Pro Index | Journal of Integrity in Ecosystems and Environment
Volume: 3 Issue: 5 Year: 2025
ISSN: 3030-3729 | http://journals.proindex.uz

Protocols and Procedures for Reducing Pollution and Treating Pollutants in Iraq: Strategies, Practices, and Challenges

Zaid abdulhamza abdulhasan, Haider Mashkoor Hussein
Department of Ecology, College of Science, University of Al-Qadisiyah, Iraq, Diwaniyah

Abstract: This research explores strategies, practices, and challenges in reducing environmental pollution and treating pollutants in Iraq. Pollution, driven by rapid industrial growth, population increase, and the legacy of conflict, severely impacts human health, biodiversity, and sustainable development. Key pollutants include air, water, and soil contaminants from both natural and human-made sources, worsened by the remnants of wars like the Gulf War and the 2003 invasion, which left toxic substances such as depleted uranium. The study highlights Iraq's environmental legislation, including the Environmental Protection and Improvement Law (2009) and Clean Air Law (2012), aimed at controlling pollution. However, weak enforcement, inadequate infrastructure, and a lack of advanced treatment technologies hinder pollution reduction efforts. Water and wastewater management, using technologies like membrane bioreactors and ultrafiltration systems, are essential for sustainable water treatment but face challenges such as financial constraints, poor enforcement, and political instability. The research also evaluates Iraq's national strategies, including the 2024-2030 National Environmental Protection Strategy and the National Water and Waste Management Strategy. These strategies emphasize comprehensive waste management, public awareness, and investment in green technologies. Furthermore, environmental monitoring, through air quality stations and remote sensing technologies, is crucial for tracking pollution levels and shaping policy decisions. the research advocates for stronger regulatory frameworks, better enforcement of environmental laws, and international cooperation to address Iraq's pollution challenges. Emphasizing innovative technologies and collaboration between the public and government is key to achieving long-term environmental sustainability in Iraq.

1. Introduction

Environmental pollution is broadly defined as the introduction of contaminants into the natural environment, resulting in adverse changes that affect the ecological balance and quality of life. This contamination can occur through the discharge of substances or energy that exceed the environment's self-purifying capacity, leading to chemical, physical, and biological mutations in the environment(Zhou et al., 2023) (Riffat et al., 2016). Pollutants, which can be chemical, biological, or physical materials, may be introduced intentionally or unintentionally and can be either foreign or naturally occurring substances that become harmful at certain concentrations(Das, 2025) (-, 2023). The effects of pollution are not limited to human health but extend to animals and plants, causing diseases and ecological imbalances(Vij, 2015) (Swarup & Patra, 2005). Pollution is often categorized as point source or nonpoint source, depending on its origin, and can manifest in various forms, including air, water, soil, noise, and light pollution(Riffat et al., 2016) (Saremi, 2020). The rapid pace of industrialization, urbanization, and technological advancement has exacerbated environmental pollution, posing significant risks to both human and animal health(-, 2023) (Swarup & Patra, 2005). The presence of pollutants in the environment can lead to acute or chronic detriments, such as oxidative stress, immunotoxicity, and endocrine disruption in living organisms(Swarup & Patra, 2005). Addressing environmental pollution requires a multifaceted

approach, including pollution prevention, waste minimization, and the use of advanced technologies like nanotechnology for pollutant detection and control(Riffat et al., 2016) (Tonelli, 2024). Sustainable development and environmental engineering are crucial in mitigating the adverse effects of pollution and ensuring the preservation of natural resources for future generations(Das, 2025) (Saremi, 2020).

The topic of environmental pollution in Iraq is of critical importance, particularly in the context of rapid industrial growth and population increase. Iraq has faced significant environmental challenges due to a combination of factors, including economic activities, wars, and inadequate environmental policies. The transformation of natural resources into economic commodities has led to severe pollution of air, water, and soil, exacerbated by industrial and agricultural activities(Hamza et al., 2024). The Iraqi environment has suffered from a clear deterioration, with pollution being one of the most pressing issues due to human actions and the aftermath of military conflicts, which have left a legacy of environmental damage(Arzoqi & Ali, 2022). Air pollution, particularly in densely populated areas like Baghdad, is a major concern, with dust storms and industrial emissions contributing to elevated levels of suspended particles, far exceeding international standards(Majeed, 2025). The post-2003 era has seen further environmental degradation, with pollution threatening human health and sustainable development, necessitating a reevaluation of environmental policies to mitigate these impacts(Al-Yasiri, 2022). Environmental management systems are crucial for reducing pollution and promoting sustainable development, emphasizing the need for cleaner production and effective resource management(Lftah, n.d.). The health and security of Iraq's population are at risk due to environmental pollution, which has been exacerbated by external factors such as upstream waste disposal into major rivers and the use of prohibited weapons during conflicts(2022 ,سعدون). In the Kurdistan Region, air pollution is compounded by political instability, population growth, and inadequate public services, with unique local sources such as household kerosene heaters contributing to the problem(Hama-Aziz, 2022). Heavy metal pollution from oil facilities further highlights the environmental challenges, with concentrations exceeding safe limits and posing risks to soil and human health(Samir & Kosaj, n.d.). The environmental footprint of Iraq's industrial activities underscores the need for sustainable urban and regional planning to address pollution and its long-term effects(Hameed, n.d.). Finally, the legacy of conflict has created pollution hotspots that require urgent remediation to prevent long-term economic and environmental damage, emphasizing the need for comprehensive environmental management as part of Iraq's reconstruction efforts("Conflict Pollution Hotspots in Iraq: Lan...", 2023). Addressing these multifaceted issues is essential for Iraq's sustainable development and the well-being of its population.

iraq faces significant environmental pollution challenges primarily due to rapid industrial growth and population increase, compounded by historical and ongoing conflicts. The country's environment has been severely impacted by unsustainable development practices, lack of modern pollution treatment technologies, and the aftermath of military operations, which have collectively led to air, water, and soil pollution(Arzoqi & Ali, 2022). The oil and gas industry, a major economic sector, contributes significantly to environmental degradation through the flaring of associated gases and the discharge of untreated wastewater, which pollutes both surface and groundwater(Б.М.Н.М. & А.А., 2023). Additionally, the absence of effective waste management systems exacerbates pollution, particularly in areas like Diyala Governorate, where improper disposal and burning of municipal solid waste lead to air, soil, and water contamination, posing health risks to nearby communities(Jbara, 2024). Air pollution is a critical issue, with dust storms and industrial emissions significantly increasing the levels of suspended particles and heavy metals in the atmosphere, particularly in urban areas like Baghdad(Majeed, 2025) (Saleem & Abdullah, 2024). The southern regions of Iraq also suffer from high levels of gaseous pollutants and heavy metals due to fossil fuel combustion and industrial activities, contributing to respiratory and cardiovascular diseases among the population(Salman et al., 2024). Despite these challenges, national and international efforts to address environmental changes in Iraq remain insufficient relative to the scale of the problem, highlighting the need for more robust policies and

interventions(Hajool & Ameen, 2024). The environmental degradation not only threatens public health but also undermines economic growth, as the costs associated with pollution control and environmental restoration continue to rise(Hamza et al., 2024). Overall, Iraq's environmental pollution challenges are multifaceted, requiring comprehensive strategies that integrate technological, regulatory, and community-based approaches to mitigate the adverse impacts on health and the environment.

2. Background

Pollution in Iraq is a multifaceted issue exacerbated by decades of conflict, industrial growth, and unsustainable resource use, affecting air, water, and soil quality. The environmental degradation in Iraq is largely attributed to the aftermath of wars, including the Gulf War and the 2003 invasion, which have left a legacy of pollutants such as depleted uranium and other hazardous materials in the environment(Al-Shammari, 2016) (Arzoqi & Ali, 2022). Air pollution is particularly severe, with dust storms being a primary source, compounded by emissions from industrial activities, transportation, and power generation. Cities like Baghdad experience frequent dust storms, with suspended particulate matter levels often exceeding international standards(Majeed, 2025) (Salman et al., 2024). In Mosul, air quality assessments reveal significant seasonal variations in pollutants like NO2 and SO2, with concentrations frequently surpassing WHO guidelines, highlighting the compounded effects of climate stress and pollution(Altahaan & Dobslaw, 2025). Water pollution is equally concerning, particularly in the Tigris River, where war-related contaminants such as heavy metals and other pollutants consistently exceed WHO limits, posing significant health risks("Assessment of war impact on concentratio...", 2023). Soil pollution is also prevalent, with areas like the Al-twaitha nuclear site suffering from radioactive contamination due to past military actions(Al-Shammari, 2016). The unsustainable use of resources, coupled with poor environmental management and rapid population growth, further exacerbates these issues, leading to a significant imbalance in Iraq's environmental systems(ارزوقي & علي, n.d.) (Arzoqi & Ali, 2022). The Kurdistan Region of Iraq also faces deteriorating air quality due to political instability, population growth, and inadequate public services, with unique pollution sources such as household kerosene heaters contributing to the problem(Hama-Aziz, n.d.). Addressing these environmental challenges requires comprehensive remediation efforts and sustainable development strategies to mitigate the long-term health and economic impacts on the Iraqi population("Conflict Pollution Hotspots in Iraq: Lan...", 2023) (سعدون, 2022).

