Comprehensive Journal of Science
Volume (11), Issue (42), (Sapt, 2026)
ISSN: 3104-6266

مجلة العلوم الشاملة
المجلد (11) العدد 42 سبتمبر 2026
ردمد: 3104-6266

critical review of published environmental measurements analytical comparability of petroleum-hydrocarbon evidence in coastal and groundwater systems of northwestern libya: implications for monitoring near zawia refinery

Rabeeah Husayn Sultan[1],Areej Masoud Ali[2], Amal Ali Mohammed[3], Nawrs Sultan Esa[4].

[1]rabeaa.hoseen@sabu.edu.ly , [2]Areej.ali@sabu.ly, [3]amal.ali@scst.edu.ly , [4]nawrs.zhmoul@gmail.com

[1,2,4]Chemical Engineering Department, Sabratha Faculty of Engineering, Sabratha University, Libya.

[3]Surman College of Science and Technology, Surman, Libya.

Received: 12/10/2026 Revised: 15/10/2026 Accepted: 02/11/2026 Publication: 25/11/2026

Abstract

Published measurements of petroleum hydrocarbons in coastal water, sediments, and groundwater are frequently compared as though they represent an identical environmental quantity. In practice, reported concentrations depend heavily on the sampled matrix, extraction procedure, analytical instrumentation, target hydrocarbon fraction, reporting unit, and sampling design. This paper critically examines the comparability of published petroleum-hydrocarbon evidence relevant to northwestern Libya, focusing on the Zawia coastal and refinery-adjacent system. The synthesis evaluates historical coastal measurements from Zawia, regional groundwater and sediment data from Sobratah, Al Ajaylat, and Al Jmayl, hydrogeological studies of seawater intrusion, and accessible findings from a recent 2026 refinery-adjacent assessment. Although these studies document hydrocarbon occurrence across settings, they are not directly interchangeable due to differences in sampling period, spatial coverage, matrix, and analyte definition; thus, their values cannot be pooled to establish a continuous temporal trend or a single regional contamination level. Rather than duplicating recent site-specific contamination surveys, this review evaluates measurement comparability, source-attribution limits, and the minimum information required for defensible cross-study interpretation. A harmonized monitoring framework is proposed, emphasizing matrix-specific sampling, fractionated and compound-specific analysis, hydrogeological context, rigorous quality assurance/quality control, and sample-level data transparency. No new field samples or laboratory measurements were generated, and no unsupported source-apportionment or health-risk estimates are claimed.

Keywords: *analytical comparability; coastal groundwater; environmental monitoring; Libya; petroleum hydrocarbons; total petroleum hydrocarbons (TPH); Zawia.*

1. Introduction

Petroleum refining and associated storage, transport, and wastewater operations can release complex mixtures of hydrocarbons and inorganic constituents into adjacent environmental compartments. In coastal settings, the fate of these substances is controlled not only by the physicochemical properties of the contaminants but also by tides, currents, sediment interactions, groundwater gradients, pumping, and water exchange between aquifers and the sea. A concentration measured at one location and time is therefore a condition-specific observation, not by itself proof of a unique source or a complete description of contaminant transport.

Zawia represents an important setting for examining these interactions because industrial activity, a Mediterranean shoreline, and coastal groundwater resources coexist within the same regional system. Earlier work documented extractable hydrocarbons in coastal water and sediments near Zawia, while subsequent studies examined groundwater chemistry and seawater intrusion. More recently, Rtemi et al. (2026) published a site-specific assessment based on 20 samples collected from offshore waters, shoreline locations, and groundwater wells around the Zawia refinery. The availability of this recent assessment materially shapes the originality requirements for any new manuscript addressing refinery-derived hydrocarbons and trace metals at the same site.

The purpose of this paper is not to repeat the 2026 site-specific assessment or to present a second integrated contamination survey. Instead, it addresses a narrower and distinct methodological question: under what conditions can published hydrocarbon measurements from Zawia and nearby northwestern Libyan locations be compared, and what methodological information is required before numerical differences are interpreted as spatial or temporal patterns? Accordingly, the paper concentrates on analytical comparability, matrix effects, hydrogeological confounding, and the design of a reproducible monitoring dataset.

