Discover Sustainability

Research

Driving sustainability: assessing KPI effectiveness in the Saudi chemical industry

Alaa Alfarsi[1] · Ziyad Sherif[1] · Sandeep Jagtap[1,2] · Sumit Gupta[3] · Konstantinos Salonitis[1]

Received: 14 May 2024 / Accepted: 12 July 2024
Published online: 05 August 2024

Abstract
This study explores the relationship between Key Performance Indicators (KPIs) and environmental performance improvement within the Saudi chemical industry. Against the backdrop of global sustainability imperatives and Saudi Arabia's Vision 2030, which promotes sustainability for economic diversification, this research aims to assess the effectiveness of KPIs in driving environmental sustainability practices. The motivation for this study stems from the identified gaps in the systematic implementation and utilisation of KPIs and the lack of awareness regarding certain aspects of environmental impact management within the industry in the Kingdom. The methodology involved a structured survey administered to a diverse range of chemical manufacturing companies, followed by rigorous data analysis using descriptive evaluation, Analysis of Variance (ANOVA), reliability analysis, and *t*-tests. The results revealed insights into pollution areas, KPI utilisation, methods for pollution assessment, alignment with strategic goals, and governance regulations. Descriptive analysis highlighted air quality management as a priority, with notable attention to water and land pollution, while quantitative analysis confirmed the significance of KPIs in driving environmental performance improvement in the area. However, it also unveiled the absence of a systematic approach to implementing and utilising KPIs effectively, coupled with a lack of awareness regarding certain aspects of environmental impact management, consequently leading to uncertainty. Overall, this study contributes to advancing sustainability efforts within the Saudi chemical sector, providing actionable insights for industry stakeholders and policymakers.

Keywords Sustainability · Saudi Arabia · Chemical industry · Sustainable practices · Key performance indicators (KPIs)

1 Introduction

In today's global business landscape, sustainability has emerged as a central principle, guiding industries towards resilience and responsible stewardship. From multinational corporations to local enterprises, the imperative to balance economic prosperity with environmental preservation and social equity has become increasingly apparent [1]. At its core, sustainability encompasses the pursuit of continuing prosperity while safeguarding natural resources and ecosystems for future generations [2]. The shift towards sustainability underscores the interconnectedness of economic, environmental, and social systems [3], requiring organisations to adopt holistic approaches to their operations. This triple-bottom-line approach recognises that economic growth must be coupled with environmental protection

✉ Sandeep Jagtap, sandeep.jagtap@tlog.lth.se | [1]Sustainable Manufacturing Systems Centre, School of Aerospace, Transport and Manufacturing, Cranfield University, Cranfield, Bedfordshire MK43 0AL, UK. [2]Division of Engineering Logistics, Faculty of Engineering, Lund University, Lund, Sweden. [3]Department of Mechanical Engineering, Amity School of Engineering and Technology, Amity University Uttar Pradesh, Noida 201313, India.

and social well-being to ensure a sustainable future [4]. Consequently, industries worldwide are evaluating their practices and policies to align with these principles, seeking to mitigate their environmental footprint and enhance their societal contributions. Within this context, environmental sustainability occupies a vital position, emphasising the need to minimise negative environmental impacts while promoting resource efficiency and conservation [5]. Environmental sustainability initiatives encompass various facets, including reducing greenhouse gas (GHG) emissions, conserving water and energy, minimising waste generation, and protecting biodiversity [6]. Realising such aspirations requires collaborative efforts from both the public and private sectors, with businesses playing a crucial role in driving innovation and implementing sustainable practices [7].

In Saudi Arabia, a nation historically reliant on oil revenues, sustainability has emerged as a strategic imperative for economic diversification and long-term prosperity. In 2022, hydrocarbon extraction constituted approximately 39% of the GDP and contributed 80% to government revenues, highlighting the economy's heavy dependence on fossil fuels and its vulnerability to market fluctuations [8]. Vision 2030, Saudi Arabia's ambitious blueprint for the future, underscores the importance of sustainability as a catalyst for economic growth and social development [9]. This transformative agenda aims to reduce the kingdom's reliance on oil, promote sustainable development across sectors, and enhance the quality of life for its citizens [10]. Among these broader sustainability efforts, the chemical industry in Saudi Arabia stands at a critical stage. As a cornerstone of the nation's economy, accounting for 9.2% of the Gulf region's GDP in 2021 and generating an estimated USD 42.1 billion in revenue [11, 12], the chemical sector assumes a pivotal role in fostering industrial growth and innovation [13]. However, it also struggles with notable environmental challenges, such as pollution, resource depletion, and ecological degradation [14]. In 2012 alone, the sector accounted for 50 million tons of CO_2 equivalent emissions [15]. Recognising the imperative to balance economic objectives with environmental considerations, Saudi chemical companies are progressively adopting sustainability principles in their operations, a transition that may entail various challenges.

The motivation for this study is to address the gaps in the systematic implementation and utilisation of KPIs in the Saudi chemical industry and the lack of awareness regarding certain aspects of environmental impact management. Advancing environmental sustainability requires an initial step of understanding an organisation's current impact levels. This comprehension is vital as it allows for the identification of specific areas that require attention and improvement, providing clarity on where efforts should be focused to mitigate adverse effects [16, 17]. This process entails meticulous monitoring and evaluation of industrial activities, assessing their impacts on the ecosystem, providing valuable insights into their environmental performance and developing targeted strategies to enhance sustainability practices. In pursuit of this objective, the adoption of robust monitoring mechanisms becomes imperative. Environmental sustainability targeted Key Performance Indicators (KPIs) serve as an essential tool in this endeavour, offering a structured approach to assess and track environmental performance over time [18, 19]. These metrics provide quantifiable measures of various operational and sustainability aspects, ranging from energy consumption and waste generation to emissions levels and resource utilisation [20–22]. By establishing benchmarks and targets, KPIs enable companies to gauge their progress towards sustainability goals and identify areas for improvement [23]. Integrating KPIs into sustainability management systems is essential across industries worldwide, facilitating informed decision-making and enhancing accountability [24, 25]. In the context of the chemical sector in Saudi Arabia, the utilisation of KPIs offers a means to systematically monitor environmental performance and drive continuous improvement efforts. However, while the adoption of KPIs presents promising opportunities, challenges persist in their implementation and interpretation within the Saudi industrial landscape [26–28] and the chemical sector remains an ill-explored domain.

Through an in-depth examination of KPI usage and its impact on environmental sustainability practices within Saudi chemical companies, this paper aims to contribute to the existing literature by providing empirical evidence on the effectiveness of KPIs in enhancing environmental performance in this specific industrial context. The research questions (RQs) guiding this study are: (1) what is the current state of KPI implementation in the Saudi chemical industry? (2) How do KPIs impact environmental performance in the sector? (3) What are the challenges and opportunities associated with KPI utilisation in the Saudi context? The research objectives (ROs) are to (1) evaluate the extent of KPI adoption in the Saudi chemical industry, (2) assess the effectiveness of KPIs in improving environmental performance, and (3) identify the barriers and facilitators for effective KPI use in the sector.

Employing both qualitative and quantitative methods to critically evaluate current practices and identify areas for enhancement, the research seeks to contribute to the ongoing dialogue on sustainable development in the region. This comprehensive analysis aims to assess the effectiveness of existing environmental sustainability initiatives in Saudi chemical companies while also identifying challenges and proposing actionable recommendations for improvement.

The originality of this research lies in its specific focus on the implementation and interpretation of KPIs within the Saudi chemical industry, a sector that has been relatively underexplored in the existing literature. While numerous studies have examined the use of KPIs in various industries, there is a significant gap in the context of Saudi Arabia's chemical sector. This study addresses this gap by providing empirical evidence on the unique challenges and opportunities associated with KPI adoption in this industry, thus contributing to the broader understanding of sustainability management in the region.

This endeavour is rooted in the commitment to advancing national and global environmental sustainability aligned with the Pillars of the Saudi Vision 2030 [9] and aligns with several Sustainable Development Goals (SDGs), specifically SDG 9 (Industry, Innovation, and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). The research contributes to SDG 9 by promoting sustainable industrialisation and innovation through the implementation of KPIs within the Saudi chemical industry. By focusing on sustainable practices and efficient resource use, the study supports SDG 12's aim of ensuring responsible consumption and production patterns. Additionally, the emphasis on reducing emissions and assessing environmental impact aligns with SDG 13, which calls for urgent action to combat climate change and its impacts. Through these contributions, the study provides valuable insights and strategies for advancing sustainability in the chemical sector [29].

