



Baseline Assessment of Stormwater Runoff Quality from Iraqi Oilfield Facilities in a Csa Climate Using Water Quality and Pollution Indices

Rawaz Rostam Hamadamin 

Department of Geography, Faculty of Education, Koya University, Koya KOY44023, Kurdistan Region– F. R. Iraq

Article Info	ABSTRACT
Article type: Research Article	Stormwater runoff from oilfield facilities can transport suspended solids, organic matter, salts, hydrocarbons, and trace metals to receiving waters, yet baseline data are limited in the region. This study provides the first integrated assessment of stormwater quality at three Iraqi oilfield facilities; Central Waste Management Area (CWMA), Central Process Facility (CPF), and Tank Loading Station (TLS) in Shewashok Oilfield. The samples were collected during storm events in January and May 2018, then analysed for physicochemical properties, oxygen-demand indicators, major ions, nutrients, hydrocarbons, and dissolved metals, and compared with Iraqi standards. Water quality was further evaluated using the Water Quality Index (WQI), Heavy Metal Pollution Index (HMPI), and Pollution Load Index (PLI).
Article history: Received: 14 May 2026 Revised: 23 Jul 2026 Accepted: 11 Sep 2026	CWMA showed the highest and most persistent contamination, with repeated exceedances in COD (410–951 mg/L), chloride (6780 mg/L), sulphate (945–1120 mg/L), boron (2170–6460 µg/L), and fluoride (up to 2540 mg/L). CPF showed moderate impairment, including elevated BOD (93 mg/L), COD (103–191 mg/L), sulphate (460 mg/L), and high TSS (up to 3200 mg/L). In contrast, TLS remained largely compliant, with low COD (<6–32 mg/L), low TSS (14–35 mg/L), and only a minor aluminium exceedance.
Keywords: <i>Stormwater Runoff</i> <i>Oilfield Facilities</i> <i>Csa Environment</i> <i>Water Quality Index (WQI)</i> <i>Heavy Metal Pollution index (HMPI)</i>	WQI values (11.83–70.20) ranked sites as CWMA > CPF >> TLS, with deterioration from January to May at CWMA and CPF, while TLS remained stable. HMPI (0.015–1.083) and PLI (0.009–0.041) were low, indicating limited metal pollution. These findings establish a regional baseline and highlight the usefulness of combining threshold and index-based approaches for stormwater management in Csa climate environments.

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INTRODUCTION

Stormwater refers to precipitation-derived runoff that flows over impervious surfaces, such as roads, rooftops, and pavements, rather than infiltrating into the soil. During its movement across these surfaces, stormwater can transport sediments and various contaminants to receiving water bodies, thereby degrading water quality and adversely affecting aquatic ecosystems (Butler & Davies, 2011; Takaijudin et al., 2016, Vogel and Moore, 2016). Stormwater quality is a global concern and is widely recognised as a major pathway by which pollutants reach rivers, lakes, coastal waters, and sometimes groundwater; consequently, it represents a significant challenge for the sustainability of water resources (Liu et al., 2025; Ziajahromi et al., 2022; UNEP, 2025). Because pollutant profiles vary significantly with land use, climate, and catchment characteristics, resulting in severe ecological impacts like eutrophication and toxicity, stormwater quality inherently requires site-specific assessment (Goonetilleke et al.,

*Corresponding Author Email: rawaz.rostam@koyauniversity.org

2005; Göbel et al., 2007; McGrane, 2016; Zivkovich and Mays, 2018; Yang and Lusk, 2018).

Despite advances in stormwater management via green infrastructure (Hatt et al., 2009), knowledge gaps remain regarding long-term system performance, emerging contaminants, and climate impacts (LeFevre et al., 2015; Olesen et al., 2019; LeFevre et al., 2017). Furthermore, most research focuses heavily on urban and municipal systems, largely overlooking specialised industrial catchments that generate distinct contaminant signatures.

Specifically, stormwater quality in industrial oilfields remains poorly characterised, notably in Iraq. Oilfield facilities—where crude handling, produced-water management, chemical storage, and heavy equipment operate—produce unique pollutant profiles. Spills and operational discharges can mobilise hydrocarbons, suspended solids, chemical residues, and elevated salinity (Abullah et al., 2017). Particularly in semi-arid climates where pollutants build up extensively between rain events, oilfield runoff differs significantly from conventional urban stormwater.

