https://doi.org/10.54809/ga11a.2025.001

Management of Water Quality and Legal Protection of Rivers from the Impacts Stone Quarries: A Case Study of the DiyaIa /Sirwan River

Shagul Abubaker Ali[1] *Hiwa Rashid Ali*[2] *Abdulmutalib Raafat Sarhat*[3]*

[1]Department of Natural Engineering and Agricultural Sciences Engineering Kurdistan Institution for Strategic Studies and Scientific Research, Kurdistan, Iraq

[2]Department of Law, University of Garmian, Kalar, Kurdistan, Iraq,Visiting Lecturer, College of Law, Arab East Colleges, Riyadh, Kingdom of Saudi Arabia

[3]Department of Chemistry, Collage of Science, University of Garmian, Kurdistan, Iraq

Abstract — **In the Kurdistan Region of Iraq (KRI), gravel and sand are among the raw materials extracted from river areas such as the Diyala/Sirwan River. These activities pose significant risks to water quality and the surrounding ecosystem. This study has two main objectives: first, to evaluate the impact of quarry activities on the water quality of the river; and second, to examine the existing legal framework governing river protection from the adverse effects of quarrying projects near riverbanks. Two main methods were employed. For water quality assessment, twelve samples were collected along the river and analyzed using various water quality indices and parameters. Additionally, a doctrinal legal method (library-based legal research) was applied, drawing on both primary and secondary data to assess the legal protection of rivers from mining activities in the KRI. The findings indicate that the river's water quality was significantly affected by quarry operations in 2021, but showed improvement in 2022 after restrictions were imposed on quarrying activities within the river area. Furthermore, the legal review revealed several shortcomings in the current legislative framework. Weak enforcement of environmental laws and poor institutional coordination were identified as key issues. Therefore, this study recommends the development of a more robust legal framework, stricter law enforcement, and improved inter-agency coordination to ensure the sustainable protection of rivers.**

Keywords— **Water quality, Diyala/ Sirwan River, Stone quarry, Water pollution, Environmental law.**

I. INTRODUCTION

In recent years, the demand for sand and gravel in developing countries has increased rapidly due to urbanization, industrialization, and infrastructural development (Al Mamun et al., 2019). It is estimated that approximately 50 billion tons of gravel and sand are extracted annually from rivers around the world (Lwanga et al., 2022; Misati & Mwenzwa, 2018; Akanwa, 2021). International guidelines and legislation promote sustainable mining practices, including the extraction of lowvalue materials such as gravel and sand from river systems (Barreto et al., 2018).

In developed countries, environmental monitoring agencies are highly active and regularly assess water quality while enforcing environmental laws strictly (Al Mamun et al., 2019; Akanwa, 2021). However, such regulations are often poorly implemented in developing nations. Unregulated gravel and sand extraction exerts significant pressure on river ecosystems, threatening aquatic habitats and causing visible degradation in small catchments (Sreebha & Padmalal, 2011), including those in the Kurdistan Region of Iraq.

Previous studies have shown that gravel and sand mining deteriorate water quality and riverine ecosystems (Attiogbe & Nkansah, 2017; Menta, 2012). Sand and gravel extraction alter the physico-chemical characteristics of river water, affecting key parameters such as total suspended solids (TSS), turbidity, dissolved oxygen (DO), and total hardness (TH), which pose

Galla-The Scientific Journal of KISSR Vol. I, No. 1 (2026), Article ID: Galla.12181. 10 pages . DOI: 10.54809/ga11a.2025.001. Received: 29 September, 2025; Accepted: 20 October, 2025 Regular research paper; Published: 2025 January,2026. *Corresponding author's e-mail: abdulmutalib. Raafat @ garmian. edu.krd.

https://doi.org/10.54809/ga11a.2025.001

risks to both human health and aquatic life (Kemgang Lekomo et al., 2021; Koehnken et al., 2020; Aliu et al., 2022). Such operations have also been linked to deforestation, habitat destruction, biodiversity loss, and erosion (Cele, 2021). Other studies have reported significant morphological changes in mined river areas, as well as environmental issues including dust, noise, and contamination of surface and groundwater (Devi & Rongmei, 2017; Pandey et al., 2022).

Despite these challenges, there is limited information on sand and gravel extraction in the Kurdistan Region. Quarry sites are widely distributed along the Diyala/Sirwan River in the Kalar District, northeastern Iraq. This river serves as the main source of sand and gravel in the Garmian Region and has attracted numerous stone quarries, particularly since 2003. Due to sediment deposition from reduced river velocity, dredging machines are frequently used to extract gravel and sand, with effluents often discharged directly into the river. The Diyala/Sirwan River plays a vital role in the region, supplying water for drinking, irrigation, domestic, and industrial uses.

Discharging untreated industrial and mining effluents into surface waters results in severe water pollution (Koehnken et al., 2020; Howladar, 2017; Kilonzo et al., 2019). Quarrying activities in the Garmian Region are therefore suspected to have polluted the Diyala/Sirwan River basin. In response to public pressure from civil society organizations and environmental activists, the Garmian Administration— the highest local authority— decided in 2022 to halt sand and gravel quarry operations and convert existing sites into crushing plants for processing previously collected riverbank materials.

Since limited research has been conducted on this topic, the present study addresses a significant knowledge gap by evaluating the effects of quarry activities on river water quality before and after the enforcement of this administrative decision (effective January 1, 2022).