The next section presents the literature review conducted as part of the research. Section 3 presents the hypotheses developed, with Sect. 4 detailing the methodology employed to test them. The results and their practical implications are discussed in Sect. 5. Lastly, Sect. 6 serves as the conclusion, identifying limitations and providing recommendations for future research.

2 Literature review

The literature review aimed to provide insights into environmental sustainability efforts, sustainable manufacturing practices and the utilisation of KPIs for the purpose of identifying global best practices and emerging trends as well as strategies for minimising environmental impact. Furthermore, it examined the utilisation of KPIs as a vital tool for quantifying and managing environmental performance, highlighting their role in the decision-making process. Additionally, the analysis of literature specific to the Saudi chemical sector sheds light on regional challenges, regulatory frameworks, and industry-specific initiatives. This localised perspective enables the identification of unique challenges and opportunities for enhancing environmental actions within the Saudi chemical industry. Such outlooks are crucial for contextualising the research within the sector.

2.1 Environmental sustainability and KPIs

Environmental sustainability has been a longstanding concern throughout human history, reflecting the recognition of the intrinsic connection between human activities and the health of the planet. From ancient soil conservation efforts to modern-day environmental movements, societies have grappled with the consequences of environmental degradation and sought ways to mitigate them [30, 31]. In the current context, the concept of environmental sustainability has gained renewed significance amidst growing awareness of the profound impact of human activities on the natural world. Industrialisation, while fuelling economic growth and technological advancement, has also contributed to widespread environmental degradation. From pollution of air and water to habitat destruction and biodiversity loss, the consequences of industrial actions on the environment are increasingly apparent [32].

In response to these challenges, researchers and policymakers have turned their attention to mitigating the environmental impact of industrial activities. Studies have explored various strategies and initiatives aimed at promoting sustainability within a wide range of industrial sectors [33]. For instance, efforts have been made to develop and implement cleaner production practices to reduce emissions and minimise waste generation in various industries. In the aluminium industry, adopting cleaner production practices is essential for environmental sustainability. These practices include implementing electrolytic processes to reduce energy consumption, utilising recycled aluminium as a raw material to minimise waste generation, and deploying advanced filtration systems to capture and recycle emissions [34]. Furthermore, within the energy sector, there is a growing recognition of the importance of adopting environmentally friendly production methods to achieve sustainable development objectives. This includes cleaner treatment of fossil energy and renewable sources, Gas reservoir well development, and Carbon Capture and Storage (CCS). These efforts aim to diminish environmental harm while maximising social and economic benefits [35]. Additionally, research has demonstrated a growing emphasis on the adoption of sustainable resource management procedures across various industries [36]. For instance, in the manufacturing sector, companies have increasingly implemented strategies such as waste reduction, recycling initiatives, and the use of renewable energy sources to conserve natural resources and promote efficient material utilisation [37].

Companies often utilise KPIs as essential tools for monitoring and evaluating their environmental performance [18, 38]. These KPIs provide quantifiable measures of various operational and sustainability aspects, including energy consumption, waste generation, emissions levels, and resource utilisation [25]. Within the chemical sector, KPIs play a crucial role in assessing and managing environmental impacts associated with manufacturing processes, material usage, and waste disposal practices [39, 40]. Various KPIs have been identified and categorised based on the type of industry as well as the associated pollution, including air, water, land, and other pollution [41, 42]. By establishing systematic approaches to identify, assess, and mitigate environmental impacts, the use of KPIs enable companies to achieve operational efficiencies and reduce environmental risks, through enhanced environmental stewardship [25].

Overall, the discourse on environmental sustainability within industrial contexts continues to evolve, with ongoing research efforts aimed at identifying effective strategies for mitigating environmental impacts and promoting sustainable development. By highlighting the significance of KPIs as integral components in driving improvement in environmental performance, the findings align with the aim of this research to assess the effectiveness of these metrics in promoting environmental sustainability within the Saudi chemical industry.

2.2 Sustainability efforts and initiatives in Saudi Arabia

Saudi Arabia has embarked on a comprehensive journey towards sustainability, characterised by its embrace of the 17 SDGs [43]. Central to this endeavour is Saudi Vision 2030, built upon three pillars: a vibrant society, a thriving economy, and an ambitious nation [9]. This ambitious vision has encouraged the Saudi government to incentivise sustainability across industries, offering rewards for land use, discounts, and contract awards to organisations prioritising sustainability. Moreover, the introduction of green bonds has provided another avenue for organisations to bolster their sustainability initiatives, aligning with both environmental and economic goals [44].

Aligned with Vision 2030, Saudi Arabia has instituted various programs to promote sustainability awareness and action within manufacturing and service organisations, both locally and internationally [45]. For instance, key players like the Saudi Electricity Company (SEC) and Saudi Telecom Company (STC) have developed a sustainability framework and issued sustainability reports [46, 47]. SEC focuses on reducing carbon emissions and promoting circular economy initiatives utilising a framework which includes multiple performance criteria and indicators, while STC prioritised 10 of the 17 SDGs within its strategy, developing a framework spanning 17 indicators. However, it's noteworthy that the indicators chosen in both frameworks, such as infrastructure resilience and digital inclusion, are often high-level and lack specific measurability [48]. This can potentially pose challenges in accurately assessing and monitoring progress towards sustainability goals.

2.2.1 Environmental impact of Saudi chemical companies

The chemical companies in Saudi Arabia are engaged in the production of a wide range of products which include petrochemicals, methanol, ammonia, urea, sulphur, chemical fertilisers, as well as polymers and plastic. They also manufacture industrial gases like hydrogen, oxygen, and nitrogen, basic chemicals like polyvinyl chloride and ethylene glycol, greases and lubricants, and speciality chemicals. The scale of production and distribution activities often correlates directly with the level of emissions attributed to each company. Notably, the top ten Saudi chemical companies collectively emit more harmful substances than all other companies combined. This observation holds significant implications, suggesting that a substantial portion of the environmental impact could be mitigated if these leading players were to enact stringent policies aimed at environmental protection [49, 50].

Saudi Arabia Basic Industries Corporation (SABIC), renowned globally for its chemical production, stands out for its commitment to sustainability. They continually evaluate fuel efficiency and environmental impact, aiming to reduce greenhouse gas emissions, energy consumption, and material and water utilisation [51]. However, this dedication to sustainability is not universal across all chemical producers in the kingdom. Despite strides in sustainability initiatives [52], Saudi chemical companies grapple with persistent environmental challenges, notably greenhouse gas emissions, hazardous waste disposal, and water pollution [53]. Moreover, while Saudi Arabia is a major petrochemical and plastics producer, many enterprises still operate under Industry 3.0 practices, with limited adoption of Industry 4.0 technologies and circular economy principles. Additionally, research on these fronts within Saudi Arabian organisations remains scarce [54].

The reliance on fossil fuels within the chemical industry significantly contributes to carbon emissions, exacerbating climate change and air pollution. By 2017, Saudi Aramco alone had released over forty billion tons of greenhouse gases, significantly contributing to rising temperatures in Saudi Arabia [55]. Evidence suggests that certain regions in Saudi Arabia experience alarming temperature increases due to greenhouse gas emissions from chemical companies. Moreover, proximity to chemical companies correlates with higher mortality rates, particularly among children. Alshahrani et al. [56] found that child mortality rates near Saudi Arabian chemical companies were thirty per cent, significantly higher than in areas located farther away. Oil spills present another significant environmental challenge in the oil production process, often difficult to control, particularly in offshore environments with unpredictable tides. Nahed and Bander [57] highlight the detrimental impact of oil spills on marine life, posing risks to food safety for communities dependent on marine habitats. These findings underscore the urgent need for enhanced environmental stewardship and sustainability measures within the Saudi chemical industry to mitigate its adverse impacts on public health and environmental well-being.

2.3 Challenges and opportunities in Saudi Arabia's sustainable development

Saudi Arabia has set ambitious targets, including a reduction goal of 130 MTon CO_2 as part of the Paris Agreement [58] and a commitment to achieving 9.5 GW of renewable energy capacity by 2030 [52]. However, significant challenges persist, such as heavy energy subsidies leading to overuse and inappropriate resource allocation, and the economy's heavy reliance on energy exports [59]. While many organisations in Saudi Arabia are gradually adopting sustainability practices, notable obstacles remain, with sustainability assessments lagging behind market sustainability efforts [60]. Some public sector agencies in the kingdom have not fully embraced new initiatives, possibly due to a lack of top management support, internal resistance to change, or limited awareness and engagement among individuals [61].