Existing Iraqi stormwater studies have primarily examined municipal networks, highway first-flush runoff, and climate-change impacts on urban drainage (Majd and Hamaamin, 2025; Al-Alossy et al., 2022; Faraj and Hamaamin, 2023; Nile et al., 2018; Wadi et al., 2022). However, these studies do not address operational oilfield environments. To address this data deficit, this study provides a field-based characterisation of Iraqi oilfield stormwater. Evaluating runoff across distinct facilities—a Central Processing Facility (CPF), Tanker Loading Station (TLS), and Central Waste Management Area (CWMA)—enables an assessment of how specific operations shape contaminant patterns. It also tests the applicability of composite indices, such as the Water Quality Index (WQI), Heavy Metal Pollution Index (HMPI), and Pollution Load Index (PLI), in these specialised settings. Due to local political circumstances, samples were collected during two campaigns in 2018, providing a vital initial baseline for future environmental management in Csa climate oilfields.

The specific objectives of this study are: (i) to characterise stormwater physicochemical properties across the CPF, TLS, and CWMA; (ii) to evaluate the occurrence and spatial variability of hydrocarbon indicators; (iii) to assess metals and relevant inorganic constituents in relation to facility activities; and (iv) to evaluate overall environmental risk using composite indices and comparisons with Iraqi standards.

MATERIAL AND METHODS

Site Discriptions: Shewashok is located in the Kurdistan region of Iraq within the Zagros Oil Province (Fig. 1). It is one of the largest oilfields in the Kurdistan Region, its production reached (140,000) bbl/day in 2016 (Hamadamin, Omer and Rasul, 2022), but for some political circumstances it has been on standby since 2022. The oilfield has several facilities, among them three locations were determined for the purpose of this study, including (CPF), (TLS) and (CWMA). The three facilities were designed to collect the surface runoff through all facility and keep it in ponds for different purposes including sampling, storage stormwater and preventing oil spill leaving the perimeter.

Based on these climatic characteristics, the study area is classified as **Csa**, corresponding to a hot-summer Mediterranean climate. This climate type is characterized by hot and dry summers, mild winters, and precipitation concentrated during the cool season. It is been confirmed that in other studies (Muslih and Abbas, 2024) (Hamadamin, Salih and Aziz, 2019). In semi-arid regions with a **Csa** climate, prolonged dry periods promote the accumulation of dust, suspended solids, heavy metals, hydrocarbons, and other pollutants on land surfaces. Subsequent rainfall rapidly mobilizes these contaminants, producing a pronounced first flush with elevated pollutant concentrations. Because rainfall events are typically brief and infrequent, dilution is limited, resulting in stormwater with higher pollutant concentrations than in more humid climates (Taebi

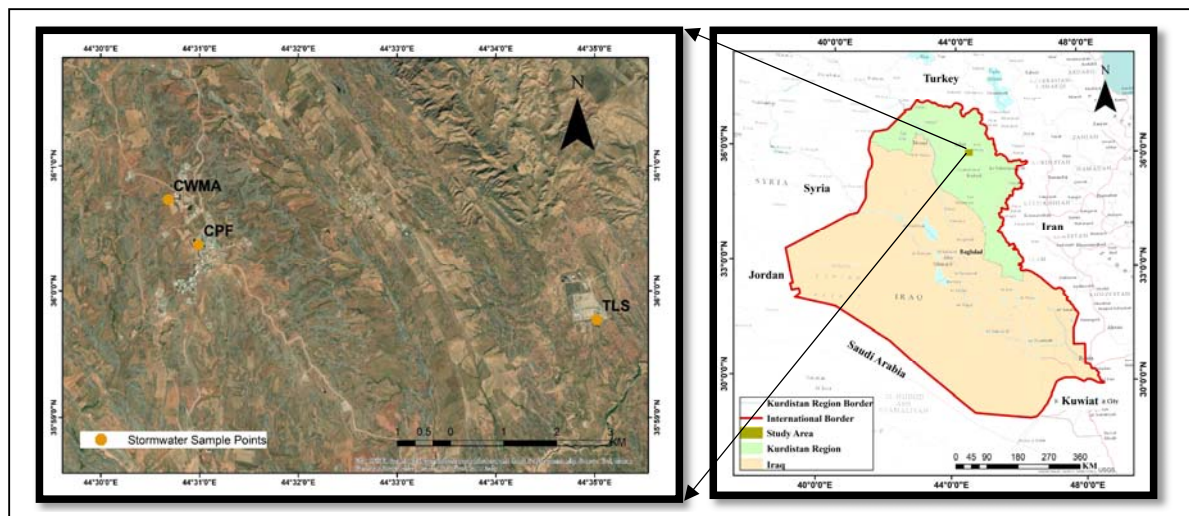


Fig. 1. Study Area and Sample Point Location

Table. 1. Monthly Precipitation in the Study Area (September 2017 – August 2018)