This study has two main objectives. The first is to assess the influence of stone quarry activities on selected physico-chemical parameters of water quality— namely turbidity, pH, total hardness (TH), electrical conductivity (EC), total suspended solids (TSS), and dissolved oxygen (DO). Water samples were collected during the dry season (June to September) for both 2021 and 2022, and the results were analyzed using the Water Quality Index (WQI) to determine the river's suitability for drinking, irrigation, fisheries, and agricultural use.

The second objective is to analyze the existing legal framework— particularly Iraqi Law No. 91 of 1988 on the Regulation of Mineral Investment— concerning river protection from the environmental impacts of quarrying activities. The findings of this study aim to inform policymakers and decision-makers about sustainable surface water management and the legal measures required to mitigate the negative effects of quarry operations.

II. MATERIALS AND METHODS

Given the dual nature of this study combining environmental science and legal analysis two distinct methodological approaches were adopted to assess both the water quality of the Diyala/Sirwan River and the legal framework governing river protection.

Water Analysis Method

To determine the water quality of the river, results from collected samples were analyzed and compared using the Water Quality Index (WQI) in accordance with international standards.

Legal Analysis Method

To examine the legal framework, the study employed a doctrinal and qualitative approach to critically evaluate the relevant legislation on quarry management and environmental protection, particularly concerning rivers such as the Diyala and Sirwan. Both primary and secondary data sources were utilized, including legislation, governmental contracts with investors, published research, and official reports.

The main legal instrument examined was Iraqi Law No. 91 of 1988, Regulation of Mineral Investment. Additionally, qualitative field observations were conducted to assess the environmental threats and actual impacts of stone quarrying on the Diyala/Sirwan River and its surrounding ecosystems.

Study Area

The study area is located along the Diyala River within the Garmian Region, Kalar District, in the Kurdistan Region of Iraq. Geographically, it extends between the following coordinates:

35°00'35.3"N, 45°38'18.9"E and 34°37'03.7"N, 45°20'24.2"E.

The Diyala River represents the most significant source of surface water in this region. Over the past three decades, numerous stone quarries have been established along its banks, leading to severe environmental degradation and a continuous decline in water quality.

Sampling

Twelve water samples were collected from stations located downstream of the quarry sites at a depth of 30 cm (see Table 1

https://doi.org/10.54809/ga11a.2025.001

and Figure 1). Sampling was conducted during the summer seasons of 2021 and 2022.

Table 1: Water sampling locations

Sample NO.	Condition
1	35°02’33.8”N 45°39’45.9”E
2	35°01’18.2”N 45°37’37.4”E
3	35°00’35.3”N 45°38’18.9”E
4	34°58’17.7”N 45°37’43.0”E
5	34°56’57.4”N 45°37’26.4”E
6	34°53’06.0”N 45°33’56.7”E
7	34°50’04.6”N 45°31’31.5”E
8	34°48’06.3”N 45°30’31.9”E
9	34°46’42.9”N 45°29’26.6”E
10	34°42’01.8”N 45°27’34.1”E
11	34°38’59.4”N 45°25’34.3”E
12	34°37’03.7”N 45°20’24.2”E

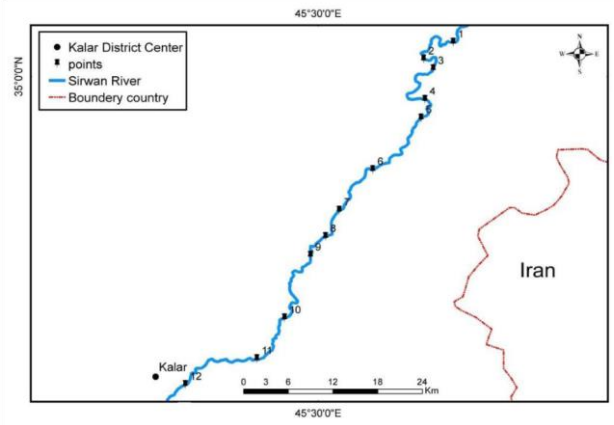

Figure 1: The study area and sampling stations

Sample Analysis

On-Site Analysis

Several parameters—pH, electrical conductivity (EC), turbidity, and dissolved oxygen (DO)—were measured in situ using portable meter devices (George et al., 2014).

Laboratory Analysis

Two additional parameters, Total Hardness (TH) and Total Suspended Solids (TSS), were determined in the laboratory.

- Total Hardness (TH): Measured using the titration method with EDTA solution, K10 buffer, and Eriochrome Black T indicator, expressed in mg/L.
- Total Suspended Solids (TSS): Determined by filtration through preweighed filter papers following the American Public Health Association (APHA) standard procedures (Federation, 1999).

Water Quality Index (WQI)

The parameters—pH, EC, DO, turbidity, TH, and TSS—were used to calculate the Water Quality Index (WQI) for the Diyala River during two periods:

- 2021: when quarry activities were operational; and
- 2022: after the Garmian Administration prohibited quarry operations near the river.

The WQI was computed using the Weighted Arithmetic Index method, as recommended by the World Health Organization (WHO). The five key parameters analyzed were pH, turbidity, TH, EC, and TSS.