Addressing these challenges requires a better understanding of the effectiveness of KPIs in enhancing environmental sustainability practices, particularly within chemical companies in the kingdom. By assessing whether companies with well-defined KPIs report significant reductions in energy consumption and pollution generation, we can justify the adoption of KPIs and encourage broader engagement in tracking and reducing emissions. Studies such as those by Al-Alqam et al. [62], Singh et al. [63], and Trianni et al. [64] underscore the importance of integrating sustainability into organisational practices and utilising KPIs for environmental monitoring to achieve long-term environmental goals and reduce emissions effectively.

3 Hypothesis development

Based on the discussions presented in Sects. 1 and 2, this study moves forward to hypothesis development regarding the role of KPIs in driving environmental sustainability practices within the Saudi chemical industry. Drawing from insights on sustainability efforts in Saudi Arabia and the challenges faced by the chemical sector, three hypotheses are proposed:

1. Greater awareness of pollution sources leads to better environmental performance.
2. The use of KPIs is positively correlated with reduced emissions in chemical manufacturing companies.
3. The alignment of KPIs with a company's strategic goals positively influences the implementation success of environmental practices.

These hypotheses aim to contribute to the understanding of how KPIs influence sustainability practices in the industry, aligning with broader sustainability goals outlined in the Saudi Vision 2030 and global initiatives. The following sections will detail the methodology used to explore and test these hypotheses.

4 Methodology

This section outlines the methodology employed to comprehensively understand KPI usage, environmental performance, governance regulations, and potential areas for improving sustainability practices within Saudi Arabian chemical companies. A structured survey methodology was utilised to test hypotheses regarding the association between KPI usage and environmental impact. This approach involves sample identification, survey development, and data analysis to yield valuable insights into KPI utilisation and efforts toward enhancing sustainable performance across the Saudi chemical industry. The chosen methodology enables the systematic gathering of quantitative data from a representative sample, allowing for comprehensive analysis and assessment of research hypotheses. By embracing both quantitative and qualitative approaches, the research facilitates empirical assessment and statistical rigour, providing valuable insights into the effectiveness of KPIs in promoting sustainable practices within the Saudi chemical industry.

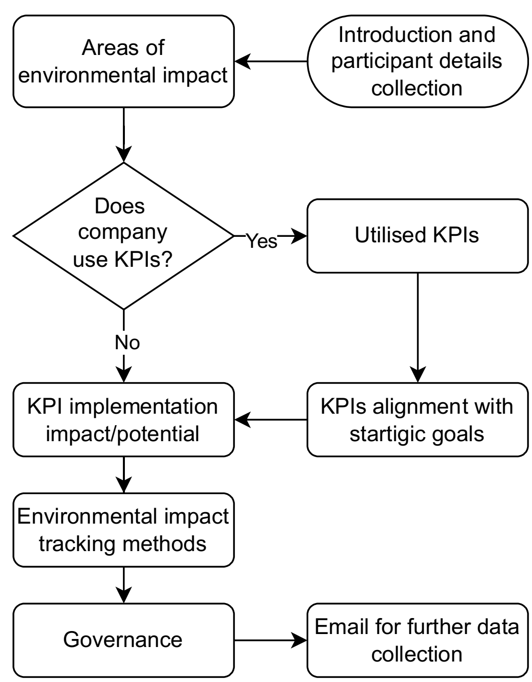
4.1 Data collection

Data were collected through a meticulously designed structured survey which was administered to a sample of Saudi chemical companies. The survey instrument aimed to extract comprehensive information on KPI implementation and usage, fostering an understanding of environmental impacts in the chemical sector.

4.1.1 Survey design

The survey design was tailored to address specific inquiries regarding stakeholders' actions to mitigate the environmental impact of chemical companies. It aimed to collect data on KPI usage, pollution assessment methods and overall environmental performance awareness, aligning with the research hypotheses for targeted analysis. An overview of the survey flow is presented in Fig. 1 while the survey questions are provided in Table 8 in Appendix. The questions encompassed various themes, including KPI Utilisation, Specific KPIs Tracked (KPIs included in the survey were identified through an extensive literature review conducted in the author's previous research [41]), Critical Factors for KPIs, Benefits and Challenges of KPIs, Methods for KPI Implementation, Alignment with Strategic Goals, Environmental Performance Improvement, Pollution Detection and Management, and Government Regulations. Some questions consisted of multiple choices while others were open-ended to allow for deeper insights. Clear instructions were provided to participants to ensure consistency and accuracy in their responses. Moreover, affirmation of anonymity was provided at the start to ensure truthful and unbiased responses. Skip logic was employed to ascertain the extent of KPI usage in the companies and other methods utilised in the industry. The survey was distributed to various companies in the Saudi chemical industry. To further minimise bias, we ensured a diverse sample by including companies of different sizes and operational scales. Once survey response collection had commenced, further communication was conducted with participants who left their email addresses for collecting actual data for certain KPIs.

Fig. 1 Survey flow



4.1.2 Survey administration and sample size

The survey was conducted between August and December 2023, utilising online survey platforms for efficient data collection. Approval was obtained from Al Madinah Al Munawaroh Chambers to conduct field research, ensuring the data collection was performed in accordance with the relevant guidelines and supervised distribution to chemical companies in the Kingdom. Due to time constraints, it was exclusively distributed to basic chemical manufacturers in Saudi Arabia with a total of 320 companies (NAICS: 3251) [65]. This entails focusing on establishments directly involved in producing basic chemicals, excluding those processing intermediate or end products [66]. The required sample size was calculated using Slovin's formula [67]:

$$n = \frac{N}{(1 + Ne^2)}$$

where n represents the desired sample size, N stands for the total population, and e denotes the standard error, which is set at 0.1 for a 90% confidence interval [68]. When this formula was applied to a population size of 320, it resulted in a recommended sample size of 77. This calculation ensures that the obtained sample adequately represents the larger population, allowing for statistically reliable conclusions to be drawn from the survey data.

4.2 Data analysis

After completing the data collection phase, a manual review was conducted to identify and remove any irrelevant responses, involving a thorough examination for inconsistency or illogical answers. A total of 101 responses were received, of which 23 were deemed invalid or nonsensical and thus excluded from the analysis. Therefore, the analysis focused on the remaining 78 valid responses, surpassing the required sample size of 77 for robust statistical analysis. Following this, the collected data underwent rigorous analysis. First, findings were appraised using qualitative methods including descriptive analysis and data visualisation, to explore the relationship between KPI usage and environmental impact reduction within chemical manufacturing companies. Subsequently, the reliability of the collected results was evaluated using Cronbach's alpha coefficient [69].

For hypothesis testing and evaluating the statistical significance of variations in KPIs across different chemical companies, Analysis of Variance (ANOVA) and *t*-tests were employed using SPSS 15.0 statistical software [70] using SPSS 15.0 statistical software. ANOVA was utilised to test for statistical differences among three or more groups, as summarised in Table 1 which lists the variables assessed during hypothesis testing and the corresponding questions from which measurements were extracted. Meanwhile, *t*-tests were used for pairwise comparisons between specific question pairs, detailed in Table 2. These statistical methods were chosen for their ability to compare means across multiple groups and to determine if there are statistically significant differences in environmental performance among these groups. The choice of ANOVA and t-tests was driven by the research objective to understand group differences and identify key areas for improvement in environmental performance within the chemical industry.

These methods are straightforward and appropriate given the study's scope and data characteristics. While more complex methods like SEM or PLS-SEM could explore deeper relationships, the focus was on mean comparison, making ANOVA and t-tests more suitable.

Table 1 Hypotheses variables and associated questions

Hypothesis	Independent variable	Question	Dependent variable	Question
1	Awareness of pollution sources	2	Environmental performance	5
2	Use of KPIs	3	Reduced Emissions	5
3	Alignment of KPIs with Strategic Goals	7	Implementation Success of Environmental Practices	8

Table 2 Question pairs for t-test

Pair	Questions
1	(Q2) What is the main source of pollution in your company?—(Q3) Does your company use KPIs to monitor environmental impact?
2	(Q2) What is the main source of pollution in your company?—(Q4) Overall air emissions output KPI
3	(Q2) What is the main source of pollution in your company?—(Q7) Do the KPIs always align with your company's overall strategic goals?
4	(Q2) What is the main source of pollution in your company?—(Q8) What were the challenges associated with KPIs implementation?

5 Results and discussion

This section presents the findings of the comprehensive survey conducted to explore the relationship between KPIs and environmental performance improvement within chemical manufacturing companies in Saudi Arabia. The respondents represented a diverse array of chemical-producing industries, spanning from petrochemicals, closely tied to oil and gas, to basic chemicals, plastics, and rubber, among others, showcasing a broad spectrum of products within the sector. The roles of the respondents are equally varied, ranging from owners and directors to managers, engineers, and technicians, reflecting a comprehensive cross-section of personnel involved in chemical manufacturing. This diversity in industry sectors and roles enriches the dataset, providing multifaceted insights into the utilisation of KPIs and sustainability practices across different segments of the chemical industry. This section presents the descriptive analysis of the survey data, followed by the application of various statistical tests to investigate the hypothesised relationships between KPI usage and environmental impact reduction.