1.1 Scope and distinction from the 2026 Zawia study

Rtemi et al. (2026) have already published a site-specific integrated assessment of total petroleum hydrocarbons (TPH) and selected trace metals in the Zawia refinery environment. Repeating the same broad integrated-assessment framing, site, analyte combination, and source-attribution narrative would offer limited novelty. The present critical review differs in its research question, article type, and principal output: it evaluates whether measurements from separate studies are analytically comparable, explains why historical and regional values must remain distinct, and proposes a harmonized evidence and monitoring framework. It does not claim to provide new environmental measurements, an independent estimate of refinery contribution, or a quantitative risk assessment.

1.2 Aim and objectives

The overall aim of this review is to critically evaluate published environmental-monitoring evidence relevant to petroleum hydrocarbons and groundwater-quality pressures in the Zawia coastal system and to define priorities for a harmonized monitoring strategy. Specifically, the objectives are to:

- Identify the principal published studies relevant to coastal hydrocarbons, groundwater quality, and seawater intrusion in and around Zawia.
- Compare their sampling designs, environmental matrices, analytical targets, methods, units, and reporting practices.
- Distinguish observations that directly concern Zawia from regional evidence that provides contextual background only.
- Assess the methodological limits of source attribution and cross-study numerical comparison.
- Propose a practical monitoring and quality-assurance framework suitable for future chemical-engineering investigations.

2. Literature review and previous studies

2.1 Analytical approaches for petroleum hydrocarbons

Published methods for petroleum-hydrocarbon determination are not analytically equivalent. Yue et al. (2021) reviewed extraction and determination procedures for water and sediment and identified liquid–liquid extraction as a common preparation approach for water, Soxhlet and ultrasonic extraction as common approaches for sediments, and gas chromatography as an important route for determining hydrocarbon components. Adeniji et al. (2017) compared gravimetric, infrared, GC–FID, and GC–MS approaches and emphasized that the selected method affects the fraction measured. Cao et al. (2020) similarly reviewed extraction and determination procedures and described the influence of analytical methods on reported hydrocarbon distributions. More recently, Abdykarimov et al. (2025) compared TPH determination approaches using the Green Analytical Procedure Index, showing that analytical selection should consider not only measurement performance but also solvent use, hazards, and waste generation. In particular, gravimetric procedures quantify an operationally defined extractable residue and may not provide the same compositional information as chromatographic methods. These differences support the present review's rule that historical extractable-hydrocarbon values, TPH screening results, and compound-specific measurements must not be treated as directly interchangeable.

2.2 Regional evidence on petroleum hydrocarbons and marine sediments

At the regional scale, Uddin et al. (2021) reviewed petroleum-hydrocarbon contamination in sediments from the Arabian/Persian Gulf and Omani waters, considering TPH, total organic carbon, aliphatic hydrocarbons, unresolved complex mixtures, and PAHs. Their synthesis illustrates the value of compound groups and sediment context when interpreting petroleum contamination in marine environments. Cao et al. (2020) likewise reviewed analytical methods and reported pollution characteristics for petroleum hydrocarbons in water and sediment, highlighting the influence of oil spills, industrial wastewater, and urban runoff. These studies provide methodological and regional context; they do not constitute measurements from the Zawia refinery shoreline and are therefore not pooled with Zawia observations.

2.3 Groundwater salinization and hydrogeological context in northwestern Libya

Hydrogeological studies from the Jifarah coastal plain demonstrate why salinity indicators must be interpreted independently from petroleum-specific evidence. Alfarrah and Walraevens (2018) documented groundwater overexploitation and seawater intrusion in the Tripoli sector of the Jifarah Plain. Alfarrah et al. (2011) examined hydrochemistry in the upper aquifer complex of the same plain and reported widespread hydrochemical evidence consistent with seawater intrusion. Alfarrah et al. (2016) further investigated sulfate anomalies and identified seawater intrusion, upconing of deep saline water, gypsum dissolution, and sebkha deposits as relevant hydrogeochemical processes. In the Sabratah area, Alfarrah et al. (2017) described groundwater-quality degradation associated with seawater intrusion, mineral dissolution, and nitrate pressures. Elssaidi (2015) reported petroleum-hydrocarbon contamination in groundwater wells near fuel stations in the Fezzan region; this provides Libyan groundwater context but is geographically distinct from northwestern Libya and cannot be used as direct evidence for Zawia. Collectively, these studies demonstrate the need to distinguish petroleum-specific measurements from salinity and general groundwater-quality indicators.