The following equation was applied (AlObaidi & Sarhat, 2022; Chatterjee & Raziuddin,2002).

$$WQI_A = \sum_{i=1}^{n} W_i * q_i / \sum_{i=1}^{n} W_i \dots (1)$$

WQI = Water Quality Index. W_i = unit weight of the *i*th parameter. q_i = quality rating for the *i*th parameter

The quality rating (q_i) was calculated as follows (Al-Obaidi & Sarhat, 2022; Chatterjee & Raziuddin, 2002):

$$q_i = 100 \frac{(V_i - V_{id})}{(S_i - V_{id})} \dots (2)$$

V_i = estimated value of the *i*th parameter at each station. S_i = permissible value for the *i*th parameter. V_id = ideal value for the *i*th parameter

For pH and DO, the ideal values were set at 8.5 and 14.6, respectively, while for other parameters, the ideal value was 0.

https://doi.org/10.54809/ga11a.2025.001

$$q_{pH} = 100[(V_{PH} - 7.0) / (6.5\text{-}8.5)] \ldots(3)$$

$$q_{DO} = 100[(V_{DO} - 5.0) / (5.0\text{-}14.6)] \ldots(4)$$

The WQI and corresponding water quality status were categorized according to the weighted arithmetic method shown below.

Table 2: Levels of WQI and water quality status (weighted arithmetic method)

WQI Range	Water Quality Status
0–25	Excellent
26–50	Good
51–75	Poor
76–100	Very poor
>100	Unsuitable for drinking

Table 3: Standard values and weights of WQI parameters

Parameter	Standard Value (WHO)
Turbidity	5 NTU
pH	6.5–8.5
EC	600 µS/cm
TH	500 mg/L
DO	5.0–14.6 mg/L
TSS	25 mg/L

Right to Clean Water

The right to safe and clean drinking water and sanitation was explicitly recognized by the United Nations General Assembly in its Resolution 64/292 of July 28, 2010, which declared that "The right to safe and clean drinking water and sanitation is a human right that is essential for the full enjoyment of life and all human rights" (United Nations [UN], 2010; Léo Heller, 2020). In Iraq, the Constitution of 2005 recognizes the right to a safe environment, as stated in Article 33(1) that "Every individual has the right to live in safe environmental conditions."

Moreover, Article 33(2) obliges the state to protect the environment and its biodiversity: "The State shall undertake the protection and preservation of the environment and its biological diversity." However, the Iraqi Constitution does not explicitly guarantee the right to clean water or provide clear legal mechanisms for water protection, which remains a critical legislative gap (Republic of Iraq, 2005).

III. RESULTS

Water Quality Near the Stone Quarries

As previously mentioned, data collection was conducted during the dry season, when evaporation rates are higher and precipitation is minimal, which generally provides a clear and accurate assessment of water quality. Various parameters of water quality were examined across the stone quarry sites.

The pH values of water across all twelve active stone quarry sites in 2021 averaged 7.34, with a minimum of 7.11 and a maximum of 7.7. This average falls within the permissible limits of the WHO water quality standards (Herschy, 2012). After quarry operations were suspended by the Garmian Administration in 2022, the pH values at all twelve sites slightly decreased.

The electrical conductivity (EC) of water at the active quarry sites in 2021 ranged from 408 to 428 µS/l, with an average of 415.83 µS/l. Following the cessation of quarry activities in 2022, EC values decreased, ranging from 388 to 411 µS/l with an average of 398.17 µS/l.

During active quarry operations, the average turbidity across all sites was 29.52 NTU, significantly exceeding the critical level of 5 NTU, the average turbidity dropped sharply to 4.89 NTU, indicating substantial improvement.

The results showed that TSS values during active quarry operations ranged from 65 to 98 mg/L, with an average of 81.08 mg/L. After quarry operations ceased, TSS values dropped substantially to a range of 20–33 mg/L, averaging 25 mg/L.

Total Hardness (TH) is not a direct pollutant but is associated with water quality. Naturally, TH values above 500 mg/L are uncommon (Miljojkovic et al., 2019). In 2021, TH values ranged from 318 to 380 mg/L, averaging 349.08 mg/L, classifying the water as very hard according to WHO standards. After quarry activities stopped in 2022, TH values decreased to 287– 345 mg/L, with an average of 321.58 mg/L, reflecting reduced concentrations of dissolved calcium and magnesium.

During active quarrying in 2021, DO values ranged from 4.93 to 5.88 mg/L, with a mean of 5.37 mg/L, indicating good to sufficient quality for most aquatic organisms and human use (Li et al., 2013). Only one station recorded DO below the WHO permissible limit of 5 mg/L, signaling localized pollution. In contrast, after quarry operations ceased in 2022, DO values ranged from 9.18 to 13.33 mg/L, averaging 11.07 mg/L, consistent with uncontaminated water, which typically has DO above 5 mg/L (WHO, 2004).

https://doi.org/10.54809/ga11a.2025.001

Table 4: Water parameters determined at the stone quarry site stations in 2021

Site No.	Turbidity	pH	EC	TH	DO	TSS
1	28.2	7.33	410	321	5.2	65
2	28.9	7.11	408	319	5.33	74
3	32.8	7.29	418	323	5.6	89
4	29.2	7.42	420	333	5.8	98
5	31.88	7.53	415	318	5	79
6	26	7.7	421	360	5.1	86
7	30.2	7.29	413	371	5.88	82
8	29	7.25	422	365	4.93	77
9	27.92	7.18	416	361	5.78	69
10	30	7.34	410	380	5.61	83
11	31.1	7.39	420	372	5.05	80
12	29	7.3	417	366	5.2	91
Average	29.52	7.34	415.83	349.08	5.37	81.08
Min.	26	7.11	408	318	4.93	65
Max.	32.8	7.7	422	380	5.88	98
WHO	5	6.5-8.5	600	500	5	50