Months	Precipitation (mm)	Months	Precipitation (mm)
2017-09	0.00	2018-03	90.00
2017-10	3.00	2018-04	94.00
2017-11	65.00	2018-05	60.00
2017-12	53.00	2018-06	0.00
2018-01	124.00	2018-07	0.00
2018-02	203.00	2018-08	0.00
Total			692

Source: Long-term climate data were extracted from the TerraClimate dataset accessed via the Climate Engine web platform

& Droste, 2004; Maniquiz-Redillas et al., 2022).

In order to include most of the precipitation events of the study period including first flush from November 2017 and rains of May 2018, the samples were collected on 21st Jan 2018 and 6th May 2018. For that particular climate year, from September 2017 to August 2018, the total precipitation amounted to 692 mm (Table, 1), which is higher than the average of the long term.

Examining the monthly values reveals a very clear seasonal pattern. Autumn begins extremely dry, with no rainfall recorded in September 2017 and only 3 mm in October, conditions that can still be considered effectively dry. The rainy season starts in November (65 mm) and continues in December (53 mm), showing that the onset of significant precipitation occurs in late autumn. Rainfall then reaches its peak during winter: January records 124 mm and February are the wettest month with 203 mm. Substantial rainfall continues into early spring, with 90 mm in March and 94 mm in April. The rainy season then tapers off in May 2018 with 60 mm, which represents the last notable rainfall.

Sampling Equipment and Fieldworks: The storm water samples were taken by hand directly into the sample containers from the CWMA, CPF and TLS sampling points. The samples were discharged into glass bottles, some of which contained preservatives specific to the anticipated tested parameters. The bottles were placed in cool boxes with ice packs and transported to RSK's ISO17025-accredited chemical testing laboratory at Al Majal Business Park (AMBP), near Basra, under chain of custody documentation.

Discussion approach: Two approaches followed in this paper, first the key elements interpreted simply from the raw laboratory data and compared with the Iraqi threshold, explained the

exceedance of each element could bring what incontinent to environment and the ecosystem, especially the fresh water of nearby streams. Then three indices were used to understand the suitability of the storm water to be released to the nature. The composite indices—(WQI), (HMPI), and (PLI)—were computed using standard formulations widely applied in hydrological and environmental monitoring (Brown et al., 1970; Tomlinson et al., 1980; Caeiro et al., 2005; Tyagi et al., 2013; Alobaidy et al. 2010). Equal weighting was applied for all parameters, and Iraqi threshold values were used as the reference standards for each constituent.

$$WQI = \Sigma(Q_i \times W_i) / \Sigma W_i \quad (1)$$

$$Q_i = (C_i / S_i) \times 100 \quad (2)$$

where Q_i is the sub-index of the i th parameter, C_i and S_i are the measured and standard concentrations respectively, W_i is the relative weight (set to 1 for all parameters), and n is the number of parameters. In this study, equal weighting was applied, resulting in $WQI = \Sigma Q_i / n$. Classification thresholds: Excellent (<50), Good (50–100), Poor (100–200), Very Poor (200–300), Unsuitable (>300).

(HMPI) and (PLI) are used to assess the Heavey metals as bellow:

$$HMPI = (1/n) \Sigma(C_i / S_i) \quad (3)$$

where C_i and S_i are the measured and standard concentrations of metal i , and n is the number of metals. $HMPI < 1$ indicates permissible metal load, whereas $HMPI > 1$ implies enrichment beyond the standard threshold.

$$PLI = (CF_1 \times CF_2 \times \dots \times CF_n)^{(1/n)} \quad (4)$$

$$CF_i = C_i / S_i \quad (5)$$

A PLI value <1 denotes baseline conditions, =1 moderate pollution, and >1 deteriorated environmental quality.