2.4 General frameworks for seawater-intrusion monitoring

International reviews reinforce the need for repeated and integrated groundwater monitoring. Hussain et al. (2019) reviewed management approaches for seawater intrusion in coastal aquifers, while Panthi et al. (2022) reviewed investigation approaches and monitoring networks and emphasized the importance of long-term observations and complementary geochemical, geophysical, and modelling methods. Ketabchi et al. (2016) discussed the influence of sea-level rise on seawater intrusion and the need to consider multiple interacting controls. These contributions support the proposed framework's inclusion of groundwater levels, hydraulic gradients, seasonal sampling, and major-ion chemistry alongside petroleum-specific analyses.

2.5 Analytical quality assurance and method selection

Method selection should be linked to the target analytes, matrix, and required detection range. The United States Environmental Protection Agency's SW-846 Method 8015D describes gas chromatography with flame-ionization detection for non-halogenated organic compounds, while Method 3540C describes Soxhlet extraction for nonvolatile and semivolatile organic compounds in solid matrices (U.S. EPA, 2003a, 1996). Abdykarimov et al. (2025) additionally demonstrate that method selection can be assessed in terms of analytical performance and environmental sustainability, including solvent consumption, occupational hazards, and waste generation. These methods and reviews are cited as examples of established analytical approaches, not as evidence that the reviewed Libyan studies necessarily used them.

3. Materials and method

3.1 Review design and scope

This work is structured as a focused critical evidence synthesis rather than a new field investigation or a formally registered systematic review. Targeted literature searches were conducted across accessible journal platforms, institutional repositories, and scholarly records up to 24 November 2026, focusing on published studies reporting petroleum hydrocarbons, groundwater chemistry, sediment contamination, or seawater intrusion in Zawia and the northwestern Libyan coastal region. Records were screened for geographic relevance, environmental matrix, presence of measured chemical or hydrogeological observations, and availability of sufficient bibliographic or methodological detail for cautious interpretation. The selected evidence set captures direct Zawia observations alongside clearly labelled regional context, without claiming exhaustive coverage of all environmental studies in Libya.

The principal Libya-specific sources evaluated were Walda (2002), Nour (2015), Ganfoud and Abouras (2018), Al Deeb et al. (2025), and Rtemi et al. (2026). Additional methodological and hydrogeological literature was used to interpret analytical comparability and regional context. For each source, the synthesis relied on the accessible article, thesis, publisher record, or abstract. Where full texts or sample-level datasets were not publicly accessible, interpretation was restricted to information explicitly reported in the available record, without inferring unreported methods, values, or conclusions.

3.2 Data extraction and comparison

For each included study, publication year, geographic scope, sampled matrix, sampling period (where stated), sample count and type, target analytes, analytical methodology (where available),

and principal reported findings were extracted. Numerical values were retained in their original units and attributed directly to the source study. Values from different studies were neither pooled into a common statistical dataset nor subjected to secondary correlation, regression, principal-component, positive-matrix-factorization (PMF), or health-risk calculations.

3.3 Rules for interpretation

To reduce the risk of over-interpreting heterogeneous datasets, the synthesis followed five predefined interpretation rules:

- Direct Zawia evidence is strictly separated from regional evidence obtained at Sobratah, Al Ajaylat, or Al Jmayl.
- Historical measurements are treated strictly as historical baselines and are not extrapolated to represent current environmental conditions.
- TPH, gravimetric extractable hydrocarbons, and compound-specific measurements are not treated as analytically interchangeable quantities.
- Trace-metal concentrations are not attributed solely to refinery releases based on proximity; geogenic, marine, corrosion-related, and other anthropogenic inputs are also considered.
- Seawater intrusion indicators are interpreted as hydrogeological context rather than direct evidence of petroleum contamination.