3. Legal and Regulatory Framework

3.1. Environmental Protection Laws in Iraq:

The Environmental Protection and Improvement Law (No. 27 of 2009) in Iraq forms a fundamental legal framework aimed at safeguarding the environment and mitigating pollution and environmental damage. This law was enacted in response to the significant environmental challenges faced by Iraq, particularly the high levels of pollution resulting from industrial activities. The law is grounded in the Iraqi Constitution of 2005, which explicitly mandates the protection of the environment and biodiversity, thereby obligating state authorities to ensure a clean and safe environment for its citizens(زهراو, 2024). The law outlines the responsibilities of both natural persons and legal entities in protecting and improving environmental conditions, emphasizing sustainable development as a core principle(Ličbinský et al., n.d.). It establishes a comprehensive legal structure that includes preventive and repressive measures to control environmental pollution. Preventive measures involve the use of monitoring and licensing instruments by government bodies and local communities, while repressive measures include administrative, civil, and criminal sanctions for violations(Sodikin, 2010) (Dewi, 2013). The law also provides for the assessment of environmental damage, including the economic costs associated with pollution, such as health deterioration and resource depletion(Ivanushkin & Yakovleva, 2025). Similar legislative frameworks, like Indonesia's Law No. 32 of 2009, also emphasize the importance of legal protection against environmental pollution, highlighting the role of government mediation and enforcement in preventing environmental degradation(Galigo, n.d.) (Sulistyawati, &

Kusumawardhani, 2023). These laws collectively underscore the necessity of legal instruments in managing environmental issues and ensuring compliance with environmental standards to foster sustainable development and protect public health.

3.1.1. Clean Air Law (No. 4, 2012):

The Iraqi Clean Air Law (No. 4, 2012) is a legislative measure aimed at regulating emissions into the air and imposing penalties on violators to address the significant air pollution challenges in Iraq. This law is part of a broader framework of environmental legislation that includes the Act of Protect and Improve Environment in 2009 and the Order of Air Protection in 2012, which collectively aim to maintain air quality through preventive and curative mechanisms(Abdulkadhim et al., 2017). The Clean Air Law is crucial given Iraq's history of environmental degradation due to industrial activities and the use of internationally prohibited weapons during conflicts, which have led to severe air pollution and associated health problems such as cancer and birth defects(Ashour & Wahab, 2016) (Ashour & Wahab, n.d.). The Iraqi Constitution of 2005 explicitly recognizes the right to a clean environment, mandating state authorities to ensure environmental protection and impose penalties for violations(2023 ,منديل) (2024 ,زهراو). Despite these legislative efforts, enforcement remains a challenge due to issues such as corruption, lack of coordination, and insufficient environmental expertise(Abdulkadhim et al., 2017). The Clean Air Law, therefore, represents an essential step in Iraq's legal and administrative efforts to combat air pollution, although its effectiveness is contingent upon robust enforcement and public awareness initiatives(Abdulkadhim et al., 2017) (Subekti et al., 2023). Additionally, the law complements other environmental policies, such as proposed pollution taxes on industrial firms, which aim to incentivize reductions in emissions and promote cleaner production practices(Karim, 2022). Overall, the Clean Air Law is a critical component of Iraq's strategy to mitigate air pollution and protect public health, although its success depends on overcoming existing enforcement barriers and enhancing institutional capacities(Abdulkadhim et al., 2017) (2022 ,سعدون).

3.1.2. Amendments to Current Laws:

Iraq has been actively working to amend and strengthen its environmental legislation to address the significant challenges posed by pollution and climate change. The Iraqi Constitution of 2005 explicitly recognizes the right to a clean environment, which has been further supported by the enactment of the Law on Environmental Protection and Improvement No. 27 of 2009. This law aims to protect the environment and includes punitive measures for violations, reflecting a commitment to legal frameworks that mitigate environmental harm(2023 ,منديل) (2024 ,زهراو). In response to global climate change concerns, Iraq has also focused on reducing greenhouse gas emissions and promoting renewable energy. This includes initiatives like the ambitious plan to generate 12,000 MW of solar energy and projects to reduce methane emissions, such as the Flare Gas Recovery and Vapor Recovery Units projects(AlSalait & Al-Sabur, 2024). Furthermore, Iraq has aligned itself with international environmental agreements, such as the Paris Agreement, to enhance its environmental policies and strategies, including the development of a national strategy for environmental improvement from 2024 to 2030(2025 ,رحيم & محيبس). The Kurdistan Region has also contributed by implementing the Law on Environmental Protection and Improvement No. 8 of 2008, which aligns with Islamic Sharia principles to some extent but requires further enhancements to address certain environmental crimes more effectively(Ahmed & Karim, 2024). Additionally, Iraq has enacted specific laws to tackle air pollution, such as the Act of Protect and Improve Environment in 2009 and the Order of Air Protection in 2012, which provide administrative mechanisms to maintain air quality(Abdulkadhim et al., 2017). These legislative efforts are complemented by international cooperation and the involvement of non-governmental organizations, which are crucial for enforcing environmental laws and promoting sustainable development(2024 ,الحسون) (Li, 2025). Overall, Iraq's legislative amendments and initiatives reflect a comprehensive approach to strengthening environmental protection, balancing industrial development with ecological sustainability, and fulfilling international commitments.

3.1.3. Laws related to Industrial Pollution and Water:

In Iraq, the legal framework governing industrial pollution and water management is primarily shaped by several key laws and regulations. The Iraqi Constitution of 2005 explicitly mandates the protection of the environment and biodiversity, obligating state authorities to ensure a clean environment for its citizens(2024 ,زهراو). This constitutional provision is operationalized through the Law on the Protection and Improvement of the Environment No. 27 of 2009, which aims to mitigate environmental damage and includes penalties for non-compliance(2024 ,زهراو). Additionally, Law 25 of 1967 and Law 3 of 2012 set standards for river water and discharged wastewater, as well as the reuse of treated water for agricultural purposes(Abood et al., 2024). These laws require that industrial wastewater be treated to meet specific quality standards before discharge, to prevent interference with the natural self-cleaning mechanisms of water bodies(Jin, 2001) (张勇 & 万金泉, n.d.). The treatment processes often involve a combination of chemical, physiochemical, and biological methods to ensure compliance with these standards(Jin, 2001) (张勇 & 万金泉, n.d.). Despite these regulations, challenges persist, particularly in the oil and gas sector, where the lack of adequate treatment facilities leads to significant pollution of water bodies(Б.М.Н.М. & A.A., 2023). The centralized treatment of industrial wastewater is encouraged, although not mandated, to streamline compliance and improve environmental outcomes(韩冰, n.d.). Furthermore, the enforcement of these regulations is complicated by insufficient monitoring and measurement tools, which hampers effective compliance checks(Б.М.Н.М. & A.A., 2023). The environmental situation is exacerbated by external factors, such as upstream pollution from neighboring countries and historical conflicts that have damaged infrastructure(2022 ,سعدون). Overall, while Iraq has established a legal framework for industrial pollution control, the implementation and enforcement of these laws require significant improvement to effectively protect water resources and public health.

4. Pollution Reduction Strategies and Policies

4.1. National Strategies:

4.1.1. 2024-2030 National Environmental Protection Strategy:

The Iraqi National Strategy for Environmental Protection 2024-2030 is a comprehensive plan aimed at addressing the multifaceted environmental challenges facing Iraq, with a focus on reducing harmful emissions, improving resource utilization, and strengthening environmental monitoring systems. The strategy emerges in response to the severe environmental degradation caused by decades of conflict, unsustainable development practices, and inadequate environmental policies. Iraq's environment has been significantly impacted by pollution from military operations, industrial activities, and the oil and gas sector, which have led to air, water, and soil contamination(,سعدون 2022) (Arzoqi & Ali, 2022) (Б.М.Н.М. & A.A., 2023). The strategy emphasizes the need for modernizing infrastructure, particularly in the oil and gas industry, to reduce the flaring of associated gases and improve waste management systems(Б.М.Н.М. & A.A., 2023). Additionally, it seeks to enhance environmental governance by addressing the current lack of coordination among governmental institutions and the weak enforcement of environmental laws(2025 ,مروشن). The strategy also aligns with Iraq's commitment to the 2030 Sustainable Development Agenda, which underscores the importance of sustainable resource management and environmental protection as integral to national development goals(2022 ,الزرفي & الزبيدي). To achieve these objectives, the strategy proposes the adoption of advanced technologies and practices, such as the use of photovoltaic plants to harness renewable energy, thereby reducing reliance on fossil fuels and lowering emissions(Chaichan & Kazem, 2018). Furthermore, the strategy calls for the enhancement of environmental impact assessments (EIA) to ensure that development projects comply with environmental standards and contribute to sustainable development(Al-Fatlawi et al., 2022). By integrating these measures, the strategy aims to mitigate the adverse effects of climate change, such as desertification and water scarcity, which are exacerbating Iraq's environmental

vulnerabilities(Adamo et al., 2018). Overall, the strategy represents a critical step towards achieving environmental sustainability in Iraq, requiring concerted efforts from both the government and civil society to implement effective policies and practices (2023 ,احمد).