RESULTS AND DISCUSSIONS

Results are presented in two complementary ways. First, the laboratory-measured stormwater chemistry is evaluated against Iraqi national threshold standards to identify parameters of concern (Table 2). Second, the dataset is synthesised into composite indices (WQI, HMPI, and PLI) to enable concise spatial and seasonal comparison across sites (Table 3).

Raw laboratory data and comparison with Iraqi thresholds: Stormwater samples from CWMA, CPF, and TLS were analysed for physicochemical parameters, oxygen-demand indicators, major ions, nutrients, hydrocarbons, and dissolved metals, then compared with Iraqi limits (Table 3). All six samples showed pH values within the acceptable Iraqi range (6–9.5), indicating neutral to slightly basic conditions (7.05–8.69).

Organic pollution indicators showed clear site contrasts. Biochemical oxygen demand (BOD) exceeded the Iraqi threshold (40 mg/L) only at CPF in May (93 mg/L); other samples were compliant. Chemical oxygen demand (COD) exceeded the Iraqi limit (100 mg/L) at CWMA on both dates (410 mg/L in January; 951 mg/L in May) and at CPF on both dates (103 mg/L in January; 191 mg/L in May). TLS remained compliant for COD (32 mg/L in January; <6 mg/L in May). Total suspended solids (TSS) similarly distinguished sites: CWMA and CPF recorded exceedances (CWMA reaching 201 mg/L in May; CPF showing 148 mg/L in January and a 3200

Table 2. Comparative values of physicochemical and trace element concentrations in stormwater samples from CWMA, CPF, and TLS during January and May 2018 compared with Iraqi threshold limits

Parameter	Units	CWMA		CPF		TLS		Iraqi Threshold
		21 st Jan	6 th May	21 st Jan	6 th May	21 st Jan	6 th May	
pH (w)	pH	7.98	8.27	8.69	7.05	7.41	7.47	6 to 9.5
BOD (settled, 5 day)	mg/l	13	46	5	93	<1	<1	Less than 40
TSS	mg/l	57	201	148	3200	14	35	60
TPH	µg/l	1805	26	31	<5	<5	<5	3000
Dissolved ethyne / acetylene	mg/l	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	ND (zero)
COD (settled)	mg/l	410	951	103	191	32	<6	Less than 100
Chloride (w)	mg/l	6780	6780	48	48	7	7	600
Fluoride (w)	mg/l	0.88	2540	0.48	186	<0.10	<0.10	5
Nitrate (w)	mg/l	<0.10	<0.10	<0.10	<0.10	12.12	4.78	50
Phosphate	mg/l	<0.02	0.06	0.33	<0.02	0.4	0.14	3
Sulphate (w)	mg/l	1120	945	117	460	43	46	400
Aluminium (dissolved)	µg/l	31469	32	890	20	5017	20	5000
Arsenic (dissolved)	µg/l	6	41	3	<1	1	1	50
Boron (dissolved)	µg/l	6460	2170	135	384	60	34	1000
Barium (dissolved)	µg/l	91	126	20	216	49	41	4000
Cadmium (dissolved)	µg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	10
Cobalt (dissolved)	µg/l	<1	<1	<1	<1	<1	<1	500
Copper (dissolved)	µg/l	<1	<1	3	<1	2	3	200
Chromium (dissolved)	µg/l	2	8	1	<1	3	5	100
Iron (dissolved)	µg/l	<10	37	<10	82	<10	<10	2000
Lead (dissolved)	µg/l	<1	2	<1	<1	<1	<1	100
Manganese (dissolved)	µg/l	20	75	5	343	<1	<1	500
Mercury (dissolved)	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	5
Nickel (dissolved)	µg/l	3	6	5	2	3	1	200
Selenium (dissolved)	µg/l	1	2	3	<1	<1	<1	50
Zinc (dissolved)	µg/l	<1	3	7	<1	7	4	200
VOC total	µg/l	46	6	ND*	ND*	ND*	ND*	ND (zero)

Table 3. Spatial and Temporal Variation of WQI, HMPI and PLI at the Three Storm-Water Sites (CWMA, CPF and TLS) in 2018

Site-Date	WQI	HMPI	PLI
CWMA-Jan	50.96	1.083	0.031
CWMA-May	70.20	0.280	0.041
CPF-Jan	36.02	0.045	0.022
CPF-May	60.94	0.097	0.014
TLS-Jan	14.06	0.100	0.016
TLS-May	11.83	0.015	0.009

mg/L peak in May), whereas TLS remained within the standard (14–35 mg/L). Hydrocarbons were generally low. Total petroleum hydrocarbons (TPH) were detected at CWMA in January (1805 µg/L), below the Iraqi threshold (3000 µg/L); CPF and TLS were below detection. VOCs were reported at CWMA (46 µg/L in January; 6 µg/L in May) and non-detect elsewhere (Table 2).