4. Results: published evidence and comparability

4.1 Historical coastal hydrocarbon observations in Zawia

Walda (2002) reported measurements from a 1999 coastal survey encompassing stations approximately 3 km east of the refinery, directly at the refinery, and 3 km west of the refinery. Mean extractable-hydrocarbon concentrations were 33.75, 32.75, and 21.75 ppm in seawater, respectively, and 402.5, 657.5, and 330.0 ppm in sea sediments (Table 1). While these values confirm that extractable hydrocarbons were present in coastal compartments in 1999—with sediment concentrations substantially exceeding seawater concentrations due to the hydrophobic partitioning of petroleum constituents onto particulate matter—the dataset reflects a limited historical survey using an older gravimetric extraction method. Consequently, it cannot define present-day baselines or be directly compared with modern TPH measurements without rigorous method and matrix harmonization.

Table 1. Historical coastal extractable-hydrocarbon concentrations reported near Zawia refinery (1999 survey; Walda, 2002).

Zawia sampling station (1999)	Seawater extractable hydrocarbons (ppm)	Sea-sediment extractable hydrocarbons (ppm)
3 km east of refinery	33.75	402.5
At refinery station	32.75	657.5
3 km west of refinery	21.75	330.0

Notably, the spatial distribution does not follow a simple monotonic decrease with distance from the facility: while the refinery station exhibited the highest sediment mean, the eastern seawater station slightly exceeded the refinery seawater mean. This pattern underscores the influence of local coastal hydrodynamics, sediment grain-size texture, sampling conditions, and analytical uncertainty, demonstrating that distance from a point source alone is an insufficient proxy for source strength.

4.2 Regional groundwater and sediment evidence

Nour (2015) investigated groundwater and sediments across Sobratah, Al Ajaylat, and Al Jmayl in northwestern Libya. Mean groundwater TPH concentrations were 0.115 ppm at Sobratah, 0.011 ppm at Al Ajaylat, and 1.22 ppm at Al Jmayl, whereas corresponding sediment means were 0.425, 0.389, and 0.738 ppm (Table 2). Several trace metals—including Zn, Pb, Ni, Cu, Mn, Cd, and Mo—were also reported in groundwater. Although these data confirm regional hydrocarbon and metal monitoring in northwestern Libyan aquifers and sediments, they originate outside the Zawia refinery network and cannot be used to delineate a Zawia-specific plume or quantify refinery contributions.

Table 2. Regional groundwater and sediment TPH concentrations reported in northwestern Libya (Nour, 2015).

Location (Nour, 2015)	Groundwater TPH mean (ppm)	Sediment TPH mean (ppm)
Sobratah	**0.115**	**0.425**
Al Ajaylat	**0.011**	**0.389**
Al Jmayl	**1.220**	**0.738**

Similarly, the regional trace-metal observations serve solely as contextual reference. Because the sampling design, analytical protocols, and hydrogeological setting differ from Zawia-specific investigations, valid statistical comparison would require matched matrices, compatible analytical methods, consistent units, and sample-level records.

4.3 Groundwater hydrogeology and seawater intrusion

Ganfoud and Abouras (2018) examined groundwater salinization by seawater intrusion in the Zawia area, including coastal sectors at Joddaim and Harsha. Their findings highlight that coastal aquifer salinity is strongly governed by seawater intrusion, groundwater abstraction, and local hydraulic gradients. Elevated electrical conductivity (EC), chloride, or total dissolved solids (TDS) in Zawia groundwater should therefore not be attributed to refinery operations without corroborating petroleum-specific analytes, chemical fingerprints, and hydraulic interpretation.

Al Deeb et al. (2025) conducted a groundwater-well study around the Zawia oil refinery comprising 27 samples across nine wells, reporting concentrations of selected chemical elements including iron, calcium, and magnesium. While these results characterize general inorganic water quality around the refinery, major cations and iron alone neither confirm petroleum hydrocarbon contamination nor establish an industrial source.

4.4 The 2026 Zawia refinery-adjacent study

Rtemi et al. (2026) published an integrated assessment of refinery-associated hydrocarbons and selected trace metals across offshore, shoreline, and groundwater systems around the Zawia refinery. According to the accessible publisher record, 20 samples (collected during a single June 2025 campaign) were analysed for TPH, chemical oxygen demand (COD), dissolved oxygen (DO), TDS, pH, and trace metals. The study reported maximum TPH concentrations of up to 43 mg/L at offshore stations AS7 and AS8, elevated TPH accompanied by oxygen depletion in groundwater wells AG2 and AG6, a positive correlation between TPH and COD, a negative correlation between TPH and DO, and enrichment of nickel and vanadium in the most contaminated groundwater wells. Because complete sample-level data and full laboratory protocols were unavailable for independent reanalysis in this review, these outcomes are cited strictly as published findings without recalculation or statistical pooling with earlier studies.