Table 5: Water parameters determined at the stone

Site No.	Turbidity	pH	EC	TH	DO	TSS
1	5.03	7.12	398	298	12.1	22
2	4.28	7.59	386	287	13.33	23
3	5.11	7.62	395	295	11.2	20
4	4.13	7.05	400	315	12.22	25
5	3.98	7.22	394	318	10.3	27
6	4.44	7.08	385	320	10.9	31
7	5.16	7.07	402	338	9.23	33
8	6.15	7.41	405	341	11.4	26
9	4.38	7.06	399	330	10.1	21
10	5.55	7.5	403	343	9.18	20
11	4.93	7.19	411	329	11.7	22
12	5.51	7.45	400	345	11.2	30
Average	4.89	7.28	398.17	321.58	11.07	25.00
Min.	3.98	7.05	385	287	9.18	20
Max.	6.15	7.62	411	345	13.33	33
WHO	5	6.5-8.5	600	500	5	50

Water Quality Index (WQI)

The Water Quality Index (WQI) and water quality status of the Diyala River at each monitoring station are presented in Table 6. Results show that overall water quality improved markedly in 2022 compared to 2021.

In 2021, WQI values across all stations exceeded 100, ranging from 132.18 to 168, with an average of 152.80, classifying the water as unsuitable for drinking. The main contributors to water deterioration were stone quarrying, industrial waste, and agricultural runoff.

In 2022, WQI values decreased substantially, ranging from 24.76 to 57.6, with an average of 43.19, corresponding to a "good quality" classification.

Table 6: Water quality index at the stone quarry site stations in 2021 and 2022

Site	WQI 2021	Status	WQI 2022	Status
1	142.4	Unsuitable	45.4	Good
2	152.4	Unsuitable	24.76	Excellent
3	168	Unsuitable	29.7	Good
4	153.37	Unsuitable	46.2	Good
5	154.1	Unsuitable	43.9	Good
6	132.18	Unsuitable	50.25	Poor
7	156.6	Unsuitable	57.6	Poor
8	154.67	Unsuitable	43.67	Good
9	149.2	Unsuitable	49.5	Good
10	155.99	Unsuitable	40.53	Good
11	157.64	Unsuitable	44.85	Good
12	157.1	Unsuitable	41.88	Good
Ave.	152.80	Unsuitable	43.19	Good

IV. DISCUSSION

The outcome from each of; the quarry activities on the water quality of the river, by measuring (EC, Turbidity, TSS, DO and WQI) during two different years, and the existing legal framework governing river protection from the adverse effects of quarrying projects near riverbanks were interpret.

Evaluating the impact of quarry activities on the water quality of the river;

According to the results from the study area, the electrical conductivity (EC) of water at the active quarry; lower EC values indicate reduced ionic concentration, suggesting improved water quality (Bakamwesiga et al., 2022). Regarding monitoring and evaluating water turbidity is crucial for ensuring high water quality. Elevated turbidity can hinder the efficiency of drinking water treatment, as higher turbidity increases sedimentation time (Miljojkovic et al., 2019). This high turbidity was mainly due to the direct discharge of quarry pit water into the river and continuous drilling and sand excavation. When turbidity exceeds 5 NTU, it can cause major operational problems in water treatment plants, delaying clean water production and supply. Total Suspended Solids (TSS), an optical parameter representing suspended sediment concentration, is closely associated with turbidity and is vital in managing water resources due to its link with contaminant fluxes (Dey & Vijay, 2021; Sagan et al., 2020). About high TSS concentrations limit water usability for drinking, irrigation, aquaculture, and biodiversity support. A strong correlation between TSS and turbidity during both periods confirmed that TSS is a reliable indicator of turbidity in the Diyala River Basin. Hard water is unsuitable for domestic uses such as drinking, bathing, and washing, though it can reduce pipe corrosion. In addition the Dissolved Oxygen (DO) levels determine the suitability of

https://doi.org/10.54809/ga11a.2025.001

water bodies for aquatic life (Dey & Vijay, 2021). Lower DO concentrations generally indicate poorer water quality (Bozorg-Haddad et al., 2021; Sagan et al., 2020). The absence of quarry activities was the primary factor in this improvement, with some stations even reaching the "excellent" category.

Legal Mechanisms for Protecting the River from the Impacts of Quarry Projects

In the Kurdistan Region, several laws and institutions govern the protection of rivers and the environment. Concerning quarry projects and their impacts on river water quality and the surrounding ecosystem, this study focuses primarily on Iraqi Law No. 91 of 1988 (Regulation of Mineral Investment).

In addition, it references other relevant laws that are often violated in practice, including Law No. 8 of 2008 (Environmental Protection and Improvement in the Kurdistan Region of Iraq) and Law No. 4 of 2022 (Management and Conservation of Water in the Kurdistan Region of Iraq).

Examining the existing legal framework governing river protection from the adverse effects of quarrying projects near riverbanks

Iraqi Law No. 91 of 1988 on the Regulation of Mineral Investment

The Iraqi legislature enacted Law No. 91 of 1988 to regulate mineral investment activities, including quarrying. The law acknowledges that quarry projects have substantial environmental impacts, particularly on rivers and surrounding ecosystems. Therefore, it emphasizes environmental protection by requiring investors to operate within the legal framework to ensure the sustainable use of natural resources.