5.1 Descriptive result

5.1.1 Participants demographics

The survey respondents represented a diverse array of roles and sectors within the industry, offering a comprehensive perspective on KPI implementation and sustainability practices. Participants came from various sectors, including chemical, petrochemical, oil and gas, polymers, plastics, food, water, agriculture, and energy. In terms of roles, the respondents included engineers, operations personnel, managers, production staff, chemical specialists, directors, maintenance staff, technicians, and owners. This diversity underscores the relevance and applicability of the study across different segments of the industry, reflecting the perspectives of individuals at various levels of organisational hierarchy, from technical experts to management and operational staff. The detailed distribution of respondents by sector and position is presented in Fig. 2a and b, highlighting the study's inclusive approach.

5.1.2 Pollution areas of impact

The survey queried respondents regarding the primary areas affected by their pollution activities, offering options of air, water, and land [71], with respondents able to select multiple choices. The resultant data has been visually represented in two distinct figures for enhanced comprehension. Figure 3a illustrates the selection groupings, showcasing the

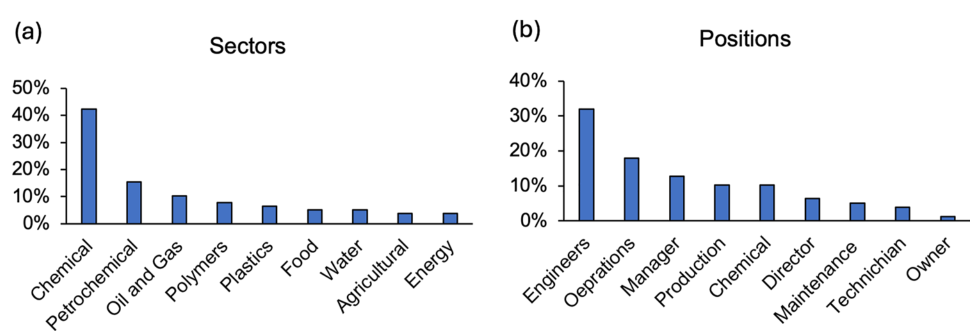


Fig. 2 Participants **a** sectors and **b** positions within companies

distribution of responses across various combinations of air, water, and land pollution. For instance, 49% of respondents identified air pollution exclusively, while 18% indicated pollution affecting both air and land, and 10% noted pollution impacting both air and water. This presentation method offers insights into the intersectionality of pollution across different environmental domains, providing a nuanced understanding of the multifaceted nature of pollution sources. Conversely, Fig. 3b presents a breakdown of the overall impact of pollution on air, water, and land individually. This approach offers a more straightforward visualisation of the prevalence of pollution in each environmental domain. For instance, it reveals that 60% of respondents reported air pollution, 35% indicated water pollution, and 25% noted land pollution. This segmentation allows for a clearer comparison of the relative magnitude of pollution across different environmental facets.

The results suggest that air quality management is a critical priority for chemical manufacturing companies. However, the acknowledgement of water and land pollution underscores the need for these companies to address a spectrum of environmental challenges to ensure sustainability and regulatory compliance. This complexity highlights the necessity for tailored solutions, recognising that a one-size-fits-all approach is inadequate in addressing the diverse range of pollution sources and environmental concerns within the industry [72, 73].

5.1.3 KPI utilisation

A set of KPIs related to air, water, land, energy, and resource use were evaluated by respondents regarding their frequency of usage. The respondents ranked the frequency using defined categories: 'Never" for not currently used, 'Eventually" for planned future use, "Sometimes" for tracking 1 to 50 days a year, "Often" for 50 to 200 days a year, and "Always" for 200 to 365 days a year.

In Fig. 4a, air emission KPIs were predominantly utilised, contrasting with lower usage rates for water and land KPIs (Fig. 4b and c). Most air KPIs were consistently tracked, while some were tracked less frequently. Notably, several air KPIs were never tracked, suggesting potential irrelevance to company operations. Water KPIs were primarily categorised as "Never," reflecting minimal attention to water pollution, aligning with global research highlighting insufficient water accountability. Similarly, land KPIs were mostly tracked "Always" or "Never," with indications of eventual tracking by some respondents, indicating increasing awareness of land pollution issues. Energy usage and raw material consumption emerged as the most tracked general KPIs (Fig. 4d), likely due to their recognised importance not only for the environmental context but also the operational.

5.1.4 Methods for assessing pollution levels

The inquired Chemical companies employ a variety of methods to assess pollution levels in their processes or factories, as revealed in the survey responses. These methods include contracting specialised firms for assessments and conducting field visits and inspections by safety inspectors. Additionally, some companies implement in-house environmental programs utilising modern technology like Volatile Organic Compound (VOC) cameras for leak detection and air quality monitors and examining process parameters regularly by spot sampling. However, it is notable that some participants indicated a lack of specific awareness regarding the methods employed by their companies, suggesting a potential gap in communication and awareness across the workforce.

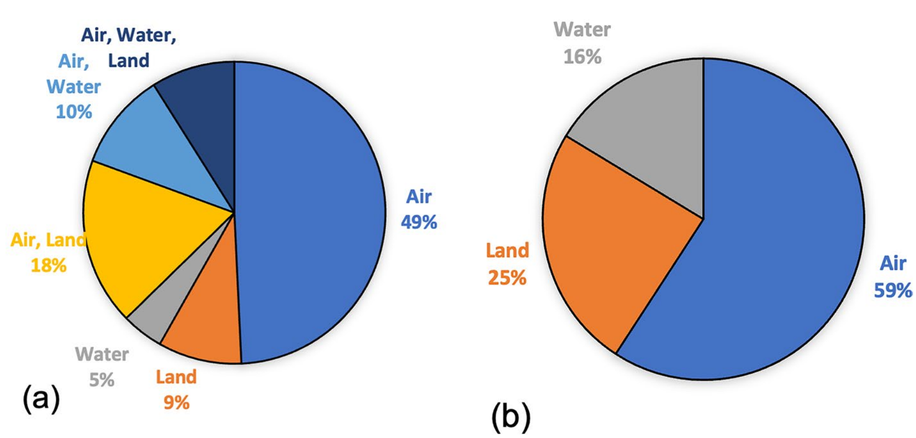


Fig. 3 Areas affected by pollution activities **a** per area groupings and **b** overall impact