While Rtemi et al. (2026) provide valuable recent site-specific evidence, their single-campaign dataset cannot establish a multi-year trend or support quantitative source apportionment beyond the authors' explicit findings. Table 3 summarizes the scope, evidence contribution, and primary comparability limitations across all five reviewed studies.

Table 3. Comparative synthesis of reviewed studies relevant to Zawia and northwestern Libya.

Study	Geographic / environmental scope	Evidence contribution	Key comparability limitation
Walda (2002)	Zawia coastal seawater and sediments; 1999 survey	Historical extractable-hydrocarbon measurements	Legacy gravimetric method and 1999 survey; not a current TPH baseline
Nour (2015)	Sobratah, Al Ajaylat, Al Jmayl; groundwater and sediments	Regional TPH and trace-metal measurements	External regional setting; not a Zawia refinery dataset
Ganfoud & Abouras (2018)	Zawia coastal aquifer (e.g., Joddaim, Harsha)	Groundwater seawater-intrusion context	Salinity and major ions are not petroleum-specific
Al Deeb et al. (2025)	Groundwater wells around Zawia refinery (27 samples, 9 wells)	Selected inorganic elements (Fe, Ca, Mg)	Selected elements alone do not identify petroleum sources
Rtemi et al. (2026)	Zawia shoreline, offshore water, groundwater (20 samples)	Recent site-specific TPH, COD, DO, TDS, pH, and metals	Single June 2025 sampling campaign; lacks sample-level public data and seasonal series

5. Discussion

5.1 What can be concluded from the combined evidence?

Synthesizing the available literature supports three bounded conclusions: (1) petroleum-related extractable hydrocarbons were historically present in Zawia coastal water and sediments during the 1999 survey (Walda, 2002); (2) recent site-specific monitoring confirms elevated TPH and selected trace metals in offshore, shoreline, and groundwater samples near the refinery (Rtemi et al., 2026); and (3) groundwater chemistry across the broader Zawia coastal plain is substantially influenced by hydrogeological processes such as seawater intrusion (Ganfoud & Abouras, 2018), which must be accounted for when interpreting salinity and major-ion patterns.

Conversely, the literature does not support combining published values into a single temporal trajectory. Because the studies differ in sampling dates, station networks, environmental matrices, analyte definitions, analytical techniques, and reporting units, any apparent numerical change between 1999 and 2025/2026 cannot be interpreted as a true environmental trend unless method equivalence, spatial alignment, and analytical uncertainty are rigorously demonstrated.

5.2 Why source attribution requires more than co-occurrence

Although nickel and vanadium are frequently associated with crude oil and refining residues, their co-occurrence near an industrial complex is not uniquely diagnostic of refinery releases; local lithology, sediment mineralogy, infrastructure corrosion, and redox-driven mobilization can also influence dissolved and particulate metal levels. Similarly, elevated COD and depressed DO indicate organic loading and aerobic biodegradation, but they are non-specific bulk indicators rather than definitive petroleum signatures. Robust source attribution requires compound-specific hydrocarbon profiling, cautiously interpreted diagnostic ratios, petroleum biomarkers where feasible, unimpacted reference sites, and hydraulic gradient verification.

Multivariate receptor models such as positive matrix factorization (PMF) require a sufficiently large, internally consistent sample-by-species matrix accompanied by method detection limits and analytical uncertainty estimates. Published summary means or small collections of unmatched studies cannot substitute for paired sample-level observations in either correlation analysis or source apportionment.

5.3 Chemical-engineering implications

From a chemical-engineering perspective, effective environmental monitoring must reflect the phase partitioning, volatility, solubility, and degradation kinetics of complex hydrocarbon mixtures. Bulk TPH serves only as an aggregate screening metric and obscures compositional differences that govern environmental fate and toxicity. Fractionated analyses—such as gasoline-range organics (GRO) and diesel-range organics (DRO)—paired with targeted quantification of BTEX (benzene, toluene, ethylbenzene, and xylenes) and priority polycyclic aromatic hydrocarbons (PAHs) provide essential insight into transport pathways and weathering stages. Analytical protocols must be matched to the target matrix and concentration range, with limits of detection (LOD) and quantification (LOQ) well below applicable environmental thresholds.