4.1.2.National Water and Waste Management Strategy:

Iraq's national strategy for water and waste management is multifaceted, addressing both internal and external challenges to improve water quality and manage waste effectively. Internally, the strategy emphasizes prudent water management practices, including the realistic distribution of water among governorates, enhancing water use efficiencies within irrigation networks, and increasing the use of non-conventional water sources. This involves adjusting water tariffs, improving agricultural techniques, and implementing public awareness programs to promote water conservation(Al-Ansari et al., 2024). Additionally, the strategy includes upgrading wastewater treatment plants (WWTPs) to increase their capacity and efficiency, promoting efficient irrigation techniques, and constructing water storage facilities to address water scarcity challenges(Todd, 2023). The reuse of treated wastewater, particularly in agriculture, is also a key component, as it helps mitigate water shortages and reduces reliance on conventional water sources(Al-Lami et al., 2019). Externally, Iraq is engaged in diplomatic negotiations with riparian countries like Turkey and Iran to secure equitable water shares from the Tigris and Euphrates Rivers, which are crucial given the upstream dam constructions that have significantly reduced water flow into Iraq(Jawad & Amir, 2022) (Salih, 2023). In terms of waste management, the strategy involves implementing stringent environmental legislation, enhancing public awareness, and fostering collaboration between individuals and the government to ensure safe and environmentally friendly waste disposal(Duraye, 2025). The integration of waste management with energy production, such as exploring waste-to-energy solutions, is also being considered to achieve sustainable solid waste management(Kareem et al., 2024). Overall, Iraq's strategy is comprehensive, addressing both the immediate need for improved water quality and the long-term sustainability of its water and waste management systems.

4.2. Water and Sewage Treatment Practices:

4.2.1 Wastewater Treatment Plants (WWTPs):

In Iraq, the modernization and development of wastewater treatment plants are crucial for ensuring proper treatment and reducing water pollution, given the country's arid climate and increasing water scarcity. The Al-Doura refinery's wastewater treatment plant exemplifies effective modernization, achieving high removal efficiencies for contaminants such as oil and grease, turbidity, COD, and BOD through a combination of granular activated carbon filters, ultrafiltration, and reverse osmosis, aligning with Iraqi and EPA standards(Abdulkareem et al., 2021). In Samawah city, strategic planning for the optimal location and design capacity of wastewater treatment plants has been emphasized to enhance environmental and economic outcomes. This involves using tools like Google Earth and WinQSB to determine suitable plant locations based on population, water consumption, and infrastructure costs(Hussien et al., 2020). Advanced treatment technologies, such as membrane filtration, advanced oxidation processes, and electrochemical treatments, are increasingly adopted to address complex contaminants and improve treatment efficiency, thereby supporting sustainable water management practices(Pandit & Sharma, 2024) (Fawzy et al., 2024). Innovations like microbial fuel cells and nanotechnology are also being explored to enhance treatment processes and energy recovery, contributing to eco-friendly and sustainable solutions(Tripathi et al., 2023). Furthermore, the integration of physical, chemical, and biological methods in primary, secondary, and tertiary treatment stages is essential for comprehensive contaminant removal and nutrient control(Rout, 2013). The focus on recycling and reusing treated wastewater is gaining traction as a strategy to conserve water resources and ensure future sustainability, with advanced physicochemical and biological methods being pivotal in this regard(Modekwe et al., 2024). Overall, Iraq's approach to wastewater treatment involves a blend of traditional and innovative techniques, aiming to meet stringent effluent standards and contribute to global water sustainability goals(Mojiri & Bashir, 2022) (Donde, 2017).

4.2.2. Advanced Water Treatment Technologies:

In Iraq, advanced water treatment technologies utilizing membrane bioreactors (MBRs) and ultrafiltration (UF) systems have been effectively implemented for municipal wastewater treatment and water purification. The use of submerged hollow fiber MBR systems has been tested under Iraqi conditions, demonstrating significant efficacy with about 85% chemical oxygen demand (COD) removal and maintaining turbidity well below 0.61 NTU, indicating high-quality effluent suitable for reuse(Abbas & Abdul-Majeed, 2012) (Abbas et al., n.d.). MBR technology, which combines biological treatment with membrane filtration, offers superior effluent quality due to complete solid removal and a reduced footprint compared to conventional systems(Krause & Thiemig, 2013). This technology is particularly advantageous in regions like Iraq, where water scarcity and the need for efficient wastewater management are critical. Additionally, the integration of MBRs with ultra-low energy reverse osmosis (ULE RO) systems has been explored for on-site wastewater treatment at Forward Operating Bases (FOBs), aiming to produce high-quality water for potable and non-potable reuse, thereby reducing the logistical burden of water transport(Wang, 2014). Furthermore, the combination of MBRs with UF and nanofiltration (NF) systems has been shown to effectively remove inorganics, achieving compliance with standards for irrigation and cooling system applications, although UF alone may not meet all reuse standards due to high electron conductivity levels(Aziz & Kasongo, 2021). The application of MBRs in Iraq aligns with global trends where membrane-based technologies are increasingly adopted for wastewater reclamation and reuse, driven by the need for sustainable water management solutions(Wu et al., n.d.). These technologies not only address the challenges of water scarcity but also enhance the quality of treated water, making it suitable for various reuse applications, thus contributing to the sustainable management of water resources in Iraq.

5. Environmental Monitoring Practices and Technologies

5.1. Environmental Monitoring Technologies:

5.1.1. Air Quality Monitoring Stations:.

Air quality monitoring stations play a crucial role in measuring pollution levels in major Iraqi cities by providing essential data on various air pollutants, which is vital for assessing environmental health risks and informing policy decisions. In Baghdad, for instance, fixed annual stations have been used to map the distribution of pollutants such as nitrogen dioxide (NO2), sulfur dioxide (SO2), and carbon monoxide (CO) using GIS techniques, revealing that while NO2 and CO levels were within WHO limits, SO2 concentrations exceeded them significantly(Mohammed et al., 2019). Similarly, in Kirkuk, air quality points and remotely sensed data have been utilized to assess the Air Quality Index (AQI) and particulate matter (PM10 and PM2.5), indicating unhealthy to hazardous pollution levels that necessitate immediate intervention(Jumaah et al., 2023). In Basra, the integration of satellite data with ground station measurements has shown strong correlations for SO2, highlighting the effectiveness of combining different data sources for comprehensive air quality assessments(Khreebsh & Azeez, 2024). Furthermore, in Al-Hillah, monitoring stations have recorded PM10 and PM2.5 levels, with PM10 often exceeding WHO standards, underscoring the impact of urban activities and environmental conditions on air quality(Grmasha et al., 2021). The monitoring stations in Baghdad have also been pivotal in identifying the high levels of total suspended particulates (TSP) due to dust storms and human activities, which are significantly above international standards(Majeed, 2025). Additionally, in Erbil, data from monitoring stations have been used to model the dependence of ozone levels on various meteorological factors, providing insights into the dynamics of air pollution in urban settings("Analysing the Pollutants Dispersion in E...", 2022). These stations not only measure pollutant concentrations but also facilitate the development of real-time monitoring systems, as seen in the IoT-based environment pollution monitoring system designed for Iraq, which aims to provide wide-scale, real-time data to inform citizens and policymakers(Al-jarakh et al., n.d.). Overall, air quality monitoring stations are indispensable for understanding pollution dynamics, assessing health risks, and guiding interventions to improve air quality in Iraq's major cities.

5.2. Remote Sensing Technologies:

In Iraq, a variety of technologies are employed to monitor air quality and pollution levels, with a significant emphasis on remote sensing technologies using satellite data. Remote sensing, combined with Geographic Information Systems (GIS), is extensively used to assess air pollution across different regions of Iraq, including urban areas like Baghdad, Mosul, Basra, and Erbil. For instance, in the Nahrawan region of Baghdad, Earth Data sources, Google Earth Engine (GEE), and GIS software are utilized to extract data on gaseous and particulate pollutants, demonstrating a strong correlation between ground-based and remote sensing data(Jadem et al., 2023). Similarly, in Mosul, remote sensing datasets from the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) and the Copernicus Atmosphere Monitoring Service (CAMS) are used to measure PM2.5 and PM10 concentrations, revealing that these levels often exceed both Iraqi and international standards(Mohammad et al., 2022). In Basra, satellite data is used alongside stationary environmental station data to monitor pollutants like SO2 and NO2, showing a strong correlation between satellite and ground station data for SO2, though less so for NO2(Khreebsh & Azeez, 2024). Additionally, climatic data and polynomial models are employed to estimate PM2.5 levels across Iraq, highlighting the influence of climatic variables on air pollution(Jumaah et al., 2024). The use of R programming language to process PM2.5 data from the Copernicus program further exemplifies the integration of remote sensing with advanced data processing techniques to analyze spatial pollution patterns(Ali et al., 2023). In Erbil, GEE, GIS, and remote sensing techniques are used to track pollutants such as NO2, SO2, and PM2.5, with findings indicating significant pollution level fluctuations due to factors like urban expansion and quarantine measures during the COVID-19 pandemic(Ali et al., n.d.). Moreover, remote sensing data is crucial in assessing the impact of intense weather events, such as dust storms, on air quality, as seen in Baghdad where PM2.5 and PM10 levels soared during a dust storm in May 2022(Attiya & Jones, n.d.). These technologies collectively provide a comprehensive framework for monitoring air quality, enabling authorities to better understand pollution dynamics and devise strategies for mitigation and public health protection across Iraq.