Part Two of this law, titled *"Prohibition,"* outlines several restrictions intended to protect sensitive areas from harmful mineral activities. It prohibits quarry operations near public and environmentally sensitive zones such as religious sites, historical monuments, agricultural lands, forests, dams, reservoirs, and areas located within or outside municipal boundaries—except for sites specifically designated by the Environment Protection Board (Article 3, Law No. 91/1988; Iraqi Laws, 2011).

However, despite these protective provisions, the law contains exceptions that weaken its environmental safeguards. For example, it prohibits quarry operations within 1000 meters of public roads and 1500 meters of bridges, but allows the competent authority to grant special permissions to establish quarry projects within these limits (Paragraph 5, Article 3). Similarly, quarrying is prohibited in military zones and oil and gas areas, and mining operations are restricted within 500 meters of such facilities, unless special approval is obtained. Quarry sites must also maintain a 1000-meter distance from power lines, unless exceptions are authorized by the relevant authorities (Articles 6–10, Law No. 91/1988; Iraqi Laws, 2011).

These provisions demonstrate an ambiguous commitment to environmental protection, as they do not explicitly address river protection or air pollution. Moreover, the numerous exceptions granted to administrative authorities undermine the law's effectiveness. To ensure robust environmental conservation and public safety, these exceptions should be eliminated, and specific provisions should be introduced to protect rivers and aquatic ecosystems from the impacts of mineral activities (Iraqi Laws, 2011).

Content of the Quarry Investment Contract

According to Articles 7 and 8 of Law No. 91 (1988), quarry investment contracts are conducted annually (Iraqi Laws, 2011). The law imposes several positive obligations on investors under Article 9, requiring them to adhere to specific environmental and operational duties. Investors must clearly mark their designated working area and submit detailed seasonal reports to the relevant authorities concerning production volumes, geological conditions, and any operational changes for monitoring purposes. They are also required to restore and rehabilitate their work areas by eliminating potential hazards such as deep pits formed during the extraction process. Furthermore, investors must ensure that at least 50% of the invested area is reclaimed at all times, and all equipment must be removed within four months of the contract's termination as instructed by the competent authority. Any remaining materials that are not removed within one month after the termination of the contract must be returned to the relevant authority.

Ensuring strict compliance with these obligations is crucial, as they have direct implications for environmental protection. Investors are expected to exercise selfmonitoring by maintaining accurate records of monthly production and geological changes. While the current law requires seasonal reporting, this study recommends amending the requirement to monthly reporting to enable more effective and timely supervision. Monthly reports would allow authorities to respond promptly to any geological or environmental issues identified in the data (Hiwa R. Ali, 2023).

Moreover, maintaining at least 50% of the area under reclamation at all times is vital to mitigating the environmental impacts of quarrying. However, in practice, many quarry projects have violated these provisions, neglecting rehabilitation obligations and leaving extraction sites hazardous.

As illustrated in Figure 2, quarry activities near the Diyala River have caused significant disruption to the river's natural flow. Investors have altered the river's course, resulting in the destruction of adjacent forests, loss of aquatic life, and reduced biodiversity. Additionally, failure to fulfill legal obligations—such as restoring deep extraction pits—has led to fatal accidents among local residents who swim in the river.

https://doi.org/10.54809/ga11a.2025.001

Figure 2: quarry activities in the Diyala/Sirwan river area

Therefore, it is imperative that the relevant authorities exercise their legal mandate to strictly monitor and regulate all quarry projects located near the river. Rigorous supervision and enforcement are essential to protect the Diyala River's ecological balance and to uphold environmental law in the Kurdistan Region.

End of the Contract and Legal Penalties

Law No. 91 of 1988 authorizes the competent authorities to terminate a license or contract with an investor under certain circumstances. As specified in Article 10 of this law, a contract may be terminated in the following situations: (1) if the investor fails to comply with the terms of the license, contract, or relevant legal instructions; (2) if the investor does not commence operations within three months of signing the contract or receiving permission to invest without a valid justification; (3) if the investor requests in writing to terminate the contract; (4) if the investor neglects the obligation under Paragraph 2 of Article 9 to submit a monthly report on their activities; (5) if the project's performance causes harm to the public interest; (6) if the investor secretly transfers or subcontracts the investment to another party; or (7) if the termination of the contract serves the public benefit, subject to ratification by the Minister of Industry (Para. 1, Article 10, Law No. 91/1988). Furthermore, the law stipulates that an investor whose contract has been terminated is not entitled to claim compensation unless the termination is based on public benefit.

These provisions grant the relevant administrative bodies the authority to revoke mineral investment licenses or contracts to ensure proper oversight and compliance with legal and scientific standards. For instance, Paragraph 1 (Point 1) of Article 10 clearly permits contract termination when an investor fails to fulfill their legal duties. However, as indicated in Points 4 and 6 of the same article, a contract may also be terminated for reasons of "public interest" or "public benefit," even if the investor has not explicitly violated the law. Importantly, the concepts of public interest and public benefit encompass environmental considerations such as the constitutional right to a safe environment and the right to access clean water, both recognized in the Iraqi Constitution. Thus, if mining or quarrying activities cause water pollution or other forms of environmental degradation in the river basin, such activities are deemed to harm the public interest. This is especially relevant in the case of the Diyala River, which holds immense socio-economic value for both the Garmian region and Iraq as a whole, providing clean air, potable water, irrigation, and supporting biodiversity (Iraqi Laws, 2011; Hiwa R. Ali, 2023).