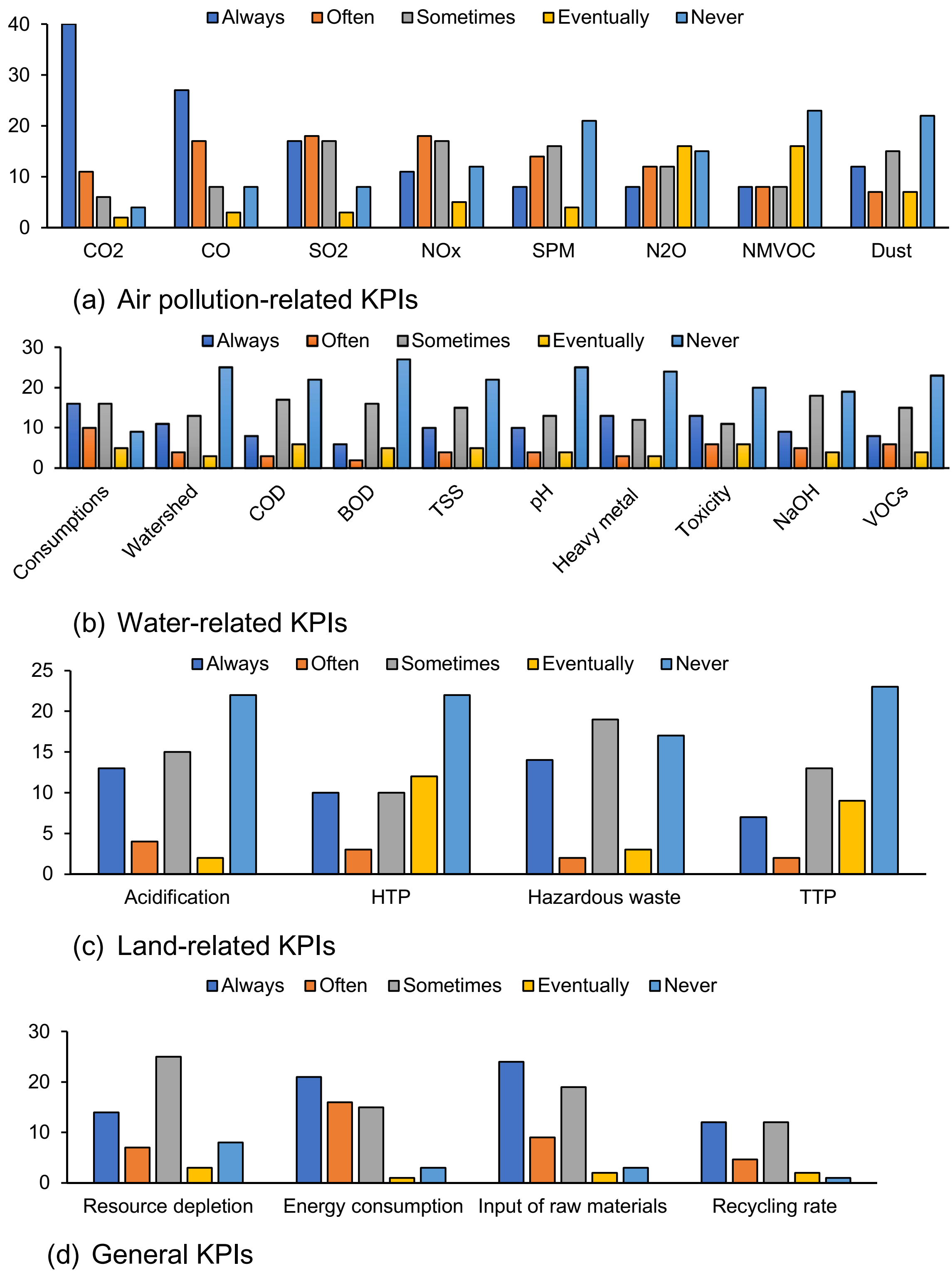


Fig. 4 The frequency at which the KPIs are being monitored by theme **a** Air, **b** Water, **c** Land and **d** General. Where *CO_2* Carbon Dioxide, *CO* Carbon Monoxide, *SO_2* Sulphur Dioxide, *NO_x* Nitrogen Oxides, *SPM* Suspended Particulate Matter, *N_2O* Nitrous Oxide, *NMVOC* Non-Methane Volatile, Organic Compounds, *COD* Chemical Oxygen Demand, *BOD* Biochemical Oxygen Demand, *TSS* Total suspended Solid, *NaOH* Sodium Hydroxide concentration, *VOCs* Volatile Organic Compounds, *HTTP* Human Toxic Potential, *TTP* Terrestrial Toxicity Potential

5.1.5 KPIs alignment with strategic goals

Based on the responses provided, the majority (94%) indicated that KPIs align with their company's overall strategic goals. However, a small percentage (6%) expressed alignment concerns, citing issues related to operational challenges impacting quality standards and raw material consumption. The high percentage of respondents indicating alignment suggests a strong integration between KPIs and strategic objectives, which is essential for driving performance improvement and achieving organisational targets [74, 75]. However, the concerns raised by the minority highlight potential discrepancies between KPIs and operational realities, emphasising the importance of regular review and adjustment to ensure alignment with strategic goals.

5.1.6 Effective implementation and impact of KPIs

Participants in the survey emphasised several essential methods for successfully implementing KPIs in chemical companies. Clear indicators were highlighted as crucial, emphasising the importance of establishing specific indicators to track performance and progress towards goals. Additionally, respondents stressed the need for strategy development and update, stressing the importance of modern, workable strategies that align with changing business environments and sustainability objectives. It was also identified that effective training programs, along with clear instructions and guidelines, were deemed crucial. Continuous education and awareness initiatives can ensure that employees at all levels of the organisation understand the significance of KPIs in driving sustainability. Furthermore, automation of monitoring processes for streamlining data collection and analysis, along with providing incentives to encourage adherence to sustainability initiatives, were suggested as essentials for effective KPI implementation.

Moving on to the impact of KPI implementation, respondents perceived KPIs as leading to improvements in environmental performance within chemical companies through various mechanisms. Goal achievement was acknowledged, highlighting how KPIs facilitate the achievement of pre-set environmental goals and desired outcomes, aligning with strategic objectives and sustainability vision. Moreover, KPIs were seen as enabling continuous monitoring and supervision of environmental performance, by permitting the tracking of pollution levels, identifying sources of pollution, and implementing corrective actions. Additionally, respondents noted the importance of KPIs in resource optimisation, enabling organisations to identify materials or processes contributing to pollution and prioritise improvements and investments in cleaner technologies.

These findings underscore the multifaceted impact of KPIs in enhancing both environmental performance and operational efficiency within chemical manufacturing companies. By tracking relevant indicators and processes, KPIs empower companies to pinpoint and address sources of pollution, a notion corroborated by prior research [25, 76, 77]. Moreover, the adoption of KPIs cultivates a corporate attitude of environmental awareness and responsibility, fuelling ongoing improvement initiatives and the adoption of sustainable practices across the organisation. This resonates with existing literature, which highlights the pivotal role of well-defined, measurable KPIs in driving effective performance improvement [78]. The clarity provided by well-defined guidelines and specific metrics further enhances alignment with organisational objectives and supports decision-making processes [79], thereby promoting robust sustainability initiatives within chemical manufacturing firms.

5.1.7 Governance

In the governance section of the survey, respondents provided insights into the regulatory landscape governing waste management, pollution limits, and associated penalties in chemical companies. Regarding waste management, respondents highlighted the presence of various guidelines, rules, and laws established by government monitoring bodies. These regulations encompassed a regulatory framework accessible through government websites, specific agreements, and waste disposal procedures. This aligns with previous research highlighting the significance of implementing proper waste management practices in the manufacturing industry to mitigate environmental impacts [80]. However, some respondents noted a lack of familiarity with these regulations, suggesting a potential gap in company-wide training on waste management practices.

Similarly, concerning pollution limits, respondents acknowledged the existence of government-imposed limits on company operations. These limits ranged from regulations regarding the presence of oil on the ground to emission limits for gases like oxides of nitrogen and sulphur. Regulatory bodies, such as safety and environmental authorities, enforce compliance with these limits, highlighting their importance in safeguarding the environment and public health. Respondents also stated that annual audits are conducted to ensure compliance.

Regarding penalties for exceeding pollution limits, respondents outlined various repercussions imposed by government authorities. These penalties included financial fines, suspension of operations, and even the withdrawal of operating licenses for repeated non-compliance. Such stringent measures underscore the government's commitment to enforcing pollution control and ensuring adherence to environmental standards within the chemical industry. Overall, as mentioned in previous research [81, 82], these responses underscore the critical role of regulatory compliance in promoting sustainable industrial practices and environmental safekeeping.

5.1.8 KPI actual data

Out of the 78 companies surveyed, 10 expressed interests in further engagement to share actual KPI data, denoted as letters A to J for anonymity. Figure 5 illustrates scaled values for energy, emissions, waste, water, and recycling rate KPIs for these 10 companies, with data normalised to a range of 0 to 1. This was performed to enable a comparative analysis and pattern recognition across companies by bringing all data points to a common scale. Their activities spanned from petrochemicals to basic chemicals, organic and synthetic chemicals, polymers, and agrochemicals.

The variability in KPI values among the 10 companies is evident, reflecting diverse operational contexts. For example, Company B's energy consumption is four times higher than Company A, likely attributed to differences in scale or operational intensity. Similarly, while Company B consumes three times more energy than Company C, their water consumption remains comparable, suggesting potential efficiencies in water management practices on Company C's part. Additionally, Company C generates twice as much waste as Company D, at the same time Company D exhibits a recycling rate 2.5 times higher than Company C, highlighting the interrelation of KPIs and the potential for recycling efforts to positively impact waste reduction strategies.

These findings underscore the complex relationships between different KPIs within chemical manufacturing operations. Variations in energy, emissions, waste, water, and recycling metrics among companies suggest the need for tailored sustainability strategies that consider unique operational factors. Furthermore, the willingness of a subset of companies to share operational data signifies a potential for collaborative learning and benchmarking, enabling sector-wide improvements in environmental performance and resource efficiency.