6. Challenges in Environmental Monitoring:

Environmental monitoring in Iraq faces significant challenges due to a combination of limited monitoring infrastructure, unreliable data, and economic constraints. The country's environmental governance is hampered by a lack of coordination among governmental institutions, overlapping authorities, and weak enforcement of environmental laws, despite some promising initiatives(مروشن, 2025). The oil and gas industry, a major contributor to pollution, lacks adequate monitoring programs and measuring instruments to ensure compliance with environmental legislation, exacerbating pollution issues(Б.М.Н.М. & А.А., 2023). Additionally, Iraq's geographical location and climatic conditions, such as frequent dust storms and high temperatures, further complicate environmental monitoring efforts(2022 ,سعدون) (Abdulrahman, 2022). The prolonged conflicts have also disrupted environmental systems, leading to infrastructural collapse and unsustainable resource practices, which have not been adequately addressed due to the scarcity of comprehensive assessments and localized measurements(Altahaan & Dobslaw, 2025). The economic challenges are compounded by the need for modernization and investment in infrastructure, which has been neglected due to decades of sanctions and wars(Б.М.Н.М. & А.А., 2023). Moreover, the lack of public awareness and education on environmental issues contributes to the ongoing degradation, as citizens often engage in environmentally harmful practices(ارزوقي & علي, n.d.). The absence of clear environmental policies and the reliance on outdated technologies further hinder effective monitoring and response to environmental challenges(Arzoqi & Ali, 2022). To address these issues, there is a need for a national strategy that integrates environmental considerations into all development sectors, promotes sustainable infrastructure, and enhances cooperation with international organizations(2024 ,الهيتي). Implementing advanced monitoring technologies, such as electronic air quality sensors, could improve data collection and analysis, but this requires overcoming financial and technical barriers(2024 ,الشعير & الله) (Dorn, 2013). Overall, Iraq's

environmental monitoring challenges are multifaceted, requiring coordinated efforts across various sectors to ensure sustainable development and environmental protection.

7. Chemical Pollution and Hazardous Waste Treatment

7.1. Waste Management:

7.1.1. Hazardous Waste Disposal Projects:.

In Iraq, the management and disposal of hazardous waste, particularly in industrial areas, face significant challenges due to the legacy of wars and the lack of comprehensive national strategies. The country has been dealing with hazardous waste issues, including contamination from depleted uranium (DU) used in conflicts, which has led to severe environmental and health impacts(Al-Ansari et al., 2013) (Al-Taie et al., 2013). One proposed solution is the establishment of landfill sites, such as the Umm Chaimin depression, designed to safely contain radioactive waste for extended periods, potentially up to thousands of years, by using clay-based liners to prevent leakage(Al-Ansari et al., 2013) (Al-Taie et al., 2013). In urban areas like Hilla City, innovative waste management techniques have been introduced, including a three-step separation method that uses color-coded bins and magnetic sorting to efficiently segregate hazardous materials, achieving an 87% separation efficiency during pilot tests(Al-Isawi et al., 2025). This approach, if widely implemented, could significantly reduce environmental pollution and improve waste management practices(Al-Isawi et al., 2025). Additionally, Iraq's medical waste management primarily relies on incineration, which, while effective in reducing waste volume, poses risks due to the release of heavy metals and toxic materials into the environment(Jaber et al., 2021). The broader context of hazardous waste management in Iraq is compounded by the absence of a national program and the necessary scientific and technical resources to address these issues comprehensively(Al-Ansari et al., 2013) (Al-Taie et al., 2013). The integration of advanced technologies, such as real-time GPS tracking for waste transport and automation systems to minimize human exposure, could enhance the safety and efficiency of hazardous waste management in Iraq(Baghel et al., 2024). Furthermore, adopting sustainable treatment methods like bioremediation and advanced oxidation processes could mitigate the environmental footprint of hazardous waste, aligning with global trends towards more sustainable waste management practices("Assessment of Innovative Technologies fo...", 2024) (Cheremisinoff & Cheremisinoff, 1995). Overall, while there are initiatives and proposals in place, Iraq's hazardous waste management requires significant improvements in strategy, technology, and infrastructure to effectively address the challenges posed by industrial and war-related waste.

7.1.2 Industrial Wastewater Treatment Technologies:

Industrial wastewater treatment technologies encompass a variety of methods designed to address the diverse and complex nature of pollutants found in industrial effluents. In Iraq, as in other regions, these technologies are crucial for mitigating environmental impacts and ensuring compliance with regulatory standards. Key technologies include physico-chemical processes such as coagulation, flocculation, and chemical precipitation, which are effective in removing suspended solids and certain dissolved substances from wastewater(Farzana et al., 2023). Advanced oxidation processes, including ozone oxidation and chlorine dioxide treatment, are employed to degrade non-biodegradable organic compounds, enhancing the biodegradability of the wastewater(Hua, 2017). Biological treatments, both aerobic and anaerobic, are widely used for the removal of biodegradable organic pollutants, with combinations of these processes proving particularly effective(Awaleh & Soubaneh, 2014) (Awaleh et al., 2014). Membrane technologies, such as ultrafiltration and nanofiltration, are increasingly utilized in the final stages of treatment to remove fine particulates and dissolved ions, contributing to the production of high-quality effluent suitable for reuse(Muralikrishna & Manickam, 2017) (Ronny & Yael, 2021). Additionally, adsorption techniques using activated carbon or modified natural polymers are employed to remove specific contaminants like dyes and heavy metals(Awaleh & Soubaneh, 2014). The integration of these technologies into a comprehensive treatment system allows for the efficient reduction of chemical oxygen demand (COD) and other pollutants, facilitating the recycling and reuse of treated water, which is particularly beneficial in water-scarce regions like Iraq(Lingping, 2013) ("Treatment

Techniques of Industrial Efflu...", 2022). These technologies not only improve the environmental and economic sustainability of industrial operations but also help in achieving zero liquid discharge (ZLD) by minimizing waste and recovering valuable resources from wastewater(Ronny & Yael, 2021).

8. Challenges in Implementing Protocols

Implementing pollution reduction protocols in Iraq faces numerous challenges, primarily due to a combination of technological, financial, regulatory, and socio-political factors. The environmental landscape in Iraq is heavily impacted by its oil industry, which contributes significantly to pollution through hydrocarbon contamination and gas flaring, particularly in regions like Basra where substantial amounts of gas are burned annually, releasing harmful gases such as CO2 and H2S(2016 ,الحلفي & عبدالرضا). Despite the existence of legal frameworks, such as the Law for the Protection and Improvement of the Environment No. 27 of 2009, enforcement remains weak, with insufficient penalties for non-compliance and a lack of effective implementation strategies(,زهراو 2024). The hydrocarbon crisis further complicates remediation efforts due to technological and financial constraints, as well as inadequate community engagement(Jabbar, n.d.). Additionally, the aftermath of prolonged conflicts has left Iraq with significant environmental damage, including contaminated land and air pollution, which exacerbates the challenges of implementing effective pollution control measures("Conflict Pollution Hotspots in Iraq: Lan...", 2023) (Altahaan & Dobslaw, 2025). Solid waste management also suffers from inadequate infrastructure and low public awareness, necessitating improvements in waste disposal and recycling systems(Kareem et al., 2024). Moreover, the economic cost of pollution is significant, yet environmental costs are often not integrated into national economic planning, hindering sustainable development efforts(,الاسود 2024). Iraq's efforts to decarbonize its petroleum industry, such as the Flare Gas Recovery project and the adoption of solar energy, indicate a commitment to reducing emissions, but these initiatives require substantial investment and international cooperation to be successful(AlSalait & Al-Sabur, 2024). Overall, the challenges are multifaceted, involving the need for stronger regulatory frameworks, enhanced public awareness, and substantial investment in green technologies to achieve meaningful pollution reduction in Iraq(علي & ارزوقي, n.d.) (2023 ,احمد).