Legal Penalties

Part Five of Law No. 91 (1988), titled *"Punishments,"* outlines the penalties imposed on investors who violate the law. According to Paragraph 1 of Article 13, investors who breach the regulations must pay a fine equal to double the value of the material illegally extracted. In practical terms, if an investor extracts raw materials beyond the permitted boundaries, they are required to pay a penalty twice the estimated market value of the excess material. More recently, the Ministry of Natural Resources (MoNR) in the Kurdistan Region has introduced stricter measures through *Instruction No. 1 of 2020*, issued by the Directorate of Mineral Investment. This instruction imposes a fine equal to three times the value of the illegally extracted material for violations within restricted areas (Instruction No. 1 of 2020, Directorate of Mineral Investment).

While this amendment represents a positive step toward stronger enforcement, many investors continue to disregard the law, particularly those operating near the Diyala River and adjacent forested areas. Consequently, further legislative reform is needed to make penalties more stringent and effective in deterring environmental violations. In parallel, the Directorate of Minerals and Oil in Garmian (DMOG) must adopt more proactive enforcement measures, including terminating the contracts of noncompliant investors. This is supported by Law No. 91 (1988), which authorizes local governments, including DMOG, to cancel investment licenses as an administrative mechanism to protect the public interest (Figure 3). Moreover, environmental oversight bodies such as the Environment Protection and Improvement (EPI) Board and the Water Council must play more active roles within their legal jurisdictions to address environmental degradation caused by quarry operations near the river.

Figure 3: Quarry activities in Diyala/ Sirwan river area violation of other related laws

https://doi.org/10.54809/ga11a.2025.001

Violation of Other Related Laws

In practice, quarry operations near the Diyala River have caused extensive environmental damage, including deforestation, destruction of vegetation, and alteration of the river's natural course through the construction of makeshift dams and extraction pits (Figure 3). These activities constitute clear violations of several environmental and natural resource protection laws in the Kurdistan Region.

One of the key pieces of legislation that has been violated is Law No. 8 of 2008 on Environmental Protection and Improvement in the Kurdistan Region of Iraq. Under this law, the Ministry of Environment (now replaced by the Environmental Protection and Improvement Board) is required to coordinate with other relevant institutions to enforce environmental standards in activities such as exploration, mining, quarrying, crushing, and washing (Article 30). However, in reality, the required environmental conditions and standards are largely absent from the implementation process (Hiwa R. Ali, 2023).

Another significant legal instrument is Law

No. 4 of 2022 on the Management and Conservation of Water in the Kurdistan Region of Iraq. Article 9 of this law prohibits the direct disposal of waste into water sources from industrial, agricultural, commercial, medical, residential, or investment activities unless appropriate scientific waste treatment is provided (Paragraph 1). The same article forbids any alteration of watercourse directions that could cause pollution, reduction of flow, flooding, or any other negative impact on water quality and quantity (Paragraphs 2 and 11) (Law No. 4 of 2022).

Additionally, Law No. 10 of 2012 on Forests in the Kurdistan Region of Iraq contains provisions explicitly designed to protect rivers and forested areas. Paragraph 3, Article 4 of this law prohibits the establishment of public or private facilities within forested areas— whether temporarily or permanently—without the approval of the Ministry of Agriculture and Water Resources (MoAWR). It further prohibits the construction of dams or barriers, diversion of rivers, establishment of quarry projects, and extraction or transportation of rocks, trees, and soil within forest areas (Points 9–10, Paragraph 3, Article 4) (Law No. 10 of 2012). These provisions reflect a strong legislative intent to preserve natural ecosystems; however, effective implementation remains limited due to weak enforcement and oversight mechanisms (Hiwa R. Ali, 2023).

Moreover, the operation of many quarry projects also violates Law No. 3 of 2018 on Preventing Illegal Overtaking in the Kurdistan Region of Iraq, as these projects often extend beyond their authorized boundaries and encroach upon the river basin, leading to overexploitation of natural resources. Despite the existence of multiple legal frameworks addressing environmental protection, quarry operations near the Diyala/Sirwan River remain poorly managed. This failure stems from inadequate enforcement of environmental laws and weak coordination among key institutions—particularly the EPI Board, Water Council, and DMOG—responsible for preventing water pollution, deforestation, and other ecological violations.

