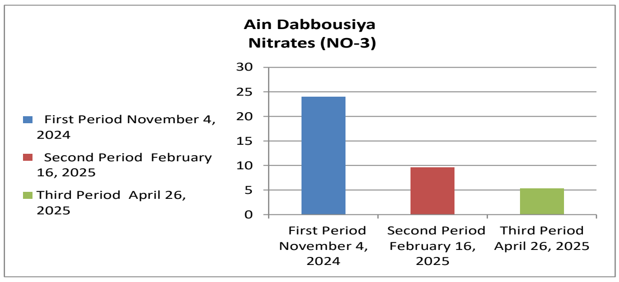

Figure (28) shows the values of all Nitrate (No_3^-) results for all periods of the Ain Dabbousiya.

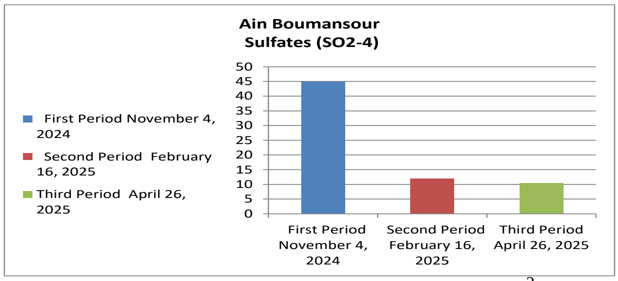

Figure (29) shows the values of all sulfate ($SO4^{-2}$) results for all periods of the Ain Bo Mansour.

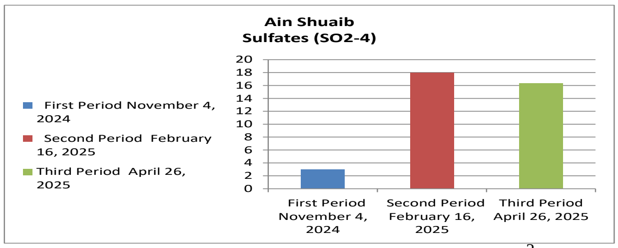

Figure (30) shows the values of all sulfate ($SO4^{-2}$) results for all periods of the Ain Shaib.

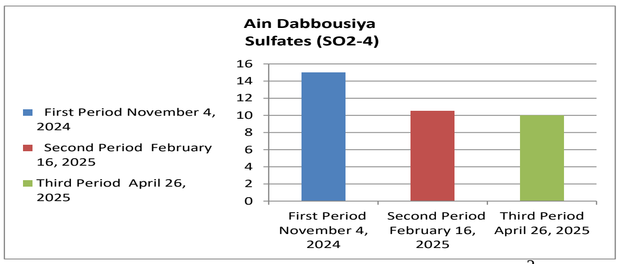

Figure (31) shows the values of all sulfate ($SO4^{-2}$) results for all periods of the Ain Dabbousiya.

DISCUSSION

The results of the analysis of water samples collected from Ain Bou Mansour, Ain Shuaib, and Ain Dabusiyah represent an important indicator of water resource quality in the Al-

Jabal Al- Akhdar region, which is considered one of the vital areas in Libya due to the abundance of its natural springs. The pH results showed full compliance with the permissible limits, with values ranging between 7.20 and 7.90, which fall within the recommended range (6.5–8.5). This indicates that the water is neutral to slightly alkaline and does not pose a risk to human health or to pipelines. The data also indicate a gradual increase in Total Dissolved Solids (TDS) in most samples, particularly in Ain Bou Mansour, where values increased from 386 to 470 mg/L. This may reflect the impact of flood events on the redistribution of sediments and dissolved materials in groundwater. In contrast, Ain Shuaib and Ain Dabusiyah recorded relatively high but less variable levels. These findings are consistent with previous studies, which have indicated that floods directly affect groundwater recharge and can lead to increased salinity (Pieper *et al*., 2020), although the recorded values remain within internationally permissible limits.

With regard to total hardness, some samples—particularly from Ain Dabusiyah—recorded values exceeding the permissible limit according to Libyan standards (200 mg/L), although they remained within the internationally accepted limit (500 mg/L). The elevated total hardness observed in some samples from the Al- Jabal Al- Akhdar region can be attributed to the geological nature of the area, which is rich in calcareous rocks such as limestone and dolomite. These formations contain high amounts of calcium carbonate and magnesium. As groundwater infiltrates and flows through these formations, it dissolves calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, leading to increased concentrations in the water. Additionally, the widespread calcareous soils in the region contribute to enriching groundwater with these salts, particularly during periods of low rainfall or limited recharge, resulting in higher concentrations of dissolved salts in general and hardness in particular. This may lead to slight effects on water taste and its use for washing, including reduced soap efficiency and increased scaling in pipes and household appliances; however, it does not pose a direct health risk. Regarding sodium concentrations, an increase was observed in some samples, particularly from Ain Shuaib and Dabusiyah; however, all values remained within acceptable limits. Elevated sodium levels may indicate infiltration from agricultural runoff or saline soils, and therefore periodic monitoring is recommended. Iron and ammonia concentrations were found to be within safe levels, indicating the absence of clear industrial or organic pollution in the area. Similarly, chloride and sulfate concentrations were within both local and international permissible limits, reflecting good chemical water quality in this respect.