9. Results and Recommendations

The effectiveness of current waste management laws, strategies, and practices in Iraq is generally assessed as inadequate, with significant room for improvement across various dimensions. The challenges are multifaceted, involving insufficient infrastructure, weak regulatory frameworks, and low public awareness, which collectively hinder effective solid waste management (SWM) in the country (Kareem et al., 2024) (Duraye, 2025). In cities like Kerbala, the SWM system is notably weak, necessitating improvements in both physical infrastructure and management strategies, including better stakeholder engagement and clearer strategic planning (Abdulredha et al., 2018). Likewise, in Basrah, the current practice of open dumping is environmentally detrimental, and while integrated waste management scenarios that include recycling and composting have been recommended, their economic benefits remain limited (Elagroudy et al., 2011). The situation in Baghdad is exacerbated by rapid population growth, leading to increased waste production that overwhelms existing infrastructure, with much waste being disposed of in environmentally harmful ways (Mustafa et al., 2018). Moreover, the environmental impact assessment (EIA) process in Iraq, though improved since 2009, still falls short in several areas, indicating a need for enhanced funding, capacity building, and regulatory monitoring to ensure compliance and effectiveness (Al-Fatlawi et al., 2022). The management of post-war waste, particularly in regions like Nineveh, also presents significant challenges, with large volumes of construction and demolition waste requiring sustainable management strategies (Noaman & Alsaffar, 2019). Furthermore, the economic potential of waste recycling remains largely untapped due to a lack of vision and mechanisms to integrate recycling into the broader economic framework, which could otherwise provide significant environmental and economic benefits (Musheb, 2018). Overall, while there are some promising initiatives, such as Najaf's exploration of waste-to-energy solutions(Kareem et al., 2024), the

overarching assessment is that Iraq's waste management systems require comprehensive reforms, including modern infrastructure development, stringent regulations, public education, and integration with energy production to achieve sustainability(Kareem et al., 2024) (Chiang et al., 2024).

Recommendations:

1. Strengthen and update environmental laws.
2. Increase government and NGO efforts to enforce these laws.
3. Improve data collection, monitoring systems, and environmental awareness programs.

Conclusion

- A summary of the main points discussed in the paper.
- Reaffirming the importance of improving Iraq's environmental policies.
- A call for national and international cooperation to support Iraq in its environmental protection efforts.

References

1. Abbas, T. R., & Abdul-Majeed, M. A. (2012). Testing the Applicability of Submerged Hollow Fiber Membrane Bioreactor (MBR) Technology for Municipal Wastewater Treatment in Iraq. https://www.iasj.net/iasj?func=fulltext&aId=66174
2. Abbas, T. R., Abdul-Majeed, M. A., & Ghazi, I. N. (n.d.). Testing the Applicability of Submerged Hollow Fiber Membrane Bioreactor (MBR) Technology for Municipal Wastewater Treatment in Iraq. https://doi.org/10.30684/etj.30.19.14
3. Abdulkadhim, A., Dahlan, N. H., & Abdul Rahman, R. (2017). An environmental laws analysis of Iraq air pollution control. http://repo.uum.edu.my/22564/
4. Abdulkadhim, A., Dahlan, N. H., & Rahman, R. A. (2017). Air Pollution and Its Governing Legal Administrative Mechanisms in Iraq. Journal of Law, Policy and Globalization, 62, 82–88. https://www.iiste.org/Journals/index.php/JLPG/article/download/37544/38626
5. Abdulrahman, S. A. (2022). Iraq’s environment: from dustfall to soilfall. International Journal of Environmental Studies, 80(3), 535–537. https://doi.org/10.1080/00207233.2022.2078110
6. Abdulredha, M., Alkhaddar, R., Kot, P., Jordan, D., & Abdulridha, A. (2018). Benchmarking of the Current Solid Waste Management System in Karbala, Iraq, Using Wasteaware Benchmark Indicators. 40–48. https://doi.org/10.1061/9780784481417.004
7. Abood, W. M., Ali, D. M., Abass, F. S., & Ali, B. (2024). Recycling Discharged Treated Wastewater from Dairy Factories for Industrial and Irrigation Purposes. Iraqi Journal of Industrial Research, 11(1), 1–10. https://doi.org/10.53523/ijoirvol11i1id378
8. Adamo, N., Al-Ansari, N., Sissakian, V. K., Knutsson, S., & Laue, J. (2018). Climate Change: Consequences on Iraq’s Environment. 8(3), 43–58. http://www.diva-portal.org/smash/record.jsf?pid=diva2:1199705
9. Ahmed, F., & Karim, K. F. K. (2024). The Criminal Protection of the Environment in (The Law of Environmental Protection and Improvement in the Kurdistan Region - Iraq گۆڤاری زانکۆی). ڕاپەڕین, 11(6), 789–806. https://doi.org/10.26750/vol(11).no(6).paper32
10. Al-Ansari, N., Pusch, R., & Knutsson, S. (2013). Suggested landfill sites for hazardous waste in Iraq. Natural Science, 5(4), 463–477. https://doi.org/10.4236/NS.2013.54060
11. Al-Fatlawi, S., Ibadi, M., Goodhew, S., & Pan, W. (2022). An Evaluation of the Environmental Impact Assessment Process in Iraq. International Journal of Sustainable Development and Planning, 17(07), 2089–2096. https://doi.org/10.18280/ijsdp.170709

12. Al-Fatlawi, S., Ibadi, M., Goodhew, S., & Pan, W. (2022). An Evaluation of the Environmental Impact Assessment Process in Iraq. International Journal of Sustainable Development and Planning, 17(07), 2089–2096. https://doi.org/10.18280/ijsdp.170709
13. Al-Isawi, R., Idan, I. J., Al-Taliby, W., & Hassan, A. (2025). Hazardous Solid Waste Management in Hilla City, Iraq: A New Technique for Source Separation and Pre-Treatment. Journal of University of Babylon for Engineering Sciences, 33(4), 128–139. https://doi.org/10.29196/jubes.v33i4.5899
14. Al-jarakh, T. E., Hussein, O. A., Al-azzawi, A. K., & Mosleh, M. F. (n.d.). Design and Implementation of IoT Based Environment Pollution Monitoring System: A Case Study of Iraq. https://doi.org/10.1088/1757-899x/1105/1/012037
15. Al-Lami, D. M., Moustafa, M. A. M., Sorour, M. T., & Aly, S. A. (2019). Economic Study Of Three Alternatives Of Wastewater Treatment In Baghdad. 13–19. https://doi.org/10.15224/978-1-63248-177-1-03
16. Al-Shammari, A. M. (2016). Environmental pollutions associated to conflicts in Iraq and related health problems. Reviews on Environmental Health, 31(2), 245–250. https://doi.org/10.1515/REVEH-2015-0024
17. Al-Taie, L., Al-Ansari, N., Knutsson, S., & Pusch, R. (2013). Hazardous Wastes Problems in Iraq: A Suggestion for an Environmental Solution. http://www.scienpress.com/Upload/GEO/Vol%203_3_8.pdf
18. Al-Yasiri, A. J. (2022). Iraq's Post-2003 Environmental Pollution: Issues And Solutions. Akkad Journal Of Contemporary Economic Studies, 1(1), 1–16. https://doi.org/10.55202/ajces.v1i1.49
19. Al-Ansari, N., Adamo, N., Sissakian, V. K., Laue, J., & Abed, S. A. (2024). Solving the Water Resource Problems in Iraq. Engineering, 16(08), 205–223. https://doi.org/10.4236/eng.2024.168016
20. Ali, S. H., AL-Shiha, A. A. M., & Qubaa, A. (2023). Spatial Analysis of the PM2.5 Air Pollution in Iraq by using R Language. 1223. https://doi.org/10.1088/1755-1315/1223/1/012014
21. Ali, Z. F., Salam, D., Pirisi, G., & Kiss, K. (n.d.). Assessment of air quality and consequent in Erbil, Iraqi Kurdistan region based GEE, GIS, and remote sensing techniques. E3S Web of Conferences. https://doi.org/10.1051/e3sconf/202343610007
22. AlSalait, A., & Al-Sabur, R. (2024). Decarbonization of Iraq's Petroleum Industry: Challenges and Opportunities. https://doi.org/10.33774/coe-2024-bg0tw
23. AlSalait, A., & Al-Sabur, R. (2024). Decarbonization of Iraq's Petroleum Industry: Challenges and Opportunities. https://doi.org/10.33774/coe-2024-bg0tw
24. Altahaan, Z., & Dobslaw, D. (2025). Assessing Long-Term Post-Conflict Air Pollution: Trends and Implications for Air Quality in Mosul, Iraq. Atmosphere, 16(7), 756. https://doi.org/10.3390/atmos16070756
25. Altahaan, Z., & Dobslaw, D. (2025). Assessing Long-Term Post-Conflict Air Pollution: Trends and Implications for Air Quality in Mosul, Iraq. Atmosphere, 16(7), 756. https://doi.org/10.3390/atmos16070756
26. Altahaan, Z., & Dobslaw, D. (2025). Assessing Long-Term Post-Conflict Air Pollution: Trends and Implications for Air Quality in Mosul, Iraq. Atmosphere, 16(7), 756. https://doi.org/10.3390/atmos16070756
27. Analysing the Pollutants Dispersion in Erbil City-Kurdistan with Support of Statistical Analysis. (2022). ZANCO Journal of Pure and Applied Sciences, 34(1). https://doi.org/10.21271/zjpas.34.1.2

