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Identification and Prioritization of Environmental Pollutants in the Bistoon Petrochemical Industry, Kermanshah

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Abstract

The global environmental pollution crisis has led scientists to believe that if development and environmental protection are not aligned and integrated, sustaining life on Earth for future generations will not be feasible. In Iran, due to the expansion of oil and gas industries and their close connection with the social and environmental lives of surrounding residents, increased attention to the environmental and health impacts of the oil, gas, and petrochemical industries is justified. Thus, eliminating or reducing these risks to an acceptable level is of great importance. Petrochemical industries are known to generate environmental pollutants throughout various stages, including the collection of raw materials, production and transformation of intermediates, and the collection and storage of final products. The primary environmental impacts of petrochemical projects involve water, soil, air, and noise pollution, as well as socio-economic consequences. Therefore, the aim of this research is to identify and prioritize environmental pollutants in the Bistoon Petrochemical Industry, Kermanshah. The research is applied in terms of purpose and exploratory-descriptive in terms of method. The research instrument is a pairwise comparison questionnaire. The statistical population consists of the managers of the Bistoon Petrochemical Company, Kermanshah, with 10 experts selected randomly using the snowball sampling method. Data analysis was conducted using the SWARA software. The results indicate that water and wastewater-related pollutants, with a weight of 0.445, rank first. Air-related pollutants, with a weight of 0.271, rank second. Soil and waste-related pollutants, with a weight of 0.164, rank third. Noise-related pollutants, with a weight of 0.120, rank fourth. Based on these findings, the implementation of advanced technologies to improve the wastewater purification processes to reduce environmental pollution is recommended.

Keywords: *Water, Environmental Strategies, Bistoon Petrochemical Industry, System Dynamics Model, Air.*

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1. Introduction

Today, the control and reduction of pollution impacts caused by petrochemical industries to protect the environment have become one of the most important issues and concerns for nations worldwide. The major environmental problems of these industries, especially when environmental regulations and standards are not adhered to, result in hazardous consequences, disrupting the ecological balance of human societies and wildlife [1].

In petrochemical and refinery industries, the type and extent of pollution vary based on the nature of the consumed and produced materials and the stage of the processes. This means that pollution can occur at three stages: the "collection of raw materials," "production and transformation of intermediates," and "collection and storage of produced materials" [2, 3].

The petrochemical industry releases various pollutants, including suspended particles, heavy metals, and hazardous airborne contaminants such as polycyclic aromatic hydrocarbons, benzene, hexane, toluene, xylene, propylene, nickel, lead, and cadmium. These have irreversible adverse effects on human health and ecosystems. Additionally, wastewater and effluents from petrochemical industries contain toxic substances and high levels of heavy metals. When discharged into sewage systems or surface runoffs and agricultural waters, these metals enter the environment in significant quantities. Improper wastewater disposal and the discharge of part of it into surface water streams have polluted many areas, exposing residents to infectious, parasitic, and toxic-element-induced diseases, significantly increasing child mortality rates [4, 5].

Soil pollution may result from residual materials from refining processes, including hazardous waste, catalysts, or coke dust, and sludge from production processes. Another form of pollution is noise pollution, which, in areas close to petrochemical industries, is caused by increased noise levels. This leads to headaches, discomfort, physical and mental health issues, stress, irritability, anger, extreme sensitivity, excessive anxiety, aggressive behaviors, and violence.

Pollution in petrochemical processes can occur at three stages: the "collection of raw materials," "production and transformation of intermediates," and the "collection and storage of produced materials." The main environmental impacts and consequences of petrochemical project operations include water, soil, air, and noise pollution, as well as socio-economic outcomes [6].

The petrochemical industry, through unlimited exploitation of natural resources to boost petrochemical production and extensive industrial development, has fractured parts of ecosystems and created unbalanced human-nature relationships. Additionally, rapid product manufacturing has led to waste and residue release in nature, resulting in various forms of pollution. Establishing petrochemical facilities, apart from the increased economic revenue flow, brings numerous adverse local and regional effects. This industry not only uses the natural environment as a raw material source but also as a waste and effluent disposal medium. In petrochemical and refinery industries, pollution type and level vary based on the nature of materials used and produced and the stage of processing. Pollution can occur at three stages: the "collection of raw materials," "production and transformation of intermediates," and the "collection and storage of produced materials" [2, 7, 8].