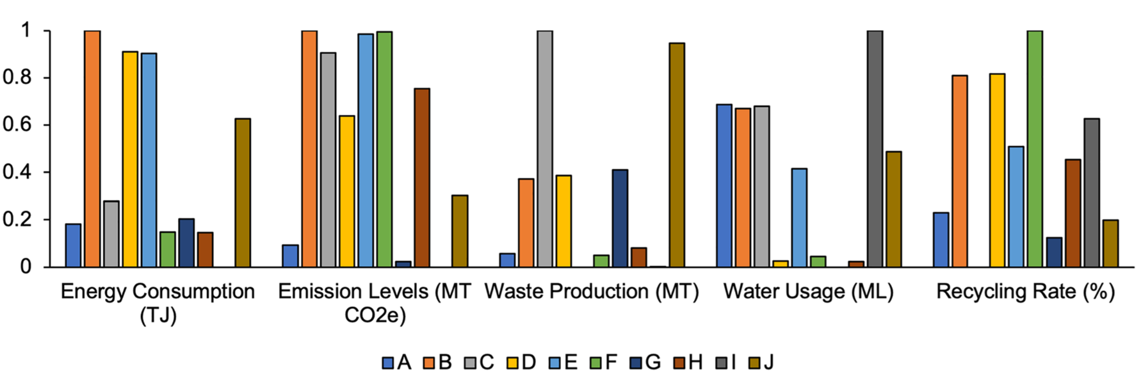


Fig. 5 Normalised KPI data from further engagement with industries following the survey

5.2 Quantitative analysis

5.2.1 Reliability analysis

Reliability analysis assesses the consistency of questionnaire items concerning their relevance to the dependent variable. The Cronbach's Alpha coefficient, a measure of internal consistency, should ideally fall between 0 and 1. In this study, the calculated Cronbach's Alpha value of 0.966 indicates a high level of internal consistency among the items, suggesting that 96% of the questionnaire items are reliable.

5.2.2 ANOVA

To test the hypothetical statements of this study, SPSS has been used to analyse the relationship of all variables through ANOVA analysis. ANOVA is an important statistical technique used in explaining the impact of independent variables on the dependent variable, thus allowing researchers to draw informed conclusions grounded in statistical evidence. This research study has more than two groups of data, ANOVA will identify the difference of their means.

Decisions regarding hypothesis acceptance were based on the p-value (typically 0.05) and F-statistics. A p-value below 0.05 indicates a statistically significant difference between group means, leading to the acceptance of hypotheses. Conversely, hypotheses were not accepted when the p-value exceeded 0.05. An elevated F-value signifies that the variance between groups is significantly greater than within groups, suggesting a substantial impact on the independent variables and implying that observed mean differences are unlikely due to random chance. Conversely, a low F-value indicates that the variance between groups is similar to within groups, suggesting a lack of significant influence by the independent variable, where observed mean differences could be attributed to chance.

- Hypothesis 1: Greater awareness of pollution sources leads to better environmental performance.

The assumption statement of this hypothesis is that identifying and understanding a company's primary source of pollution is crucial for implementing effective environmental management strategies in the chemical industries of Saudi Arabia. The pollution awareness was assessed based on the assumption that selecting less than two sources of pollution was hence marked as low awareness while selecting 2 indicated medium awareness and selecting 3 was considered as high awareness. Table 3 shows the value of the sum of squares 12.020 between groups and 226.090 within groups for the source of pollution in chemical companies. F-Statistics value 5.210 examines the relationship of variables while the significance value 0.025 is less than the cutoff value ($p > 0.05$) showing that the hypothetical statement is accepted.

- Hypothesis 2: the use of KPIs is positively correlated with reduced emissions in chemical manufacturing companies.

The analysis aimed to investigate the relationship between the use of KPIs to monitor environmental impact and the levels of emissions in chemical manufacturing companies. Hypothesis 2 stated that there is a positive correlation between the use of KPIs and reduced emissions. The analysis was performed on the respondents who reported reduced emissions and either reported always using air emissions KPIs, often using them or only sometimes tracking them.

Table 3 The main source of pollution

	Sum of squares	Df	Mean square	F	Sig
Between Groups	12.020	1	12.020	5.210	0.025
Within Groups	226.090	98	2.307		
Total	238.110	99			

Table 4 Environmental impact with air emission

	Sum of Squares	Df	Mean Square	F	Sig
Between Groups	29.859	4	7.465	3.405	.012
Within Groups	208.251	95	2.192		
Total	238.110	99			

As presented in Table 4, the relationship between the utilisation of air emission KPIs and the perceived effect has been analysed. The results of ANOVA show the significance value of 0.12 with F-Statistics 3.405 which suggests that tracking air emissions consistently has a positive relation with the reduction of emissions in chemical companies. This could be due to the greater understanding of the companies' operations and the root causes of the pollution resulting from a more continuous review of their emissions.

- Hypothesis 3: The alignment of KPIs with a company's strategic goals positively influences the implementation success of environmental practices.

The objective was to investigate whether the alignment of KPIs with a company's strategic goals has a positive influence on the successful implementation of environmental practices. The KPIs' strategic alignment to company goals was analysed with comparison to respondents who identified 1 challenge, 2 challenges and 3 or more challenges. As shown in Table 5 of ANOVA, F-Statistics 2.586 with a significant value of 0.018 signifies that if a company's overall strategic goals are aligned with KPIs then the implementation of environmental practices is more straightforward. This could be due to the clear alignment of KPIs with strategic goals, facilitating focused efforts and streamlined decision-making in environmental practices. When KPIs are directly tied to strategic objectives, they serve as effective metrics for monitoring progress and ensuring accountability across the organisation. This alignment helps prioritise sustainability initiatives, allocate resources efficiently, and enhance overall environmental performance within chemical manufacturing companies.

Table 6 summarises the hypotheses results.

5.2.3 T-test

The *t*-test was employed to determine whether there exists a significant difference between the means of two distinct groups. Specifically, it compares the means of two independent groups to ascertain whether a statistically significant difference exists between them.

In this study, the t-test was used to examine the relationship between responses to different pairs of survey questions related to KPI usage and environmental impact within Saudi Arabian chemical companies. Each pair of

Table 5 Strategic alignment of KPIs with their implementation

	Sum of Squares	Df	Mean Square	F	Sig
Between Groups	39.143	7	5.592	2.586	.018
Within Groups	198.967	92	2.163		
Total	238.110	99			

Table 6 Hypotheses results

No	Hypothesis	Significance ($p > 0.05$)	Remarks
1	H1: Greater awareness of pollution sources leads to better environmental performance	0.025	Accepted
2	H2: the use of KPIs is positively correlated with reduced emissions in chemical manufacturing companies	0.012	Accepted
3	H3: the alignment of KPIs with a company's strategic goals positively influences the implementation success of environmental practices	0.018	Accepted

Table 7 T-test results

		Paired differences					T	dF	Sig (2-tailed)
		Mean	Std. deviation	Std. error mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	What is the main source of pollution in your company?—Does your company use KPIs to monitor environmental impact?	1.100	1.696	0.169	0.763	1.436	6.483	99	0.000
Pair 2	What is the main source of pollution in your company?—Overall air emissions output KPI	−0.930	2.175	0.217	−1.361	−0.498	−4.275	99	0.000
Pair 3	What is the main source of pollution in your company?—Do the KPIs always align with your company's overall strategic goals?	1.330	1.550	0.155	1.022	1.637	8.576	99	0.000
Pair 4	What is the main source of pollution in your company?—What were the observed challenges associated with KPIs implementation?	−1.280	2.296	0.229	−1.735	−0.824	−5.573	99	0.000

questions represents a comparison between distinct aspects of environmental management or KPI implementation within the surveyed companies.

The t-test calculates the t-value, which is a ratio derived from the disparity between the means of the two groups and the variability within each group. This t-value is then compared to a critical value obtained from the t-distribution, based on the degrees of freedom and the predetermined level of significance (typically 0.05). If the calculated t-value exceeds the critical value, it indicates a statistically significant difference between the means of the two groups. Hypotheses are accepted or rejected based on these significance values: hypotheses with p-values less than 0.05 are accepted, indicating a significant difference, while those with p-values greater than 0.05 are not accepted. Table 7 presents the results.

- Pair 1: Main source of pollution vs. use of KPIs to monitor environmental impact

The statistically significant p-value ($p < 0.05$) indicates a substantial difference between responses regarding the main sources of pollution and the use of KPIs to monitor environmental impact. Therefore, the hypothesis that there is no difference between these aspects is rejected. This suggests that companies identifying specific pollution sources are more likely to employ KPIs for monitoring environmental impact. There may be a strong link between recognising pollution sources and implementing KPIs as a proactive measure.

- Pair 2: Main source of pollution vs. overall air emissions output KPI

Similarly, the significant p-value indicates a notable difference in responses between the main sources of pollution and the tracking of air emissions through KPIs. The null hypothesis is rejected in favour of the alternative hypothesis that there is a significant difference. This indicates that companies that identify air emissions as a primary source of pollution are more diligent in tracking these emissions with KPIs. It reflects the prioritisation of air quality management in their environmental monitoring efforts.