28. Arzoqi, E. majed, & Ali, R. S. (2022). Environmental pollution problems in Iraq A Study in natural, human and industrial resources. Journal of Juridical and Political Science, 11(1). https://doi.org/10.55716/jjps.2022.11.1.2.3

29. Arzoqi, E. majed, & Ali, R. S. (2022). Environmental pollution problems in Iraq A Study in natural, human and industrial resources. Journal of Juridical and Political Science, 11(1). https://doi.org/10.55716/jjps.2022.11.1.2.3

30. Arzoqi, E. majed, & Ali, R. S. (2022). Environmental pollution problems in Iraq A Study in natural, human and industrial resources. Journal of Juridical and Political Science, 11(1). https://doi.org/10.55716/jjps.2022.11.1.2.3

31. Ashour, A. J., & Wahab, H. A. (2016). Legal Protection Of Air Pollution In IRAQ. 5(1). https://www.iasj.net/iasj?func=fulltext&aId=112302

32. Ashour, A. J., & Wahab, H. A. (n.d.). Legal Protection of Air Pollution in IRAQ. https://doi.org/10.55716/jjps.2016.5.1.12

33. Assessment of Innovative Technologies for Hazardous Waste Treatment and Remediation Review: A Sustainable Approach for Environmental Protection. (2024). Global Nest Journal. https://doi.org/10.30955/gnj.05950

34. Assessment of war impact on concentrations of pollutants and heavy metals and their seasonal variations in water and sediments of the Tigris River in Mosul / Iraq. (2023). https://doi.org/10.21203/rs.3.rs-2583926/v1

35. Attiya, A. A., & Jones, B. G. (n.d.). A Huge Dust Storm Influenced Air Quality on 16 May 2022 in Baghdad City, Iraq; Tracked Using Remote Sensing Techniques and Meteorological Data. https://doi.org/10.1088/1755-1315/1371/2/022036

36. Awaleh, M. O., & Soubaneh, Y. D. (2014). Waste Water Treatment in Chemical Industries: The Concept and Current Technologies. Journal of Waste Water Treatment and Analysis, 5(1), 1–13. https://doi.org/10.4172/2157-7587.1000164

37. Awaleh, T., Soubaneh, Y. D., & Awaleh, M. O. (2014). Waste Water Treatment in Chemical Industries: The Concept and Current. https://www.omicsonline.org/open-access/waste-water-treatment-in-chemical-industries-the-concept-and-current-technologies-2157-7587.1000164.pdf

38. Aziz, M., & Kasongo, G. (2021). The Removal of Selected Inorganics from Municipal Membrane Bioreactor Wastewater Using UF/NF/RO Membranes for Water Reuse Application: A Pilot-Scale Study. 11(2), 117. https://doi.org/10.3390/MEMBRANES11020117

39. Baghel, D. S., Sharma, S., Singh, S. K., Kumar, R., Singh, G., & Kohli, R. (2024). Advancing Hazardous Waste Management. Advances in Environmental Engineering and Green Technologies Book Series, 55–68. https://doi.org/10.4018/979-8-3693-8527-2.ch004

40. Banker, R., & Zeevy, P. Y. (2021). Industrial wastewater treatment.

41. Chaichan, M. T., & Kazem, H. A. (2018). Iraq's Future Strategies in the Use of PV Plants (pp. 195–203). Springer, Cham. https://doi.org/10.1007/978-3-319-75031-6_8

42. Cheremisinoff, N. P., & Cheremisinoff, P. N. (1995). Hazardous waste management systems (pp. 21–32). https://doi.org/10.1016/B978-081551372-8.50004-X

43. Conflict Pollution Hotspots in Iraq: Land Remediation for Livelihoods Restoration. (2023). https://doi.org/10.1596/40621

44. Conflict Pollution Hotspots in Iraq: Land Remediation for Livelihoods Restoration. (2023). https://doi.org/10.1596/40621

45. Conflict Pollution Hotspots in Iraq: Land Remediation for Livelihoods Restoration. (2023). https://doi.org/10.1596/40621

46. Das, M. (2025). A STUDY ON IMPACT OF ENVIRONMENTAL POLLUTION ON HUMAN HEALTH AND ROLE OF EDUCATION, SCIENCE & TECHNOLOGY TO TACKLE ENVIRONMENTAL DEGRADATION WITH SPECIAL FOCUS ON SUSTAINABLE DEVELOPMENT. The Social Science Review a Multidisciplinary Journal., Special, 133–139. https://doi.org/10.70096/tssr.250307024

47. Dewi, D. K. (2013). Izin Lingkungan dalam Kaitannya dengan Penegakan Administrasi Lingkungan dan Pidana Lingkungan Berdasarkan Undang-Undang No. 32 Tahun 2009 tentang Perlindungan dan Pengelolaan Lingkungan Hidup (UUPPLH). 1(1), 1–14. https://repositori.usu.ac.id/handle/123456789/43204

48. Donde, O. O. (2017). Wastewater Management Techniques: A Review of Advancement on the Appropriate Wastewater Treatment Principles for Sustainability. Environmental Management and Sustainable Development, 6(1), 40–58. https://doi.org/10.5296/EMSD.V6I1.10137

49. Dorn, A. W. (2013). Challenges and problems (pp. 176–191). Organisation for Economic Cooperation and Development (OECD). https://doi.org/10.18356/8B4D2D86-EN

50. Duraye, S. A. (2025). Environmental Awareness as an Instrument of Public Policy for Waste Management in Iraq. Political Science Research Journal, 64(64), 395–410. https://doi.org/10.31272/ipj.i64.495

51. Duraye, S. A. (2025). Environmental Awareness as an Instrument of Public Policy for Waste Management in Iraq. Political Science Research Journal, 64(64), 395–410. https://doi.org/10.31272/ipj.i64.495

52. Elagroudy, S., Elkady, T. Y., & Ghobrial, F. H. (2011). Comparative Cost Benefit Analysis of Different Solid Waste Management Scenarios in Basrah, Iraq. Journal of Environmental Protection, 02(5), 555–563. https://doi.org/10.4236/JEP.2011.25064

53. Farzana, M., Sonali, S. N., Razzak, M. T., & Khan, R. A. (2023). Types and Treatment Technology of Industrial Wastewater. Journal of Chemical, Environmental and Biological Engineering. https://doi.org/10.11648/j.jcebe.20220602.12

54. Fawzy, M. E., Ahmed, H. M., & Nassar, H. F. (2024). Advanced Treatment Technologies for Pollutants Removal in Wastewater. Key Engineering Materials, 983, 99–115. https://doi.org/10.4028/p-0bwb2m

55. Galigo, A. M. R. (n.d.). Perlindungan Hukum Terhadap Masyarakat Terkait Pencemaran Lingkungan Hidup Berdasarkan Undang-Undang Nomor 32 Tahun 2009 Tentang Perlindungan Dan Pengelolaan Lingkungan Hidup (studi Kasus Pencemaran Sungai Cikijing Kecamatan Rancaekek Bandung Jawa Barat). https://doi.org/10.5281/zenodo.1257745

56. Grmasha, R. A., Al-Azzawi, S. N. A., Al-sareji, O. J., Alardhi, T., Abdellatif, M., Mubarak, H. A., & Alkhayyat, A. (2021). Analysis of Air Quality Index Distribution of PM 10 and PM 2.5 Concentrations in Ambient Air of Al-Hillah City, Iraq. 1058(1), 012014. https://doi.org/10.1088/1757-899X/1058/1/012014

57. Hajool, Z. M., & Ameen, S. A. S. (2024). National and International Efforts to Confront Environmental Changes in Iraq: A Survey. International Journal of Religion, 5(11), 3236–3247. https://doi.org/10.61707/wc9xbh66

58. Hama-Aziz, Z. (n.d.). Air pollution in Kurdistan Region of Iraq: A review. https://doi.org/10.22135/sje.2021.6.3.127-136

59. Hama-Aziz, Z. Q. (2022). Assessment of air pollution in kurdistan region of iraq. Pollution Research, 457–466. https://doi.org/10.53550/pr.2022.v41i02.011

60. Hameed, A. A. S. (n.d.). The Role of Studying the Environmental Foot Print in Measuring Pollution in Iraq. https://doi.org/10.36037/ijrei.2021.5614

61. Hamza, A. R., Ali, H. A. A., & Jabbar, H. W. (2024). Environmental pollution and its impact on economic growth in iraq (an applied study on the reality of the iraqi economy). https://doi.org/10.55640/ijbms-04-05-09

62. Hamza, A. R., Ali, H. A. A., & Jabbar, H. W. (2024). Environmental pollution and its impact on economic growth in iraq (an applied study on the reality of the iraqi economy). https://doi.org/10.55640/ijbms-04-05-09

63. Hua, Z. (2017). Industrial wastewater treatment technology.

64. Hussien, A., Hussien, A., Al-Mukaram, N., Al-Mukaram, N., Mohammed, R., & Mohammed, R. (2020). Development of optimal location and design capacity of wastewater treatment plants for urban areas: a case study in Samawah city. 671(1), 012089. https://doi.org/10.1088/1757-899X/671/1/012089