Most petrochemical companies pay significant pollution-related fines annually, yet they still cause environmental damage. Preventing environmental damage and avoiding economic losses for petrochemical entities requires cultural and research-based work in this area and strict enforcement of environmental laws [9]. Since short-term planning and decisions are no longer adequate to address the environmental challenges posed by industries, and because developed countries plan and implement all environmental actions within the framework of long-term environmental strategies, it is necessary to conduct a comprehensive applied research study on petrochemical pollutants and provide practical strategies to address this problem. Therefore, this research uses system dynamics modeling to evaluate and analyze the petrochemical industry comprehensively and systematically. Addressing petrochemical company pollution will not only safeguard the environmental cycle but also relieve petrochemical companies from paying heavy pollution-related fines. If the results of this research are meticulously compiled and implemented with the earnest commitment of officials, they could become the key to solving environmental challenges of the petrochemical industry and even serve as a successful model for other industries.

Therefore, this research raises the following questions:

What are the environmental pollutants in the Bistoon Petrochemical Industry, Kermanshah?

How are the environmental pollutants in the Bistoon Petrochemical Industry, Kermanshah prioritized?

2. Methodology

Considering that the objective of this article is to identify and prioritize environmental strategies in the Bistoon Petrochemical Industry, Kermanshah, the research is applied in terms of its purpose and exploratory-descriptive in terms of its method. The research instrument is a pairwise comparison questionnaire. The statistical population consists of the managers of the Bistoon Petrochemical Company, Kermanshah, with 10 experts selected randomly using the snowball sampling method. Data analysis was conducted using the SWARA software.

Step One: Arrange the indicators.

Step Two: Determine the relative importance of the main criteria (SJ).

Step Three: Calculate the coefficient kj.

The coefficient kj is a function of the relative importance of each indicator, calculated using Equation 1.

$$(1)\quad KJ = SJ + 1$$

(2)

Step Four: Calculate the initial weight and normalized weight of the criteria.

The initial weight of the main criteria is obtained using Equation 2.

$$(2)\quad qj = (qj-1) / kj$$

To obtain the normalized weight, Equation 3 is used.

$$(3)\quad wj = qj / (\sum qj)$$

3. Findings

In the first step, the indicators are identified (the research criteria are provided in Table 1), and then, based on expert opinions, the most important indicators are screened and ranked according to their significance. Thus, the most significant indicator is placed first. In this research, the criterion "Water and Wastewater" is considered of high importance based on expert opinions. The normalized weights of the main criteria are shown in Table 1.

Table 1. Normalized Weights of Main Criteria

Research Indicator	Average Relative Importance of Each Indicator (SJ)	Calculation of Coefficient (KJ)	Calculation of Initial Weight (qj)	Normalized Weight (wj)
Water and Wastewater	1	1	1	0.445
Air	0.640	1.64	0.610	0.271
Soil and Waste	0.650	1.65	0.370	0.164
Noise	0.370	1.37	0.270	0.120

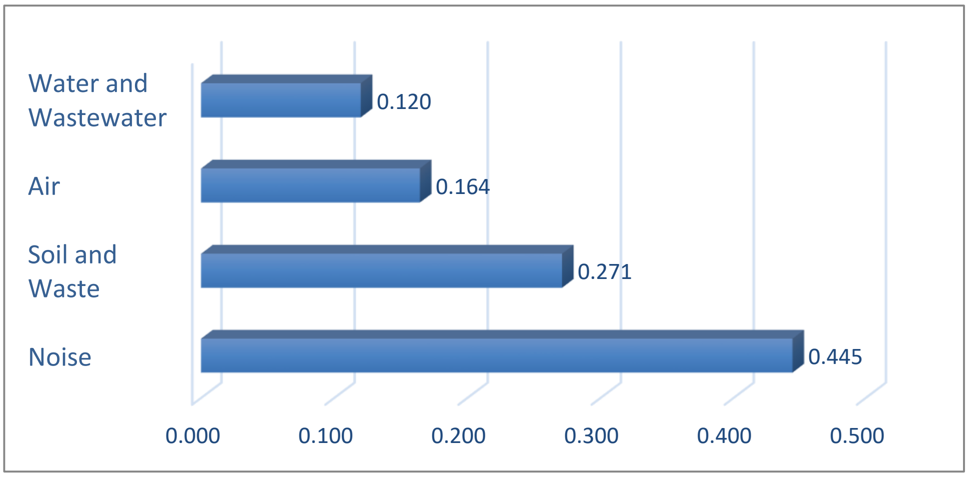

Figure 1. Normalized Weights of Main Criteria

According to the findings:

- Water and Wastewater, with a weight of 0.445, ranks first.
- Air, with a weight of 0.271, ranks second.
- Soil and Waste, with a weight of 0.164, ranks third.
- Noise, with a weight of 0.120, ranks fourth.

Table 2. Normalized Weights of Air Criteria

	Average Relative Importance of Each Indicator (SJ)	Calculation of Coefficient (KJ)	Calculation of Initial Weight (qj)	Normalized Weight (wj)
CO2	1	1	1	0.376
SO2	0.56	1.560	0.641	0.241
NOx	0.52	1.520	0.422	0.159
H2S	0.51	1.510	0.279	0.105
DUST	0.5	1.500	0.186	0.070
CO	0.45	1.450	0.128	0.048

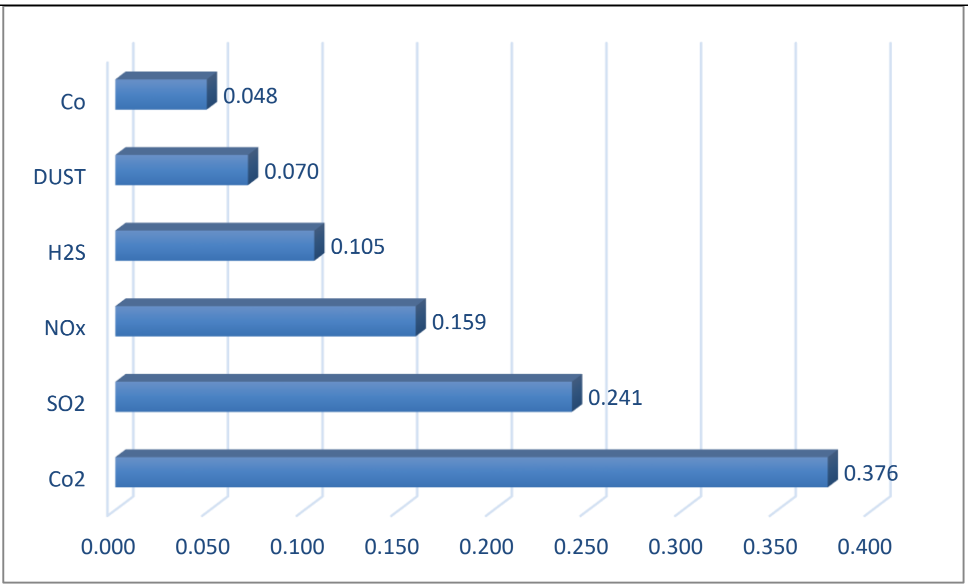

Figure 2. Normalized Weights of Air Criteria

According to the findings:

- CO2, with a weight of 0.376, ranks first.
- SO2, with a weight of 0.241, ranks second.
- NOx, with a weight of 0.159, ranks third.
- H2S, with a weight of 0.105, ranks fourth.
- DUST, with a weight of 0.070, ranks fifth.
- CO, with a weight of 0.048, ranks sixth.