Major ions and salinity-related parameters showed the strongest, most persistent exceedances at CWMA. Chloride at CWMA was 6780 mg/L in January and May, far exceeding the Iraqi threshold (600 mg/L), whereas CPF and TLS were well below it (48 mg/L and 7 mg/L, respectively). Sulphate exceeded the Iraqi standard (400 mg/L) at CWMA in both months (1120 mg/L in January; 945 mg/L in May) and at CPF in May (460 mg/L); TLS remained compliant (43–46 mg/L). Fluoride presented extreme exceedances: CWMA recorded 2540 mg/L and CPF 186 mg/L in May, both well above the 5 mg/L threshold, whereas TLS remained <0.10 mg/L. Nutrients were low throughout. Nitrate was below the Iraqi limit (50 mg/L) in all samples, and orthophosphate (PO₄) remained below 3 mg/L at all sites, peaking at TLS in January (0.4 mg/L).

Dissolved metals were largely compliant with Iraqi thresholds, barring specific exceptions.

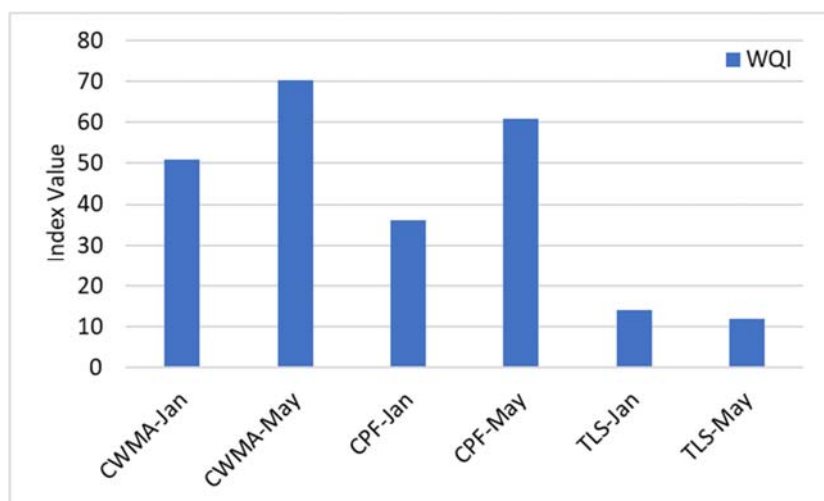


Fig. 2. Spatial and Temporal Variation of WQI at the Three Storm-Water Sites in 2018

Aluminium exceeded the threshold ($5000 \mu\text{g/L}$) at CWMA in January ($31469 \mu\text{g/L}$) and marginally at TLS in January ($5017 \mu\text{g/L}$); CPF remained within limits. Boron exceeded the $1000 \mu\text{g/L}$ limit at CWMA in January ($6460 \mu\text{g/L}$) and May ($2170 \mu\text{g/L}$), whereas CPF and TLS remained below it. Other metals (lead, mercury, cadmium, cobalt, copper, chromium, nickel, selenium, and zinc) were within thresholds across all sites. Iron and manganese remained below limits but peaked at CPF in May (iron $82 \mu\text{g/L}$; manganese $343 \mu\text{g/L}$).

Overall, threshold comparisons highlight a consistent pattern: CWMA exhibited the greatest frequency and magnitude of exceedances (notably COD, TSS, chloride, fluoride, sulphate, boron, and aluminium), CPF showed intermediate impairment, and TLS was largely compliant. Although certain elements may naturally occur geologically, their contribution to measured stormwater quality is expected to be limited because the study area's engineered surfaces minimize direct runoff contact with underlying bedrock and soils. This site ordering (CWMA > CPF >> TLS) is reflected in the index-based synthesis below.