CONCLUSION

This study compared the Water Quality Index (WQI) of the Diyala River in the Kalar District across two different years—2021, when stone quarries were operating actively, and 2022, following the suspension of quarry activities by decision of the Garmian Administration. The findings indicate that quarry operations had a clear and measurable impact on the river's water quality, particularly through increased turbidity and higher concentrations of Total Suspended Solids (TSS). A strong correlation was observed between quarrying activities and these parameters, confirming that quarry operations significantly contributed to water quality degradation. Among the analyzed parameters, dissolved oxygen (DO), turbidity, and TSS were identified as the most critical factors influencing WQI in the study area.The results further revealed that WQI values in 2021 were substantially elevated, placing the river water in the *"unsuitable for drinking"* category and indicating complete pollution throughout the sampling period. However, following the restriction of quarry activities in 2022, the WQI values declined notably, demonstrating a clear improvement in water quality. This reduction in WQI values supports the recovery of aquatic life and enhances the ecological health of the river ecosystem. From a legal perspective, the study highlights that the current legislative framework governing quarry operations and environmental protection in the Kurdistan Region is insufficient. On one hand, the existing laws and regulations lack comprehensive provisions that prioritize environmental sustainability; on the other hand, enforcement mechanisms remain weak due to limited institutional capacity and poor inter-agency coordination. The study also observed that existing quarry investment contracts do not adequately incorporate environmental protection clauses, which undermines the effectiveness of legal oversight. Additionally, weak collaboration among governmental bodies—such as the Directorate of Minerals and Oil in Garmian (DMOG), the Environmental Protection and Improvement Board (EPI), and the Water Council—continues to hinder sustainable management of quarrying activities. Therefore, this study concludes that the legal framework must be reformed and strengthened to ensure sustainable management of quarry operations. Such reform should focus on minimizing environmental degradation, preventing water pollution, and protecting the constitutional human right to clean water and a safe environment. Integrating environmental safeguards into quarry contracts, enhancing institutional cooperation, and enforcing existing laws more rigorously are essential steps toward achieving sustainable development and safeguarding the ecological integrity of the Diyala River basin.

CONFLICT OF INTEREST

The authors declare no conflict of interest

FUNDING

This research did not receive any specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

Akanwa, A. O. (2021). *River sand mining and its ecological footprint at Odor River, Nigeria.* In A. Banerjee, R. S. Meena, M. K. Jhariya, & D. K. Yadav (Eds.), *Agroecological footprints management for sustainable food systems.* Springer. https://doi.org/10.1007/978-981-15-9496-0_16

Al-Obaidi, B. S., & Sarhat, A. R. (2022).

Assessment of Darbandikhan Reservoir's water for different purposes using WQI, HPI, and MI indices. *IOP Conference Series: Earth and Environmental Science, 1120*(1). https://doi. org/10.1088/1755-1315/1120/1/012014

Al Mamun, M. A., Howladar, M. F., & Sohail, M. A. (2019). Assessment of surface water quality using Fuzzy Analytic Hierarchy Process (FAHP): A case study of Piyain River's sand and gravel quarry mining area in Jaflong, Sylhet. *Groundwater for Sustainable Development, 9.* https://doi.org/10.1016/j.gsd.2019.03.002

Aliu, I. R., Akoteyon, I. S., & Soladoye, O. (2022). Sustaining urbanization while undermining sustainability: The socio-environmental characterization of coastal sand mining in Lagos, Nigeria. *GeoJournal, 87*(6), 5265–5285. https://doi.org/10.1007/s10708-021-10563-7

Attiogbe, F., & Nkansah, A. (2017). The impact of mining on water resources in Ghana: Newmont case study at Birim North District (New Abirem). *Energy and Environment Research, 7*(2), 27. https://doi.org/10.5539/eer.v7n2p27

Bakamwesiga, H., Mugisha, W., Kisira, Y., & Muwanga, A. (2022). An assessment of air and water pollution accrued from stone quarrying in Mukono District, Central Uganda. *Journal of Geoscience and Environment Protection, 10*(5), 25–42. https://doi.org/10.4236/gep.2022.105003

Barreto, M. L., Shein, P., & Hinton, J. (2018). *Economic contributions of artisanal and smallscale mining in Kenya: Gold and gemstones.* UK Department for International Development. https://assets.publishing.service.gov.uk/ media/5a392bb8e5274a79051c9d7c/Kenya_case_ study.pdf

Bozorg-Haddad, O., Delpasand, M., & Loáiciga, H. A. (2021). Water quality, hygiene, and health. In O. Bozorg-Haddad (Ed.), *Economical, political, and social issues in water resources* (pp. 217– 257). Elsevier. https://doi.org/10.1016/B978-0323-90567-1.00008-5

Cele, N. (2021). *The impact of sand mining on water quality and quantity at Mpenjati River.* Mangosuthu University of Technology.

Chatterjee, C., & Raziuddin, M. (2002). Determination of water quality index (WQI) of a degraded river in Asansol industrial area (West Bengal). *Nature, Environment and Pollution Technology, 1*(2), 181–186.

Devi, M. A., & Rongmei, L. (2017). Impacts of sand and gravel quarrying on the stream channel and surrounding environment. *Asia Pacific Journal of Energy and Environment, 4*(1), 7–12.

https://doi.org/10.18034/apjee.v4i1.236

Dey, J., & Vijay, R. (2021). A critical and intensive review on assessment of water quality parameters through geospatial techniques. *Environmental Science and Pollution Research, 28*(31), 41612–41626. https://doi.org/10.1007/s11356-021-14726-4

Federation, W. E. (1999). *Standard methods for the examination of water and wastewater.* American Public Health Association (APHA). https://doi. /10.2105/AJPH.51.6.940-a

George, N. J., Nathaniel, E. U., & Etuk, S. E. (2014). Assessment of economically accessible groundwater reserve and its protective capacity in Eastern Obolo Local Government Area of Akwa Ibom State, Nigeria, using electrical resistivity method. *ISRN Geophysics, 2014,* 1–10. https://doi. org/10.1155/2014/578981

Herschy, R. W. (2012). Water quality for drinking: WHO guidelines. In *Encyclopedia of Earth Sciences Series* (pp. 876–883). https://doi. org/10.1007/978-1-4020-4410-6_184

Hiwa, R. A. (2023). *Legal protection of water resources in the Kurdistan Region of Iraq: Sirwan River as an example* (1st ed.). Tabaye, Erbil.