Table 3. Normalized Weights of Water and Wastewater Criteria

	Average Relative Importance of Each Indicator (SJ)	Calculation of Coefficient (KJ)	Calculation of Initial Weight (qj)	Normalized Weight (wj)
Chemical	1	1	1	0.348
Ammoniacal	0.54	1.54	0.649	0.226
Industrial Effluent Containing Oil	0.46	1.46	0.445	0.155
Sanitary Effluent	0.39	1.39	0.320	0.111
Surface Water and Drainage Effluent	0.54	1.54	0.208	0.072

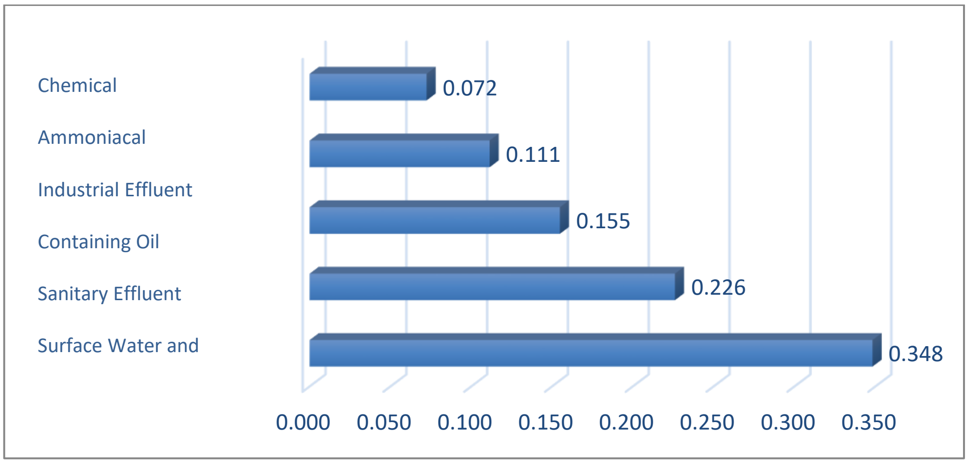

Figure 3. Normalized Weights of Water and Wastewater Criteria

According to the findings:

- Chemical, with a weight of 0.348, ranks first.
- Ammoniacal, with a weight of 0.226, ranks second.
- Industrial Effluent Containing Oil, with a weight of 0.155, ranks third.
- Sanitary Effluent, with a weight of 0.111, ranks fourth.
- Surface Water and Drainage Effluent, with a weight of 0.072, ranks fifth.

Table 4. Normalized Weights of Soil and Waste Criteria

	Average Relative Importance of Each Indicator (SJ)	Calculation of Coefficient (KJ)	Calculation of Initial Weight (qj)	Normalized Weight (wj)
Industrial Waste	1	1	1	0.588
Personnel Waste	0.43	1.430	0.699	0.412

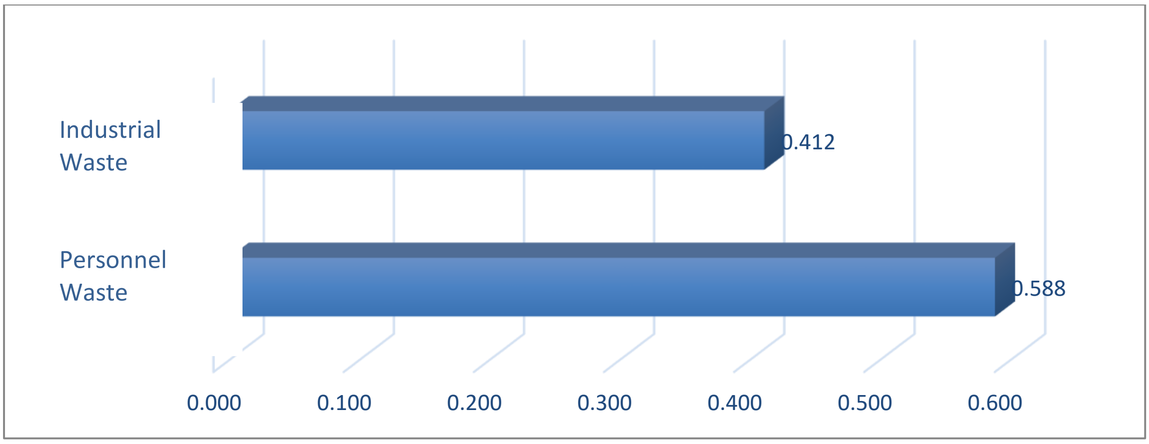

Figure 4. Normalized Weights of Soil and Waste Criteria

According to the findings:

- Industrial Waste, with a weight of 0.588, ranks first.
- Personnel Waste, with a weight of 0.412, ranks second.