Index-based synthesis (WQI, HMPI, and PLI): To summarise the dataset, a composite WQI was derived from consistently measured physicochemical variables, while two metal-focused indices (HMPI and PLI) were calculated using Iraqi stormwater thresholds as reference standards (Table 3). These indices provide an interpretable way to compare stormwater quality across sites and between the two sampling events (21 January and 6 May 2018).

WQI values ranged from 11.83 to 70.20, spanning "Excellent" to "Good" classes. TLS consistently recorded the lowest WQI values (14.06 in January; 11.83 in May), both "Excellent", indicating the best composite stormwater quality. CPF was "Excellent" in January (36.02) but shifted to "Good" in May (60.94). CWMA recorded the highest WQI values (50.96 in January; 70.20 in May), remaining "Good" but exhibiting clearly higher impairment. In terms of spatial ranking, CWMA shows the greatest impairment ($\text{WQI} \approx 51\text{--}70$), CPF is intermediate ($\approx 36\text{--}61$), and TLS is consistently lowest ($\approx 12\text{--}14$). Temporally, CWMA and CPF show deterioration from January to May, whereas TLS remains low and stable (Fig. 2).

Metal-based indices were consistently low relative to critical thresholds. HMPI ranged from 0.015 to 1.083, peaking at CWMA in January (1.083) before decreasing in May (0.280). CPF showed a moderate increase from 0.045 to 0.097, while TLS decreased from 0.100 to 0.015. HMPI remained below unity for all samples except CWMA-Jan, indicating an episodic elevation in average metal-to-standard ratios. PLI values were very low across all sites (0.009–0.041), far below the conventional threshold of 1, with CWMA slightly increasing from January

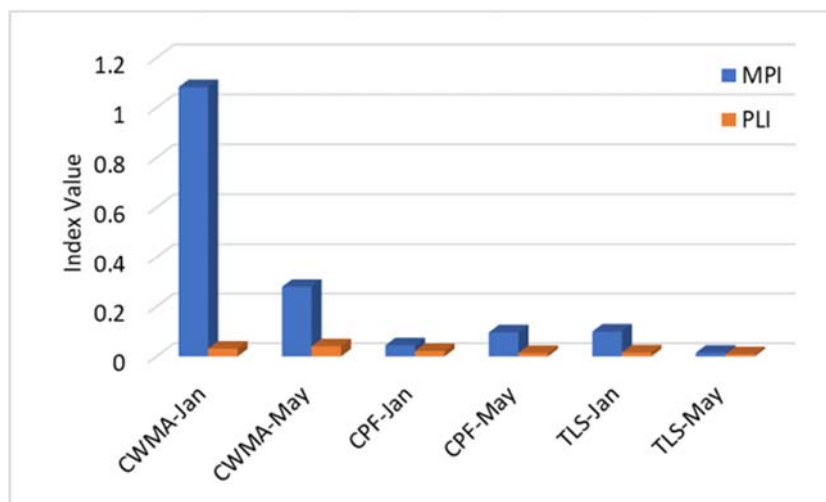


Fig. 3. Spatial and Temporal Variation of HMPI and PLI at the Three Storm-Water Sites

to May (0.031 $\rightarrow$ 0.041), while CPF (0.022 $\rightarrow$ 0.014) and TLS (0.016 $\rightarrow$ 0.009) decreased (Fig. 3). Together, HMPI and PLI indicate low cumulative dissolved-metal pollution pressure; site differences are largely driven by non-metal stressors captured in the WQI.

Samples collected in January and May 2018 represent contrasting seasonal conditions for the study area (wet and relatively dry periods). Although more recent routine monitoring data are not available, the measurements reported here provide a field-based chemical characterisation of stormwater at these industrial facilities and therefore serve as a baseline for future monitoring and comparison.

Dominant stressors and site contrasts: The threshold comparison and indices together show that stormwater impairment at CWMA and CPF is primarily associated with elevated organic/oxygen-demand parameters and suspended solids, and at CWMA additionally with strong salinity and selected ion exceedances. COD exceedances at CWMA and CPF indicate a high load of oxidisable material, which may reduce dissolved oxygen in receiving waters and degrade aquatic habitat quality (Li et al., 2018; Akpor & Muchie, 2011; Bashir et al., 2020). Elevated TSS at CWMA and especially CPF (3200 mg/L in May) indicates substantial particulate mobilisation during runoff events; high suspended solids can reduce light penetration, alter habitats, and transport particle-associated contaminants (Bilotta & Brazier, 2008; Davies-Colley & Smith, 2001; Kjelland et al., 2015). These patterns are consistent with oilfield-related stormwater observations where runoff can carry elevated solids and oxygen-demand loads in operational areas (Nyieku et al. 2024), and they align with produced-water remediation literature showing that organic and particulate burdens are common concerns in oil-industry wastewater contexts (Kumar et al. 2023).