Howladar, M. F. (2017). An assessment of surface water chemistry with its possible sources of pollution around the Barapukuria Thermal Power Plant impacted area, Dinajpur, Bangladesh. *Groundwater for Sustainable Development, 5,* 38–48. https://doi.org/10.1016/j.gsd.2017.03.004

Iraqi Laws. (2011). *Law for the regulation of mineral investments No. 91 for 1988 (as amended).*Kemgang Lekomo, Y., Mwebi Ekengoue, C.,

Douola, A., Fotie Lele, R., Suh, G. C., Obiri, S., & Kagou Dongmo, A. (2021). Assessing impacts of sand mining on water quality in Toutsang locality and design of wastewater purification system. *Cleaner Engineering and Technology, 2,* 100045. https://doi.org/10.1016/j.clet.2021.100045

Kilonzo, W., Home, P., Sang, J., & Kakoi, B. (2019). The storage and water quality characteristics of Rungiri Quarry Reservoir in Kiambu, Kenya, as a potential source of urban water. *Hydrology, 6*(4), 1–23. https://doi.org/10.3390/hydrology6040093

Koehnken, L., Rintoul, M. S., Goichot, M., Tickner, D., Loftus, A. C., & Acreman, M. C. (2020). Impacts of riverine sand mining on freshwater ecosystems: A review of scientific evidence and guidance for future research. *River Research and Applications, 36*(3), 362–370. https://doi. org/10.1002/rra.3586

Law No. 10 (2012) for Forests in the Kurdistan Region of Iraq. (2012). Kurdistan Parliament. https://www.parliament.krd/business/legislation/

Law No. 3 (2018) for Preventing Illegal Overtaking in the Kurdistan Region of Iraq. (2018). Kurdistan Parliament.

https://www.parliament.krd/english/parliamentbusiness/legislation/2018/

Law No. 4 (2022) on Management andConservation of Water in the Kurdistan Region of Iraq. (2022). KurdistanParliament. https://www.parliament.krd/english/parliament-business/legislation/2022/

Léo Heller, Special Rapporteur on the Human Rights to Safe Drinking Water and Sanitation. (2020). *10th anniversary of the recognition of water and sanitation as a human right by the General Assembly.* United Nations Human Rights Office of the HighCommissioner.https://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews. aspx?NewsID=26116&LangID=E

Li, H., Shi, A., Li, M., & Zhang, X. (2013). Effect of pH, temperature, dissolved oxygen, and flow rate of overlying water on heavy metal release from storm sewer sediments. *JournalofChemistry,2013.*https://doi.org/10.1155/2013/434012

Lwanga, A. I., Tsingalia, H. M., Agevi, H., & Shilenje, Z. W. (2022). Effects of sand harvesting on river water quality and riparian soil physicochemical properties. *Open Journal of Ecology, 12*(8), 570–583. https://doi.org/10.4236/oje.2022.128032

Menta, C. (2012). Soil fauna diversity—Function, soil degradation, biological indices, soil restoration. In *Biodiversity conservation and utilization in a diverse world* (pp. 59–94). IntechOpen. https://doi.org/10.5772/51091

Miljojkovic, D., Trepsic, I., & Milovancevic, M. (2019). Assessment of physical and chemical indicators on water turbidity. *Physica A: Statistical Mechanics and Its Applications,527,*121171. https://doi.org/10.1016/j.physa.2019.121171

Pandey, S., Kumar, G., Kumari, N., & Pandey, R. (2022). Assessment of causes and impacts of sand mining on river ecosystems. In S. S. S. Madhav, V. B. Singh, & M. Kumar (Eds.), *Hydrogeochemistry of aquatic ecosystems* (pp. 357–379). Wiley. https://doi.org/10.1002/9781119870562.ch16

Republic of Iraq. (2005). *The Constitution of Iraq.* World Intellectual Property Organization (WIPO). https://www.wipo.int/wipolex/en/legislation/ details/10027

Sagan, V., Peterson, K. T., Maimaitijiang, M., Sidike, P., Sloan, J., Greeling, B. A., Maalouf, S., & Adams, C. (2020). Monitoring inland water quality using remote sensing: Potential and limitations of spectral indices, bio-optical simulations, machine learning, and cloud computing. *Earth-Science Reviews, 205,* 103187. https://doi.org/10.1016/j. earscirev.2020.103187

Sreebha, S., & Padmalal, D. (2011). Environmental impact assessment of sand mining from small catchment rivers in the southwestern coast of India: A case study. *Environmental Management,47*(1),130–140. https://doi.org/10.1007/s00267010-9571-6

United Nations. (2010). *Resolution 64/292: The human right to water and sanitation.* United Nations General Assembly. https://digitallibrary. un.org/record/687002?ln=en

World Health Organization. (2004). *Guidelines for drinking-water quality* (3rd ed., Vol. 1). Geneva: WHO. https://www.loc.gov/item/2021763198/

World Health Organization. (2017). *Guidelines for drinking-water quality* (4th ed., incorporating the first addendum). Geneva: WHO. https://www. who.int/publications/i/item/9789241549950