It is noteworthy that a significant decrease in nitrate concentrations was observed after the first sampling period. For example, Ain Dabusiyah recorded 24 mg/L in November, which decreased to 9.58 mg/L and then to 5.34 mg/L in subsequent months. This decline may be attributed to either natural attenuation processes, such as biological nitrate removal over time, or improvements in water resource management following the disaster.

This interpretation is supported by similar studies conducted in hurricane-affected regions, such as the study carried out in Puerto Rico after Hurricane Maria (Warren *et al*., 2023). These findings are also consistent with other international studies on the impact of storms on groundwater quality, which report sharp increases in nitrate and salinity levels immediately after such events, followed by a gradual decline over time (Zhang *et al*., 2009; Jiang *et al*., 2020).

From a biological perspective, the results showed that all samples were free from total coliform bacteria and fecal coliforms (E. coli), indicating the absence of microbial contamination. This is a positive indicator of effective protection of water sources from human or animal waste.

Overall, the water of the Al- Jabal Al- Akhdar region can be considered safe and suitable for drinking from a microbiological perspective, and it exhibits acceptable to good chemical quality. However, some observations regarding total hardness, sodium, and nitrate concentrations warrant continued monitoring. Regular surveillance and seasonal analyses are recommended to ensure the long-term sustainability and quality of water resources in the region. In conclusion, several factors have contributed to the quality of water in Al- Jabal Al- Akhdar:

-The karstic geological nature of the region, which facilitates natural water filtration.

-Low population density in certain areas, reducing pressure on water resources.

-Intervention by relevant authorities to carry out urgent repairs to water infrastructure following the disaster.

Nevertheless, the possibility of localized contamination in areas not included in the analysis cannot be ruled out, which highlights the need to expand the scope of future studies.

CONCLUSION

Based on the results, the spring water studied in Jabal Akhdar is safe for human consumption from a health and microbiological standpoint. Continued periodic monitoring is recommended, along with localized treatment of high-hardness water, and preservation of the environment surrounding the springs to prevent any future pollution resulting from agricultural or urban activity.

1. Periodic monitoring and analysis of water sources: Implementing continuous monitoring programs (monthly or quarterly) to analyze the physical, chemical, and microbiological properties of the water.

2. Disinfection and treatment of water before distribution: Recommending the use of regular chlorination and studying the feasibility of establishing small-scale treatment plants for springs before transferring water to consumers, especially after natural disasters.

3- Community awareness on water safety: Launching awareness campaigns for residents of affected areas on safe water storage methods, home boiling or filtering techniques, and distributing informational brochures through schools and health centers.

4- Utilizing artificial intelligence technologies and smart systems: Developing an early warning system and analyzing water quality data using smart data analysis and Geographic Information Systems (GIS), and recommending the establishment of a shared digital database between the Ministry of Water Resources and municipalities.

5- Encouraging local scientific research: Supporting universities and research centers to conduct field studies after the disaster, particularly in Ain Shaib and Ain Al-Dabusiyah, and establishing a regional laboratory specializing in water quality in the Green Mountain region.

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تقييم جودة مياه الشرب بعد كارثة عاصفة دانيال في مدن درنة – عين مارة-القبة (حوض الجبل الأخضر)

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الملخص

شهدت مدينة درنة ومناطق الجوار الواقعة في (حوض الجبل الأخضر) أحد أهم الاحواض المائية في ليبيا كارثة بيئية جسيمة نتيجة الى عاصفة دانيال التي اجتاحت المنطقة في سبتمبر 2023 وقد أدى هذا الحدث الى فيضانات مدمرة وانهيارات في البنية

التحتية، بما في ذلك شبكات المياه والصرف الصحي، ما يثير القلق حول مدى تأثير مصادر مياه الشرب بالتلوث الكيميائي والميكروبيولوجي. حيث تتناول هذه الدراسة تقييم جودة مياه الشرب في 3 مناطق تقع ضمن (حوض الجبل الأخضر) درنة ,عين مارة والقبة وتم تنفيذ هذا العمل الميداني في فترات مختلفة بعد الكارثة (نوفمبر2024 الى أبريل 2025)لتحليل مدى تأثر نوعية المياه بالعوامل البيئية الناتجة عن الفيضانات.شملت التحاليل (العناصر الفيزيائية)مثل درجة الحرارة والعكارة (والكيميائية)مثل النترات وال كلور (والمكروبيولوجية) مثل القولونيات و تمت مقارنة النتائج بالمواصفة القياسية الليبية رقم 82لسنة 2013وكذلك لمنظمة الصحة العالمية 2011. اظهرت النتائج ان جميع العينات كانت مطابقة للمواصفات الليبية،دون مؤشرات على تلوث خطير أو دائم، مما يشير إلى قدرة النظام البيئي في الجبل الأخضر على امتصاص الصدمة البيئية ، و فعالية الجهود المبذولة من الجهات المختصة في احتواء التأثيرات السلبية للكوارث الطبيعية. توصلت الدراسة إلى عدد من التوصيات كاستمرار المراقبة الدورية لجودة المياه، وتوسيع نطاق التقييم الجغرافي،وتطوير خطة طوارئ بيئية مائية في حالات الكوارث المستقبلية.

الكلمات المفتاحية:
جودة المياه، عاصفة دانيال، تلوث الفيضانات، الجبل الأخضر ، المرونة البيئية.