65. Ivanushkin, S., & Yakovleva, E. A. (2025). Environmental damage and protection measures against environmental pollution. 425–428. https://doi.org/10.58168/e-sestti2025_425-428

66. Jabbar, N. A. M. (n.d.). Iraq's Hydrocarbon Crisis Demands Integrated Remediation Solutions. https://doi.org/10.21070/acopen.9.2024.9253

67. Jaber, S., Aljawad, A. A., Prisecaru, T., & Pop, E. (2021). The environmental situation of the ash medical waste in Baghdad city, Iraq. 286, 02017. https://doi.org/10.1051/E3SCONF/202128602017

68. Jadem, A. M., Jasem, I., & Al-Ramahi, F. K. M. (2023). Monitoring Pollution and the Trend of Air Quality in Brick Factories in the Nahrawan Region and its Impact on Baghdad, Using Remote Sensing Data. https://doi.org/10.30526/36.4.3162

69. Jawad, S. M., & Amir, L. G. A. (2022 الأزمة المائية العراقية والأستراتيجيات المقترحة لحلها. مجلة كلية التربية الاساسية, 26(107), 123–145. https://doi.org/10.35950/cbej.v26i107.5126

70. Jbara, A. A. (2024). Environmental and Health Impacts Resulting From Burning Solid Waste Near Residential Areas in Diyala Governorate, Iraq. Academia Open, 9(2). https://doi.org/10.21070/acopen.9.2024.10088

71. Jumaah, H. J., Jasim, A. T., Rashid, A., & Ajaj, Q. M. (2023). Air Pollution Risk Assessment Using GIS and Remotely Sensed Data in Kirkuk City, Iraq. Journal of Atmospheric Science Research, 6(3), 41–51. https://doi.org/10.30564/jasr.v6i3.5834

72. Jumaah, H. J., Mahmood, S., & Mahmood, S. A. I. (2024). Estimating Chemical Concentrations of Dust PM2.5 in Iraq: A Climatic Perspective Using Polynomial Model and Remote Sensing Technology. Journal of Atmospheric Science Research, 7(3), 44–56. https://doi.org/10.30564/jasr.v7i3.6381

73. Kanagarathinam, K. (2023). Causes of Environmental Pollution and Conservation Management. International Journal For Multidisciplinary Research, 5(4). https://doi.org/10.36948/ijfmr.2023.v05i04.5327

74. Kareem, I. M., Ahmed, A. M., & Abdulateef, L. A. (2024). Review of solid waste management challenges and solutions in iraq. International Journal of Trendy Rresearch in Engineering and Technology, 08(04), 22–25. https://doi.org/10.54473/ijtret.2024.8404

75. Kareem, I. M., Ahmed, A. M., & Abdulateef, L. A. (2024). Review of solid waste management challenges and solutions in iraq. International Journal of Trendy Rresearch in Engineering and Technology, 08(04), 22–25. https://doi.org/10.54473/ijtret.2024.8404

76. Kareem, I. M., Ahmed, A. M., & Abdulateef, L. A. (2024). Review of solid waste management challenges and solutions in iraq. International Journal of Trendy Rresearch in Engineering and Technology, 08(04), 22–25. https://doi.org/10.54473/ijtret.2024.8404

77. Karim, S. N. (2022). Pollution taxation for clean production systems: a case of iraq. 1(3), 167–181. https://doi.org/10.55202/ajcas.v1i3.16

78. Khreebsh, H. T., & Azeez, N. M. (2024). Application of satellite data and GIS services for studying air pollutants in Basra province, south of Iraq. GSC Advanced Research and Reviews. https://doi.org/10.30574/gscarr.2024.19.3.0194

79. Khreebsh, H. T., & Azeez, N. M. (2024). Application of satellite data and GIS services for studying air pollutants in Basra province, south of Iraq. GSC Advanced Research and Reviews. https://doi.org/10.30574/gscarr.2024.19.3.0194

80. Krause, S., & Thiemig, C. (2013). Membrane Bioreactors, Applications to Wastewater Treatment and Reuse. 1–17. https://doi.org/10.1002/9781118522318.EMST150

81. Lftah, A. khalaf. (n.d.). Environmental Management As an Entry Point to Achieve Sustainable Development with Reference to Reality Sustainable Development in Iraq. https://doi.org/10.30684/etj.34.4a.14

82. Li, Z. (2025). Advancing Environmental Protection through Legislative Measures: Case Studies and Best Practices. Lex Localis, 1(11). https://doi.org/10.52152/3242

83. Ličbinský, R., Dufek, J., Jedlička, J., & Ličbinská, M. (n.d.). Legislation Framework. https://doi.org/10.2478/v10158-011-0014-8

84. Majeed, A. A. W. (2025). Using the Direct Method in the Environmental Impact Assessment of Air Pollution in Iraq .195–179 ,46 ,مجلة العلوم التربوية والانسانية . https://doi.org/10.33193/jeahs.46.2025.669

85. Majeed, A. A. W. (2025). Using the Direct Method in the Environmental Impact Assessment of Air Pollution in Iraq .195–179 ,46 ,مجلة العلوم التربوية والانسانية . https://doi.org/10.33193/jeahs.46.2025.669

86. Majeed, A. A. W. (2025). Using the Direct Method in the Environmental Impact Assessment of Air Pollution in Iraq .195–179 ,46 ,مجلة العلوم التربوية والانسانية . https://doi.org/10.33193/jeahs.46.2025.669

87. Modekwe, H. U., Ayeleru, O. O., Olubambi, P. A., & Ramatsa, I. M. (2024). New Trends in Wastewater Recycling, Treatment, and Management (pp. 299–321). Informa. https://doi.org/10.1201/9781003441069-13

88. Mohammad, A., Ali, S., & Fathi, R. (2022). Using Remote Sensing Techniques and GIS to Study of PM2.5 and PM10 Concentrations in the Atmosphere of Mosul City, Iraq. https://doi.org/10.33899/earth.2022.174661

89. Mohammed, Z. B., Kamal, A. A. K., Resheq, A., & Alabdraba, W. M. Sh. (2019). Assessment of Air Pollution over Baghdad City Using Fixed Annual Stations and GIS Techniques. Journal of Southwest Jiaotong University, 54(6). https://doi.org/10.35741/ISSN.0258-2724.54.6.36

90. Muralikrishna, I. V., & Manickam, V. (2017). Industrial Wastewater Treatment Technologies, Recycling, and Reuse (pp. 295–336). Butterworth-Heinemann. https://doi.org/10.1016/B978-0-12-811989-1.00013-0

91. Mustafa, A. S., Mohsin, A. A., & Ali, L. N. (2018). Management of Municipal Solid Waste in Baghdad, Iraq. 11(7), 700–704. https://doi.org/10.5281/ZENODO.1316235

92. Pandit, J., & Sharma, A. K. (2024). Advanced Techniques in Wastewater Treatment: A Comprehensive Review. Asian Journal of Environment & Ecology, 23(10), 1–26. https://doi.org/10.9734/ajee/2024/v23i10605

93. **Persistent Organic Pollutants (POPs) Removal Project**: Iraq is working with international environmental organizations to eliminate harmful chemical pollutants in the environment. (UNDP)

94. Riffat, S., Hanley, N., Pavel, C. E., Pullin, A. S., van Leeuwen, C. J., Rind, E., Scheurer, M. E., Futter, M. N., Naims, H., & Xu, Y. (2016). Environmental Pollution and Control. https://www.scirp.org/book/DetailedInforOfABook.aspx?bookID=2408

95. Rout, S. K. (2013). Wastewater Treatment Technologies. http://www.idosi.org/ijwres/2(1)13/4.pdf

96. Saleem, A., & Abdullah, E. (2024). Assessment of Particulates and Heavy Metals Concentration Distribution in Ambient Air around Al-Dora Refinery in Baghdad City, Iraq. Iraqi Geological Journal, 57(2E), 149–160. https://doi.org/10.46717/igj.57.2e.12ms-2024-11-21

97. Salih, S. M. (2023). Iraqi Water Security: Research on Rights and Possibilities of Solutions. Qadaya Siyasiya, 74, 143–180. https://doi.org/10.58298/742023369

98. Salman, N. A., Al-Mishrey, M. K., Al-Saad, H. T., & Rushdi, A. I. (2024). Air Pollution in the Southern Part of Iraq and Its Health Risks (pp. 107–122). https://doi.org/10.1007/978-3-031-55836-8_6

99. Salman, N. A., Al-Mishrey, M. K., Al-Saad, H. T., & Rushdi, A. I. (2024). Air Pollution in the Southern Part of Iraq and Its Health Risks (pp. 107–122). https://doi.org/10.1007/978-3-031-55836-8_6

100. Samir, B. A., & Kosaj, A. D. (n.d.). Assessment of Environmental Impacts of Heavy Metal Pollution and Risk Assessment in Soil of Oil Depots and Distribution Centers in Anbar Governorate, Iraq. https://doi.org/10.18280/ijei.070217