In groundwater systems, chemical measurements must be coupled with physical hydrogeological characterization, including static water levels, hydraulic gradients, well screen depth and

construction, pumping schedules, aquifer lithology, and distance to the shoreline. Ancillary redox parameters—such as DO, oxidation-reduction potential (ORP), pH, and major ions—clarify metal mobility and natural attenuation processes, serving as complementary lines of evidence alongside petroleum-specific analyses. This integrated approach is consistent with regional and international reviews of coastal-aquifer salinization and monitoring (Alfarrah & Walraevens, 2018; Hussain et al., 2019; Panthi et al., 2022).

5.4 Proposed harmonized monitoring framework

Future investigations around the Zawia coastal and refinery system should be designed as prospective, standardized monitoring campaigns rather than retrospective compilations of incompatible datasets. Table 4 outlines a practical eight-component monitoring framework adaptable to site access, laboratory capacity, and regulatory standards. The need for repeated observations and hydrogeological context is also supported by broader coastal-aquifer monitoring literature (Ketabchi et al., 2016; Panthi et al., 2022).

Table 4. Proposed harmonized monitoring and quality-assurance framework for future Zawia coastal and groundwater studies.

Monitoring component	Recommended measurements / records	Scientific and engineering purpose
Spatial design	Upgradient reference wells; refinery-proximal wells; downgradient transects; shoreline, offshore, and sediment stations	Distinguish background conditions from localized impacts and trace land–sea transport pathways
Temporal design	At least wet- and dry-season campaigns; repeated sampling at fixed stations; tidal stage and recent rainfall logs	Capture seasonal and hydrodynamic variability and avoid single-snapshot bias
Hydrocarbon suite	Fractionated TPH (GRO/DRO), targeted BTEX and priority PAHs, and petroleum biomarkers where feasible	Advance from aggregate screening to compositional characterization and source discrimination
Water chemistry	pH, temperature, EC/TDS, DO, ORP, COD (where appropriate), major ions, and alkalinity	Evaluate salinization, redox state, organic loading, and water–rock interactions
Trace metals	Dissolved (0.45 µm filtered) and total recoverable fractions of Ni, V, Fe, Pb, Cr, Cu, Cd, and Hg	Separate mobile dissolved fractions from particulate-bound metal burdens
Hydrogeology	Well depth, screen interval, groundwater level, hydraulic head, pumping status, lithology, and coastal distance	Verify groundwater flow directions, hydraulic connectivity, and contaminant migration routes
QA/QC protocol	Field blanks, trip blanks (for volatiles), field duplicates, matrix spikes, certified reference materials, LOD/LOQ, recoveries	Ensure analytical reliability, precision, accuracy, and inter-campaign comparability
Data reporting	Sample-level tables, protected coordinates, date/time, matrix, method, units, data qualifiers, and uncertainty	Support reproducibility, independent verification, and valid multivariate statistical analysis

5.5 Statistical and modelling strategy for a future dataset

Statistical evaluation should follow strict data-quality verification. Initial workflows should report descriptive statistics, detection frequencies, appropriate censored-data treatments (for values below LOD/LOQ), and spatial-temporal visualizations. Exploratory correlation analyses should rely exclusively on paired sample-level measurements after verifying distributional assumptions. Multivariate source-apportionment techniques should be applied only when sample size, species coverage, uncertainty matrices, and geochemical interpretability meet established modeling criteria. Likewise, numerical groundwater-flow and solute-transport models should be calibrated against measured hydraulic heads and aquifer hydraulic conductivity data rather than inferred from sparse conceptual observations.

5.6 Limitations of this review

This review is constrained by the limited number of accessible peer-reviewed studies specific to the Zawia refinery system and by substantial methodological heterogeneity across historical and regional publications. As a focused critical synthesis rather than an exhaustive systematic review, it relies on published summary metrics and abstracts where raw sample-level datasets were unavailable, precluding independent statistical reanalysis. No new field sampling, laboratory testing, source-apportionment modeling, or quantitative health-risk assessment was conducted; the proposed monitoring framework is intended to guide future empirical investigations.