- Pair 3: Main source of pollution vs. alignment of KPIs with strategic goals

The results indicate a significant difference between responses regarding the main sources of pollution and the alignment of KPIs with strategic goals. Therefore, the hypothesis of no difference is rejected. This suggests that companies that recognise specific pollution sources tend to align their KPIs with overall strategic goals, indicating an integrated approach to environmental management and strategic planning.

- Pair 4: Main source of pollution vs. challenges associated with KPI implementation

The significant p-value suggests a significant discrepancy between responses regarding the main sources of pollution and the challenges associated with KPI implementation. This finding rejects the null hypothesis that there is no difference between these aspects. This implies that companies identifying certain pollution sources face distinct challenges in implementing KPIs. Understanding these challenges can help in developing targeted strategies to overcome barriers to effective KPI utilisation.

5.3 Discussion and summary

The comprehensive survey conducted among chemical manufacturing companies in Saudi Arabia revealed significant insights into the relationship between KPIs and environmental performance improvement. The study encompassed a diverse array of industry sectors and roles, reflecting a broad cross-section of personnel engaged in KPI implementation and environmental management. The findings highlight several key points. Firstly, the predominance of air pollution as a primary concern underscores the sector's focus on air quality management, albeit with significant impacts on water and land also acknowledged. This nuanced understanding of pollution sources emphasises the need for tailored environmental strategies that address multifaceted challenges across different domains, ensuring regulatory compliance and sustainable practices.

The frequency analysis of KPI utilisation indicated that while air-related metrics were extensively monitored, water and land-related KPIs received comparatively less attention. This disparity suggests potential areas for improvement in comprehensive environmental monitoring strategies within the industry, aligning closely with global trends emphasising integrated pollution control and resource management practices. Moreover, the high level of alignment between KPIs and strategic goals among respondents underscores the strategic integration of environmental objectives within corporate planning frameworks. This alignment not only facilitates goal achievement but also enhances operational efficiency and regulatory compliance, crucial for maintaining competitive advantage and stakeholder confidence. The findings from the t-test analyses further corroborate these insights, revealing significant associations between the recognition of pollution sources and the adoption of KPIs for environmental monitoring. Companies that identified specific pollution sources demonstrated a proactive approach by aligning KPIs with strategic goals, thereby enhancing their capacity to address environmental challenges effectively. Additionally, the challenges associated with KPI implementation highlighted in the survey underscore the importance of targeted strategies to overcome barriers and optimise the use of performance metrics in driving sustainable practices.

Overall, these findings contribute to the growing body of knowledge on KPIs and environmental management within the chemical industry, providing empirical evidence of their role in enhancing environmental performance and regulatory compliance. The study's implications extend beyond organisational practices to policy development and industry standards, advocating for tailored interventions that promote holistic environmental stewardship. Future research could explore longitudinal studies to assess the long-term impact of KPI implementation on environmental sustainability metrics, thereby fostering continuous improvement and innovation within the chemical manufacturing sector.

6 Conclusion

In synthesising insights from a multifaceted exploration of KPIs and their impact on environmental sustainability within the Saudi chemical industry, this study contributes significantly to the discourse on sustainable development in the region. Rooted in the context of the Saudi Vision 2030 and aligned with global sustainability initiatives, the research endeavours to illuminate the efficacy of KPIs in driving positive environmental outcomes while addressing challenges prevalent in the sector. The designed methodology which utilised a combination of qualitative and quantitative approaches, enabled a comprehensive understanding of KPI implementation, environmental performance, and governance regulations within Saudi chemical companies. Through structured surveys and rigorous data analysis, the study unearthed nuanced insights into the utilisation of KPIs and their influence on environmental sustainability practices.

Findings underscored the critical role of KPIs in driving environmental performance improvement, with significant correlations observed between KPI adoption and emissions reduction. Moreover, the prioritisation of specific KPIs aligned with strategic environmental goals demonstrated a tangible impact on environmental outcomes, highlighting the importance of tailored sustainability strategies within the industry. The statistical analyses, including ANOVA and correlation tests, provided empirical evidence supporting the hypothesised relationships between KPI usage and environmental performance metrics. These findings offer valuable guidance for industry stakeholders and policymakers, facilitating targeted interventions and policy formulation to enhance environmental stewardship and sustainable practices within the Saudi chemical sector.

The findings highlight the critical role of awareness and management support in successful KPI implementation within the Saudi chemical industry. The significant differences observed between groups underscore the importance of targeted interventions to enhance environmental performance. The practical implications of this study suggest that policymakers and industry leaders should prioritise awareness programs and robust management support to achieve sustainability goals.

Future research endeavours will extend this study's findings by developing a streamlined framework for companies to adopt and utilise KPIs effectively for environmental performance management. This framework will provide clear and actionable steps for implementation, empowering the Saudi chemical industry to promote sustainable practices systematically and efficiently. However, the study is not without limitations, primarily stemming from the reliance on self-reported data and the exclusion of certain segments of the chemical industry. Future research endeavours could address these limitations by employing longitudinal studies and expanding the scope to encompass a broader spectrum of chemical manufacturing enterprises.

In conclusion, this study advances the understanding of the interplay between KPIs and environmental sustainability within the Saudi chemical industry. By clarifying the mechanisms through which KPIs drive environmental performance improvement, the research paves the way for informed decision-making and transformative action towards achieving sustainable development goals at both national and global levels.

Author contributions Conceptualisation was done by A.A., Z.S. and S.J. Methodology was produced by A.A. Data collection was performed by A.A. and Z.S. Data analysis was done by A.A. and S.G. Original draft preparation was accomplished by A.A. and Z.S. Review and editing was completed by S.J, S.G and K.S. Supervision of work was under K.S. All authors read and approved the final manuscript.

Funding Open access funding provided by Lund University.

Data availability All data that support the findings of this study are included within the article.

Declarations

Ethics approval and consent to participate This study, involving a survey of chemical companies in Saudi Arabia, was conducted in strict adherence to recognised ethical standards, aligning with the principles of the 1964 Helsinki Declaration and its subsequent amendments or comparable ethical standards. Following approval from the Chamber of Commerce and Industry in Almadinah Al-Monawarah to conduct field research, further ethical approval from an ethics committee or Institutional Review Board (IRB) was deemed not necessary, given the specific nature of this study and the agreed supervision of the Madinah Chamber.

This decision was based on the study's methodology, which did not involve any invasive procedures or the collection of sensitive personal data beyond what participants were willing to share within the context of an informed consent process. Despite the absence of a formal ethics committee or IRB approval, comprehensive measures were taken to ensure the ethical integrity of the study. Informed consent was directly obtained from all individual participants included in the survey. Prior to their participation, all respondents were thoroughly informed about the study's objectives, the nature of the data being collected, and how this data would be used. We guaranteed the confidentiality and anonymity of all participants' responses throughout the data collection stage. This was done to ensure that the data collected were used exclusively for the purposes of this study, with no other ulterior motives. The ethical approach adopted for this study was designed to respect the dignity, rights, and welfare of all participants, ensuring that the research was conducted responsibly and ethically, even in the absence of a formal ethics committee or IRB oversight. Informed consent was obtained from all individual participants included in the study.

Competing interests The authors declare no competing interests.

Appendix A

See Table 8.

Table 8 Survey questions

Question	Details	Options
1. Personal details	Company name, sector and main product as well as position	n/a
2. Main source of pollution	Select sources of pollution, multi-selection possible	Air, water and Land
3. KPI usage	Does the company use KPIs to monitor environmental impact?	Yes or no
4. Specific KPI usage	Rank the specific KPI usage for each theme based on timescales ranging from not used to continuously monitored	Always, Often, Sometimes, Eventually and Never
5. KPIs usage impact	Select or enter the perceived impact of KPI usage	"Decreased pollution", "better understanding of pollution causes" and "increased action to tackle pollution"
6. Pollution level assessments	What are the methods used to assess pollution levels?	n/a
7. KPIs alignment with strategic goals	Do the KPIs always align with your company's overall strategic goals? If no, then elaborate	Yes or no
8. Challenges of KPIs implementation	What were the challenges associated with KPIs implementation? Select or enter	"Training of people", "Understanding of KPIs" and "Usefulness of KPIs"
9. Essential factors for KPI usage	What factors or methods are essential for successfully implementing KPIs in a chemical company?	n/a
10. KPIs contribution to environmental performance	How can the implementation of KPIs contribute to improvements in environmental performance within your company?	n/a
11. Regulations	Are there any specific guidelines, rules, or laws from a government monitoring body that your company must follow to manage waste generated by production? Elaborate	Yes or no
12. Limits	Are there any pollution limits imposed by the government on your company's operations?	n/a
13. Penalties and fines	What are the penalties and fines imposed by the government in case your company exceeds permissible pollution limits?	n/a