101. Saremi, P. (2020). Environmental Pollution and ways to Reduce Contamination with use of Environmental Engineering Techniques in Metropolises of Developing Countries. International Journal of Environment, Agriculture and Biotechnology, 5(3), 566–581. https://doi.org/10.22161/IJEAB.53.9

102. Sodikin, S. (2010). Penegakan Hukum Lingkungan menurut Undang-Undang Nomor 32 Tahun 2009 tentang Perlindungan dan Pengelolaan Lingkungan. 12(3), 543–563. https://doi.org/10.24815/KANUN.V12I3.6308

103. Subekti, R., Silalahi, D. G. P., Purbadi, D. A., & Sangkara, R. K. (2023). Law Enforcement against Environmental Pollution by Vehicle Exhaust Emissions. Kosmik Hukum. https://doi.org/10.30595/kosmikhukum.v23i1.15306

104. Sulistyawati, N. P. Y., & Kusumawardhani, S. A. M. A. (2023). Perlindungan hukum terhadap pencemaran lingkungan dikawasan hutan mangrove badung bali terkait undang-undang nomor 32 tahun 2009 tentang perlindungan dan pengelolaan lingkungan hidup. Jurnal Komunikasi Hukum. https://doi.org/10.23887/jkh.v9i1.58042

105. Swarup, D., & Patra, R. C. (2005). Environmental pollution and its impact on domestic animals and wildlife. Indian Journal of Animal Sciences, 75(2). http://epubs.icar.org.in/ejournal/index.php/IJAnS/article/download/8111/3142

106. Todd, E. C. D. (2023). Waterborne Diseases and Wastewater Treatment in Iraq. Journal of Food Protection. https://doi.org/10.1016/j.jfp.2023.100204

107. Tonelli, F. M. P. (2024). Environmental pollution: a worldwide threat (pp. 3–9). Elsevier BV. https://doi.org/10.1016/b978-0-443-14118-8.00001-2

108. Tripathi, M., Yadav, S., Ojha, S., & Vishwakarma, P. K. (2023). Advancements in Wastewater Treatment: Sustainable Solutions and Technological Innovation. https://doi.org/10.21467/proceedings.161.18

109. Vij, P. (2015). Environmental Pollution:Its Effects on Life and its Remedies. National Journal of Management and Technology, 3(2), 88–92. http://www.i-scholar.in/index.php/AADYA/article/download/122058/110510

110. Wan, J. (2001). New development of the industrial wastewater pollution control. Industrial Water Treatment. https://en.cnki.com.cn/Article_en/CJFDTOTAL-GYSC200101002.htm

111. Wang, H. (2014). Membrane Bioreactor/Ultra Low Energy Reverse Osmosis Membrane Process for Forward Operating Base Wastewater Reuse. Defense Technical Information Center. https://dx.doi.org/10.21236/ada619412

112. Wu, J., Zhang, Y., Wang, J., Zheng, X., & Chen, Y. (n.d.). Municipal Wastewater Reclamation and Reuse Using Membrane-Based Technologies: a Review. https://doi.org/10.5004/dwt.2021.27175

113. Zhao, L. (2013). Industrial wastewater treatment technology.

114. Zhou, K., Yi, L. H., Su, X., & Sun, Y. (2023). Overview of Environmental Pollution Prevention and Control Law (pp. 99–108). https://doi.org/10.1007/978-981-99-4448-4_5

115. Аль, Б. М. Н. М., & Липаев, А. А. (2023). Воздействие нефтегазовой промышленности ирака на окружающую среду. https://doi.org/10.34828/udsu.2022.75.88.007

116. Аль, Б. М. Н. М., & Липаев, А. А. (2023). Воздействие нефтегазовой промышленности ирака на окружающую среду. https://doi.org/10.34828/udsu.2022.75.88.007

117. ارزوقي, ا. م., & علي, ر. ص. (n.d.). والبشرية الطبيعية المصادر في دراسة العراق في البيئي التلوث مشكلات والصناعية. https://doi.org/10.55716/jjps.2022.11.1.15

118. الاسود, غ. ص. س. (2024). العراق في المستدامة التنمية منظور من البيئي للتلوث الاقتصادية الكلفة. Mağallaẗ Tikrīt Li-l-‘ulūm al-Idāriyyaẗ Wa-al-Iqtiṣādiyyaẗ, 20(68, part 1), 280–294. https://doi.org/10.25130/tjaes.20.68.1.16

119. الحسون, ه. ف. (2024). العراق “ المستدامة التنمية اهداف حلول كأحد القوانين بتنازع والاولويات الحراري الاحتباس انموذجاً.” https://doi.org/10.61856/ijhss.v2ispc..134

120. الزبيدي, ح. ل. ك., & الزرفي, ع. م. ح. (2022). Iraq and achieving the 2030 Sustainable Development Agenda. Al-Ghary Journal of Economic and Management Sciences, 18(2), 75–104. https://doi.org/10.36325/ghjec.v18i2.13834

121. زهراو, د. ا. (2024). العراق في للبيئة القانونية الحماية (تحليلية دراسة). Govar-î Yasa-w Ṛamyarî/Govarî Zanko Bo Yasa-w Ṛamyarî, 22(special), 523–536. https://doi.org/10.21271/zjlp.22.sp.24

122. زهراو, د. ا. (2024). العراق في للبيئة القانونية الحماية (تحليلية دراسة). Govar-î Yasa-w Ṛamyarî/Govarî Zanko Bo Yasa-w Ṛamyarî, 22(special), 523–536. https://doi.org/10.21271/zjlp.22.sp.24

123. زهراو, د. ا. (2024). العراق في للبيئة القانونية الحماية (تحليلية دراسة). Govar-î Yasa-w Ṛamyarî/Govarî Zanko Bo Yasa-w Ṛamyarî, 22(special), 523–536. https://doi.org/10.21271/zjlp.22.sp.24

124. زين العابدين احمد, د. ب. ا. (2023). دور التخطيط البيئي في معالجة التلوث من المخلفات الحربية في العراق بعد عام 2003. Enterprenuership Journal For Finance and Bussiness, 126–134. https://doi.org/10.56967/ejfb2023218

125. زين العابدين احمد, د. ب. ا. (2023). دور التخطيط البيئي في معالجة التلوث من المخلفات الحربية في العراق بعد عام 2003. Enterprenuership Journal For Finance and Bussiness, 126–134. https://doi.org/10.56967/ejfb2023218

126. سعدون, م. م. ه. ف. (2022). التلوث البيئي في العراق واثره على الصحة والامن الصحي. مجلة كلية التربية الاساسية, 24(102), 397–424. https://doi.org/10.35950/cbej.v24i102.6226

127. عبد الله, ح. ع. ح., & ابو الشعير, م. (2024). انحاء جميع في الهواء نقاوة لدراسة (الكترونية – إحصائية) منظومة بناء العراق. Journal of Al-Rafidain University College For Sciences (Print ISSN: 1681-6870 ,Online ISSN: 2790-2293). https://doi.org/10.55562/jrucs.v54i1.585

128. عبدالرضا, ن. ج., & الحلفي, ع. ع. (2016). مجلة العراق في البيئية والتشريعات النفطي التلوث بين العلاقة إشكالية. العربية والجزيرة الخليج دراسات, 42(162). https://doi.org/10.34120/jgaps.v42i162.2393

129. محيبس, أ. م. د. أ. ك., & عبد رحيم, ا. س. (2025). طبقة بحماية المعنية الدولية القانونية بالقواعد الإلتزام أدوات منها العراق وموقف والمناخ الأوزون. 2(3), 631–702. https://doi.org/10.64184/ajlps.v2.i3.y2025.p631-702.144

130. منديل, م. (2023). ٢٠٠٣ سنة بعد العراق في سليمة بيئة في الإنسان لحق القانوني التنظيم. https://doi.org/10.61353/ma.0070259

131. مهاوي, م. م. خ., & مروشن. (2025). ولإجراءات التحديات العراق في البيئية الحوكمة. 2(3), 240–265. https://doi.org/10.64184/ajlps.v2.i3.y2025.p240-265.130

132. هاشم, ح. ع. ا. (n.d.). المستقبل وضرورات الماضي ارث العراق في المستدامة التنمية ومتطلبات واقع. https://doi.org/10.36322/jksc.v1i21.5160

133. الهيتي, ن. ع. ا. (2024). للعراق خاصة إشارة مع المناخي للتغير والاقتصادية البيئية الاثار. Al-Mağallaẗ al-ʻirāqiyyaẗ Li-l-ʻulūm al-Iqtiṣādiyyaẗ, 22(82), 1–16. https://doi.org/10.31272/ijes.v22i82.1107

134. 张勇, & 万金泉. (n.d.). New Development of the Industrial Wastewater Pollution Control. https://doi.org/10.3969/j.issn.1005-829x.2001.01.003

135. 韩冰. (n.d.). On Legal Status of Industrial Wastewater Centralized Treatment Plants —— based on Review of Administrative Law Enforcement Interpretation of Environmental Protection Department. https://doi.org/10.3969/j.issn.1671-6191.2011.03.011