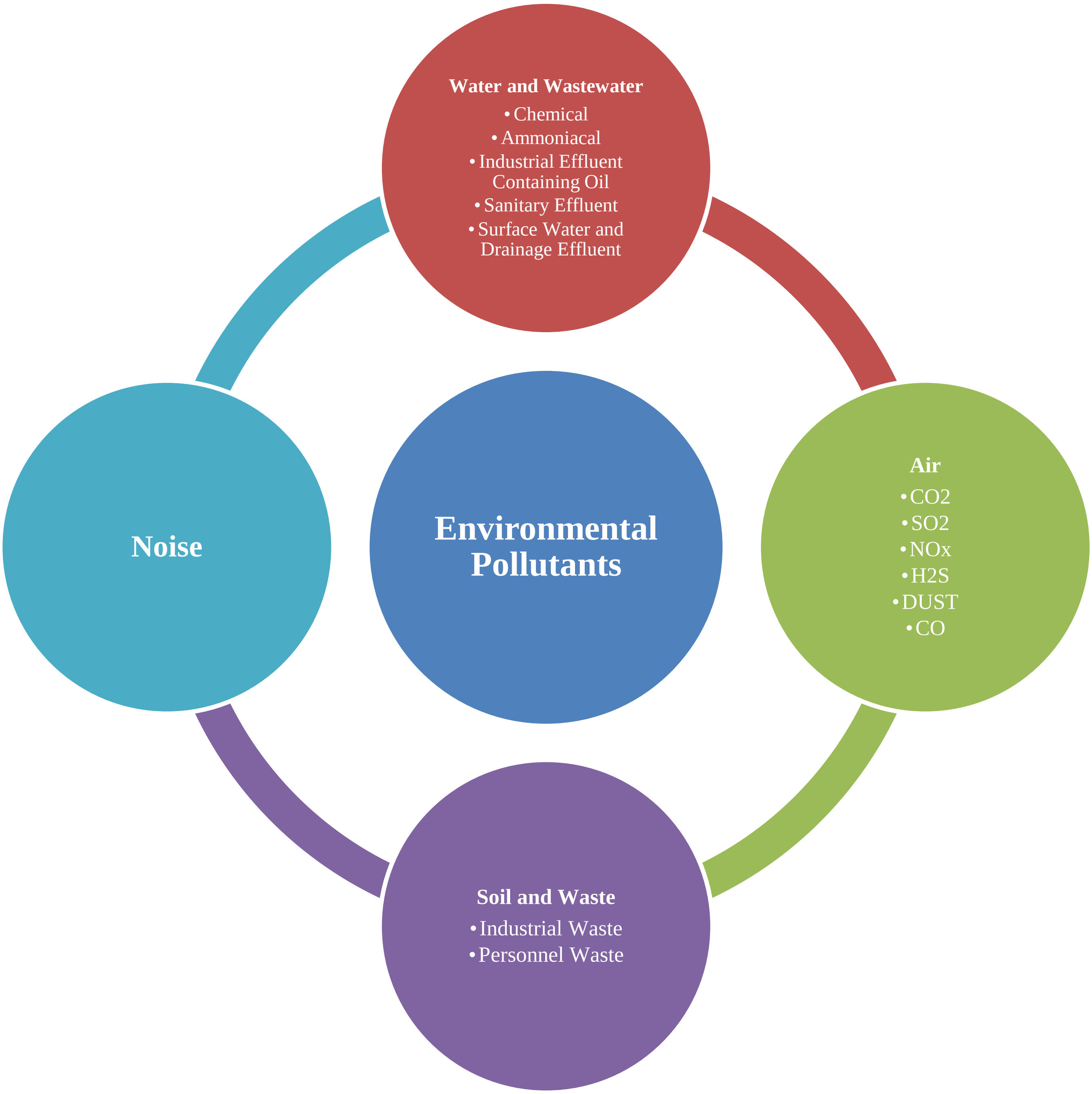

Figure 5. Research Model (Source: Research Findings)

4. Discussion and Conclusion

The findings of this research reveal that among the identified environmental criteria in the Bistoon Petrochemical Industry, "Water and Wastewater" was given the highest priority with a normalized weight of 0.445. This is followed by "Air" (0.271), "Soil and Waste" (0.164), and "Noise" (0.120). These results underscore the critical need for targeted strategies to mitigate environmental impacts in petrochemical operations, especially concerning water and wastewater management.