6. Conclusions

Published literature documents historical extractable hydrocarbons in Zawia coastal waters and sediments (1999), recent refinery-adjacent TPH and trace-metal occurrences (2025/2026), regional groundwater and sediment hydrocarbon concentrations across northwestern Libya, and significant seawater-intrusion pressures in the Zawia coastal aquifer. Collectively, these studies underscore the importance of sustained environmental surveillance, yet their numerical outputs cannot be directly merged or compared as a continuous time series due to differences in sampled matrices, analytical definitions, methods, and reporting units.

Because Rtemi et al. (2026) have already presented a site-specific integrated contamination survey for Zawia, future research adds greatest value by moving beyond broad screening toward harmonized, multi-seasonal, sample-level monitoring. Integrating fractionated and compound-specific hydrocarbon analyses with physical hydrogeological measurements and rigorous QA/QC protocols will be essential to quantify refinery contributions, evaluate long-term trends, and support defensible environmental risk assessments.

References

Abdykarimov, B., Alimzhanova, M., López-Serna, R., & Syrgabek, Y. (2025). Green analytical procedure index assessment for total petroleum hydrocarbons determination methods in soil and sediments: A review. Trends in Environmental Analytical Chemistry, 46, e00262. https://doi.org/10.1016/j.teac.2025.e00262

Adeniji, A. O., Okoh, O. O., & Okoh, A. I. (2017). Analytical methods for the determination of the distribution of total petroleum hydrocarbons in the water and sediment of aquatic

systems: A review. Journal of Analytical Methods in Chemistry, 2017, Article 5178937. https://doi.org/10.1155/2017/5178937

Al Deeb, F. A. B., Al Khuwaidi, H. A., & Ihfeethah, F. M. (2025). Studying the characteristics and determining the rate of contamination of groundwater wells with heavy chemical elements in the area surrounding the Zawiya oil refinery. Bani Waleed University Journal of Humanities and Applied Sciences, 10(4), 142–149. https://doi.org/10.58916/jhas.v10i4.985

Al Farrah, N., Martens, K., & Walraevens, K. (2011). Hydrochemistry of the upper Miocene–Pliocene–Quaternary aquifer complex of Jifarah Plain, NW-Libya. Geologica Belgica, 14(3–4), 159–174.

Alfarrah, N., Berhane, G., Mjemah, I. C., Van Camp, M., & Walraevens, K. (2016). The origin of high sulfate concentrations and hydrochemistry of the Upper Miocene–Pliocene–Quaternary aquifer complex of Jifarah Plain, NW Libya. Environmental Earth Sciences, 75(20), 1388. https://doi.org/10.1007/s12665-016-6209-x

Alfarrah, N., Reda, G. B., Bakundukize, C., & Walraevens, K. (2017). Degradation of groundwater quality in coastal aquifer of Sabratah area, NW Libya. Environmental Earth Sciences, 76(19), 664. https://doi.org/10.1007/s12665-017-6999-5

Alfarrah, N., & Walraevens, K. (2018). Groundwater overexploitation and seawater intrusion in coastal areas of arid and semi-arid regions. Water, 10(2), 143. https://doi.org/10.3390/w10020143

Cao, X., Wu, X., Xu, W., Xiong, Z., Wang, C., Hu, S., & Hu, F. (2020). Research progress of analytical methods and pollution characteristics of petroleum hydrocarbons in water and sediment. Journal of Environmental Engineering Technology, 10(5), 871–882. https://doi.org/10.12153/j.issn.1674-991X.20200077

Elssaidi, M. A. M. (2015). Groundwater contamination by petroleum hydrocarbons due to leakages of fuel stations tanks in Fezzan region, Libya. Journal of Marine Science and Environmental Technologies, 1(1), A1–A16.