Salinity indicators were most pronounced at CWMA. Chloride (6780 mg/L in both months) and sulphate (945–1120 mg/L) consistently exceeded Iraqi standards, suggesting that salinity-related stress is persistent at this facility. Regional assessments have similarly reported elevated salinity in waters influenced by oil operations and industrial zones (Oleiwi & Al Dabbas 2022), and regional groundwater research reports elevated boron and other ions in impacted settings (Awad et al. 2022). Elevated salinity can alter ionic composition and osmotic conditions in freshwaters, affecting sensitive taxa and shifting communities toward salt-tolerant assemblages (Cañedo-Argüelles et al., 2013; Nielsen et al., 2003; Cunillera-Montcusí et al., 2022). In the present dataset, the combination of high chloride/sulphate and elevated WQI at CWMA indicates a mixed impairment regime in which salinity and oxygen-demand/particulate stressors co-occur.

Fluoride exceedances are particularly notable because they were extreme at CWMA in May

(2540 mg/L) and substantial at CPF in May (186 mg/L), both far above the Iraqi threshold (5 mg/L). Within the scope of the present dataset, this identifies fluoride as a key parameter of concern at CWMA and CPF during the May event, and it contributes to the overall impairment classification at these sites.

Most dissolved metals were within Iraqi threshold limits across all sites and dates, which is consistent with the low HMPI and PLI values. However, aluminium exceeded the threshold at CWMA in January (31,469 µg/L) and slightly at TLS in January (5,017 µg/L), and boron exceeded the threshold at CWMA in both January and May. Heavy-metal mobilisation associated with oilfield infrastructure has been documented in Iraq (Nematollahi et al. 2022). In this dataset, the selective elevation of aluminium and boron, despite broad compliance of other metals, indicates parameter-specific risks that may not be fully captured by composite indices alone. Since metals can be persistent and pose ecological and health risks through exposure and accumulation pathways (Tchounwou et al., 2012; Ali et al., 2019; Briffa et al., 2020), these episodic exceedances support the value of combining index-based assessment with parameter-level threshold analysis.

The elevated BOD at CPF in May (93 mg/L) indicates high biodegradable organic loading at that site-date combination. TPH was detected at CWMA in January (1805 µg/L) but remained below the Iraqi limit, and VOCs were detected only at CWMA. Previous Iraqi studies report hydrocarbon contamination associated with oil activities and corresponding increases in oxygen-demand indicators and hydrocarbon markers (Al Hassen et al. 2013). Even where hydrocarbon indicators are within regulatory limits, oxygen-demand measures such as BOD and COD remain relevant because high organic loads can reduce dissolved oxygen and impair aquatic habitat and water uses (Vigiak et al., 2019; Davis, 1975). In the present dataset, oxygen-demand exceedances (COD at CWMA and CPF; BOD at CPF-May) provide a clearer and more persistent signal of impairment than TPH.

Regarding temporal contrast and seasonal patterning, both the raw data and WQI indicate deterioration from January to May at CWMA and CPF, while TLS remained consistently low. This seasonal contrast is consistent with literature indicating that in arid to semi-arid climates, evaporation and antecedent conditions can contribute to more concentrated runoff signatures (Oleiwi & Al Dabbas 2022), and that operational activity patterns may influence stormwater quality (Kumar et al. 2023). Within this dataset, the May sampling at CWMA and CPF coincides with higher COD/TSS and the major fluoride exceedances, which collectively drive higher WQI values.

Context for attenuation and broader environmental relevance: Evidence of hydrocarbon-degrading microbial communities in Iraqi oilfield soils suggests potential for natural attenuation of some hydrocarbons, although this does not address salinity or metals (Mohammed et al. 2023). Recent Iraqi bioremediation studies similarly emphasise that petroleum hydrocarbon loads may be reduced while inorganic ions can persist (Taher & Saeed 2022). Beyond facility-scale implications, multiple Iraqi studies point to cumulative environmental and health risks near oil operations, including combined hydrocarbon and metal contamination and related risk assessment outcomes (Elliott et al. 2022; Grmasha et al. 2023). In this context, the present findings—particularly elevated TSS/COD, persistent salinity at CWMA, and episodic aluminium/boron exceedances—identify stressors that warrant attention in stormwater management and monitoring.