The prioritization of water and wastewater pollutants aligns with global concerns over water pollution resulting from industrial effluents. Previous studies have highlighted the significant environmental and health threats posed by petrochemical wastewater. Ding et al. (2016) discuss how petrochemical wastewater contains complex pollutants, such as polycyclic aromatic hydrocarbons, phenols, and heavy metals, which are resistant to biodegradation and cause severe environmental damage [10]. The high priority given to water and wastewater in this research reinforces findings by the World Health Organization (2010), which identified water contamination as a major contributor to global health risks, including millions of deaths and disabilities annually.

Air pollution was identified as the second most critical environmental concern. Petrochemical industries are significant sources of hazardous air pollutants, including CO2, SO2, NOx, and volatile organic compounds. The results of this study are consistent with findings by Zakaria et al. (2018), who emphasized that air pollutants from industrial processes pose severe health risks, such as respiratory and cardiovascular diseases [11].

Soil and waste pollution ranked third in importance. The impact of petrochemical activities on soil contamination is well documented in the literature. Hazardous waste, including heavy metals and chemical residues, poses long-term risks to soil quality and agricultural productivity. The study by Hansen et al. (2016) highlights the necessity of employing both physical and biological methods to treat hazardous waste, as improperly managed waste can leach into the soil and groundwater, exacerbating environmental degradation [12]. This finding also corroborates research by Asghari et al. (2018), which discussed the need for practical solutions to manage hazardous waste effectively in developing countries [13].

Noise pollution was the least prioritized but remains significant due to its adverse effects on human health, such as stress, sleep disturbances, and hearing impairment. The findings of this study align with Prochaska et al. (2019), who utilized system dynamics to understand the cumulative health impacts of environmental stressors, including noise pollution [7]. Despite being ranked last, the need to address noise pollution should not be underestimated, as it contributes to a reduced quality of life for communities near petrochemical facilities.

The SWARA method used for weighting and prioritizing environmental criteria proved effective in this study. The approach allowed for an in-depth assessment of expert opinions, highlighting the most pressing environmental challenges faced by the Bistoon Petrochemical Industry. The use of system dynamics modeling, as proposed in previous studies [7], could further enhance understanding and provide a comprehensive framework for predicting the long-term environmental and health impacts of petrochemical pollutants.

The results also emphasize the need for a holistic approach to environmental management, considering the interconnected nature of air, water, and soil pollution. As noted by Speight (2007), industrial pollutants often interact with each other, exacerbating their overall environmental impact [14]. This interconnectedness necessitates integrated management strategies, as single-faceted solutions are likely insufficient. The insights from this research can guide policymakers and industry leaders in prioritizing environmental interventions that yield the most significant benefits for both the environment and public health.

One of the main limitations of this research is the relatively small sample size, as only 10 experts from the Bistoon Petrochemical Industry were consulted. While the snowball sampling method provided access to knowledgeable participants, the limited sample may not fully represent the diverse perspectives within the industry. Additionally, the research focuses on a single petrochemical plant, which may limit the generalizability of the findings to other regions or industries with different environmental challenges.

Future research should consider expanding the sample size and incorporating experts from various fields, such as environmental science, public health, and community advocacy, to gain a more comprehensive understanding of environmental priorities. Longitudinal studies could also be conducted to monitor the effectiveness of implemented environmental strategies over time. Additionally, incorporating real-time environmental monitoring data could enhance the accuracy of pollutant assessments and provide a more dynamic understanding of pollution patterns.

Petrochemical companies should invest in advanced wastewater treatment technologies to mitigate water pollution effectively. Implementing continuous air quality monitoring systems and adopting cleaner production techniques could also significantly reduce air pollution. Moreover, regular training and awareness programs for employees on waste management practices could help minimize soil contamination. Lastly, soundproofing measures and noise control initiatives should be considered to reduce the impact of noise pollution on nearby communities.

Authors' Contributions

Authors equally contributed to this article.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

All procedures performed in this study were under the ethical standards.

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