Ganfoud, A. A., & Abouras, G. M. (2018). Groundwater pollution with seawater in Zawia area. The Libyan Journal of Agriculture, 23(1–2), 17–29. https://ljagric.uot.edu.ly/lj/index.php/ljagric/article/viewFile/96/102

Hussain, M. S., Abd-Elhamid, H. F., Javadi, A. A., & Sherif, M. M. (2019). Management of seawater intrusion in coastal aquifers: A review. Water, 11(12), 2467. https://doi.org/10.3390/w11122467

Ketabchi, H., Mahmoodzadeh, D., Ataie-Ashtiani, B., & Simmons, C. T. (2016). Sea-level rise impacts on seawater intrusion in coastal aquifers: Review and integration. Journal of Hydrology. https://doi.org/10.1016/j.jhydrol.2016.01.083

Nour, H. E. S. (2015). Distribution of hydrocarbons and heavy metals pollutants in groundwater and sediments from northwestern Libya. Indian Journal of Geo-Marine Sciences, 44(7), 993–999.
https://nopr.niscpr.res.in/bitstream/123456789/34845/1/IJMS%2044%287%29%20993-999.pdf

Panthi, J., et al. (2022). Saltwater intrusion into coastal aquifers in the contiguous United States—A systematic review of investigation approaches and monitoring networks. Science of the Total Environment, 836, 155641. https://doi.org/10.1016/j.scitotenv.2022.155641

Rtemi, L., Rashed, M., Ahteewish, R., & Albilaezi, M. (2026). Environmental assessment of refinery-derived hydrocarbon and trace metal contamination in coastal and groundwater systems: A case study from Zawia, Libya. Academy Journal for Basic and Applied Sciences, 8(1). https://doi.org/10.5281/zenodo.19154802

Uddin, S., Fowler, S. W., Saeed, T., Jupp, B., & Faizuddin, M. (2021). Petroleum hydrocarbon pollution in sediments from the Gulf and Omani waters: Status and review. Marine Pollution Bulletin, 173, 112913. https://doi.org/10.1016/j.marpolbul.2021.112913

U.S. Environmental Protection Agency. (1996). SW-846 Test Method 3540C: Soxhlet extraction. https://www.epa.gov/hw-sw846/sw-846-test-method-3540c-soxhlet-extraction

U.S. Environmental Protection Agency. (2003a). SW-846 Method 8015D: Nonhalogenated organics using gas chromatography/flame ionization detection (GC/FID), Revision 4. https://www.epa.gov/sites/default/files/2015-12/documents/8015d_r4.pdf

Walda, W. (2002). Oil pollution on the Libyan coast [PhD thesis, University of Southampton]. University of Southampton Institutional Repository. https://eprints.soton.ac.uk/464841/

Yue, Z., Shi, Q., Ai, J., Peng, S., Miao, X., & Wang, Z. (2021). A review on analytical methods of petroleum hydrocarbons in water and sediment of aquatic systems. IOP Conference Series: Earth and Environmental Science, 621, 012011. https://doi.org/10.1088/1755-1315/621/1/012011

Al Deeb, F. A. B., Al Khuwaidi, H. A., & Ihfeethah, F. M. (2025). Studying the characteristics and determining the rate of contamination of groundwater wells with heavy chemical elements in the area surrounding the Zawiya oil refinery. Bani Waleed University Journal of Humanities and Applied Sciences, 10(4), 142–149. https://doi.org/10.58916/jhas.v10i4.985

Ganfoud, A. A., & Abouras, G. M. (2018). Groundwater pollution with seawater in Zawia area. The Libyan Journal of Agriculture, 23(1–2), 17–29. https://ljagric.uot.edu.ly/lj/index.php/ljagric/article/viewFile/96/102

Nour, H. E. S. (2015). Distribution of hydrocarbons and heavy metals pollutants in groundwater and sediments from northwestern Libya. Indian Journal of Geo-Marine Sciences, 44(7), 993–999. https://nopr.niscpr.res.in/bitstream/123456789/34845/1/IJMS%2044%287%29%20993-999.pdf

Rtemi, L., Rashed, M., Ahteewish, R., & Albilaezi, M. (2026). Environmental assessment of refinery-derived hydrocarbon and trace metal contamination in coastal and groundwater systems: A case study from Zawia, Libya. Academy Journal for Basic and Applied Sciences, 8(1). https://doi.org/10.5281/zenodo.19154802

Walda, W. (2002). Oil pollution on the Libyan coast [PhD thesis, University of Southampton]. University of Southampton Institutional Repository. https://eprints.soton.ac.uk/464841/