The composite indices provide a coherent synthesis that is consistent with the threshold-based interpretation. WQI consistently ranks CWMA as the most impacted site, CPF as intermediate, and TLS as the lowest-impacted site, which aligns with wider evidence that index-based approaches effectively condense multi-parameter datasets and differentiate impacted industrial/urban catchments from less disturbed systems (Banda and Kumarasamy, 2020; Ewaid et al., 2020; Gabr et al., 2023). Conversely, HMPI and PLI remain below 1 at all sites and dates, with only CWMA-Jan marginally exceeding 1 for HMPI, confirming that dissolved metals are not the dominant driver

of composite impairment in this dataset. Similar decoupling between low composite metal indices and episodic parameter exceedances has been reported where a small subset of metals dominates risk despite broad compliance (Kamali Maskooni et al., 2020; Ahirvar et al., 2023; Qasim et al., 2025). As discussed, this supports the use of indices alongside parameter-level interpretation in monitoring and management (Ahirvar et al., 2023; Qasim et al., 2025).

Consistent with the raw data, the elevation of WQI at CWMA and CPF tracks oxygen-demand and particulate parameters (TSS, BOD₅, COD), while persistent chloride and sulphate contribute strongly at CWMA. Nutrients are generally modest, with TLS showing measurable but sub-threshold nitrate. Fluoride stands out as a dominant exceedance in May at CWMA and CPF. Overall, across indices and threshold exceedances, the rank order of impairment is robust: CWMA > CPF >> TLS. Interpreted together, these findings provide a technically grounded baseline and a clear prioritisation of parameters and facilities for targeted stormwater management and future monitoring, consistent with best practice in multi-indicator water-quality assessment (Ewaid et al., 2020; Ahirvar et al., 2023; Qasim et al., 2025).

CONCLUSION

Stormwater quality differed markedly among the three facilities, with a consistent impairment gradient (CWMA > CPF >> TLS) across both monitored events (January and May 2018). Exceedances were dominated by suspended solids, oxygen-demand indicators, and salinity-related parameters, indicating that stormwater risk at CWMA and CPF is characterised by both event-associated peaks and persistent ionic enrichment. This is reflected in the highest observed event concentrations (e.g., TSS up to 3200 mg/L at CPF in May and COD up to 951 mg/L at CWMA in May) together with consistently elevated chloride at CWMA (6780 mg/L in both January and May). Composite indices reinforced these patterns: WQI reproduced the site impairment gradient, whereas HMPI and PLI remained generally low, indicating that dissolved metals were not the dominant pressure overall, despite episodic exceedances (notably aluminium at CWMA in January).

This study contributes a field-based baseline dataset for stormwater quality in Iraqi oilfield facilities and demonstrates the value of combining parameter-specific threshold exceedance analysis with composite indices to prioritise dominant stressors across facility types. Regionally, the findings support targeted monitoring and mitigation planning for oilfield infrastructure in the Kurdistan Region of Iraq by identifying the parameters and sites most consistently associated with impairment. More broadly, the results highlight that in oilfield industrial stormwater settings, non-metal stressors (solids, oxygen demand, and salinity) may govern overall water-quality impairment even when most dissolved metals remain below standards, which has relevance for stormwater assessment and management in comparable industrial catchments.

Management should prioritise measures that reduce particulate and oxygen-demand loads and address salinity-related inputs at CWMA and CPF, complemented by targeted follow-up of parameters showing pronounced event variability. Although based on two sampling campaigns, the dataset provides an initial baseline for extending monitoring across additional storms and seasons and for evaluating the effectiveness of future mitigation actions.

GRAND SUPPORT DETAIL

The present research did not receive any financial support.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this

manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

DECLARATION ON AI USE

The authors declare that no generative AI tools were used to produce scientific content, data, results, analysis, interpretations, figures, tables, or references in this manuscript. ChatGPT was used solely for language editing and clarity improvement. All AI-assisted text was reviewed, edited, and approved by the authors, who take full responsibility for the final content of the submitted manuscript.

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