References

1. Parag Y, Elimelech E, Opher T. Bottled water: an evidence-based overview of economic viability, environmental impact, and social equity. Sustainability. 2023;15:9760. https://doi.org/10.3390/SU15129760.
2. Chen C, Jayaraman V, Chen Y. Pursuing sustainability: an interdisciplinary perspective. Internat Ser Oper Res Management Sci. 2021;301:1–11. https://doi.org/10.1007/978-3-030-58023-0_1/COVER.
3. Voulvoulis N, Giakoumis T, Hunt C, et al. Systems thinking as a paradigm shift for sustainability transformation. Glob Environ Chang. 2022;75: 102544. https://doi.org/10.1016/J.GLOENVCHA.2022.102544.
4. Elkington J. Partnerships from cannibals with forks: the triple bottom line of 21st-century business. Environ Qual Manage. 1998;8:37–51. https://doi.org/10.1002/TQEM.3310080106.
5. Ziaul IMD, Shuwei W. Environmental sustainability: a major component of sustainable development. Int J Environ Sustain Soc Sci. 2023;4:900–7. https://doi.org/10.38142/IJESSS.V4I2.296.
6. Arpit S, Das PK, Dash SK. Exergetic sustainability analysis of a naphtha-based combined cycle power plant (CCPP). Arab J Sci Eng. 2023;48:11741–53. https://doi.org/10.1007/S13369-022-07548-0/TABLES/7.
7. Rahardjo B, Wang FK, Lo SC, Chu TH. A Sustainable innovation framework based on lean six sigma and industry 5.0. Arab J Sci Eng. 2023. https://doi.org/10.1007/S13369-023-08565-3/TABLES/7.
8. Ministry of Economy and Planning. Annual report on the state of the Saudi Economy. Riyadh: Ministry of Economy and Planning; 2022.
9. Government of Saudi Arabia. Saudi Vision 2030; 2016. https://www.vision2030.gov.sa/en. Accessed 12 Mar 2024
10. Alshuwaikhat HM, Mohammed I. Sustainability matters in national development visions—evidence from Saudi Arabia's vision for 2030. Sustainability. 2017;9:408. https://doi.org/10.3390/SU9030408.
11. Puri-Mirza A. GCC: share of contribution the chemical industry to the GDP by country|Statista; 2021. https://www.statista.com/statistics/1406687/gcc-share-of-contribution-to-the-gdp-of-chemical-industry-by-country/. Accessed 12 Mar 2024
12. GPCA. The GCC petrochemical and chemical industry facts and figures 2022. Dubai: GPCA; 2022.
13. Nurunnabi M. Transformation from an Oil-based economy to a knowledge-based economy in saudi arabia: the direction of Saudi vision 2030. J Knowl Econ. 2017;8:536–64. https://doi.org/10.1007/S13132-017-0479-8.
14. Ennetta R, Soyhan HS, Koyunoğlu C, Demir VG. Current technologies and future trends for biodiesel production: a review. Arab J Sci Eng. 2022;47:15133–51. https://doi.org/10.1007/S13369-022-07121-9.
15. UN. Framework convention on climate change. UN; 2012.
16. Schaltegger S, Burritt R. Contemporary environmental accounting: issues, concepts and practice. contemporary environmental accounting: issues, concepts and practice. Routledge; 2017. p. 1–462. https://doi.org/10.4324/9781351282529.
17. Lozano R. A Holistic perspective on corporate sustainability drivers. Corp Soc Responsib Environ Manag. 2015;22:32–44. https://doi.org/10.1002/CSR.1325.
18. Munmun SA, Moktadir MA, Tiwari S, et al. Investigation of key performance indicators for performance management of the manufacturing industry in the era of the COVID-19 pandemic. Ann Oper Res. 2023. https://doi.org/10.1007/S10479-023-05717-4/TABLES/9.
19. Moktadir MA, Dwivedi A, Rahman A, et al. An investigation of key performance indicators for operational excellence towards sustainability in the leather products industry. Bus Strat Environ. 2020;29:3331–51. https://doi.org/10.1002/BSE.2575.
20. Nair A, Nayar SK. Key performance indicators of sustainability. IOP Conf Ser Earth Environ Sci. 2020;491: 012047. https://doi.org/10.1088/1755-1315/491/1/012047.
21. Sherif Z, Sarfraz S, Jolly M, Salonitis L. Identification of the right environmental kpis for manufacturing operations: towards a continuous sustainability framework. Materials. 2022;15:7690. https://doi.org/10.3390/MA15217690.
22. Haddad Y, Pagone E, Afy-Shararah M, et al. The transition to environmentally sustainable production: a roadmap timeline methodology. Procedia CIRP. 2021;103:79–84. https://doi.org/10.1016/J.PROCIR.2021.10.012.
23. Neri A, Cagno E, Lepri M, Trianni A. A triple bottom line balanced set of key performance indicators to measure the sustainability performance of industrial supply chains. Sustain Prod Consum. 2021;26:648–91. https://doi.org/10.1016/J.SPC.2020.12.018.
24. Hristov I, Appolloni A, Chirico A. The adoption of the key performance indicators to integrate sustainability in the business strategy: a novel five-dimensional framework. Bus Strat Environ. 2022;31:3216–30. https://doi.org/10.1002/BSE.3072.
25. Hristov I, Chirico A. The role of sustainability key performance indicators (KPIs) in implementing sustainable strategies. Sustainability. 2019;11:5742. https://doi.org/10.3390/SU11205742.
26. Falqi I, Alsulamy S, Mansour M. Environmental performance evaluation and analysis using iso 14031 guidelines in construction sector industries. Sustainability. 2020;12:1774. https://doi.org/10.3390/SU12051774.
27. Yusuf N, Lytras MD. Competitive sustainability of Saudi companies through digitalization and the circular carbon economy model: a bold contribution to the vision 2030 Agenda in Saudi Arabia. Sustainability. 2023;15:2616. https://doi.org/10.3390/SU15032616.
28. Facchini F, Silvestri B, Settembre-Blundo D, et al. Sustainability indexing model for saudi manufacturing organizations. Sustainability. 2023;15:953. https://doi.org/10.3390/SU15020953.
29. United Nations. Transforming our world: the 2030 agenda for sustainable development. United Nations; 2015.
30. Singh VP, Yadav S, Yadav KK, Yadava RN. An overview on environmental degradation and mitigation; 2022. p. 3–15. https://doi.org/10.1007/978-3-030-95542-7_1
31. Karatayev VA, Wilson RS, Webster DG, et al. Acclimating to degraded environments: the social rationale for swift action on restoration. bioRxiv 2022.09.27.509807; 2022. https://doi.org/10.1101/2022.09.27.509807
32. Armansyah, Jaman UB. Legal analysis of the impact of industrial development on the environment. Easta J Law Human Rights. 2023;1:87–92. https://doi.org/10.58812/ESLHR.V1I03.84.
33. Prigozhin V, Zheng W, Lee F. Implementing cleaner production technologies: general aspects. E3S Web Conf. 2023;392:01006. https://doi.org/10.1051/E3SCONF/202339201006.
34. Agustina D, Wicaksono AD, Meidiana C. The influencing factors in cleaner production adoption on the aluminium processing industry. JEMIS J Eng Manag Ind Syst. 2023;11:14–25. https://doi.org/10.21776/UB.JEMIS.2023.011.01.2.

35. Bian J, Cao X, Teng L. Editorial: cleaner treatment technologies and productions in the energy industry. Front Energy Res. 2022;10: 951477. https://doi.org/10.3389/FENRG.2022.951477/BIBTEX.
36. Schaltegger S, Hörisch J, Freeman RE. Business cases for sustainability: a stakeholder theory perspective. Org Environ. 2017;32:191–212. https://doi.org/10.1177/1086026617722882.
37. Gomes S, Pinho M, Lopes JM. From environmental sustainability practices to green innovations: evidence from small and medium-sized manufacturing companies. Corp Soc Responsib Environ Manag. 2023. https://doi.org/10.1002/CSR.2657.
38. Thoresen J. Environmental performance evaluation—a tool for industrial improvement. J Clean Prod. 1999;7:365–70. https://doi.org/10.1016/S0959-6526(99)00154-7.
39. Eissen M, Metzger JO. Environmental performance metrics for daily use in synthetic chemistry. Chem Eur J. 2002;8:3580. https://doi.org/10.1002/1521-3765(20020816)8:16%3c3580::AID-CHEM3580%3e3.0.CO;2-J.
40. Makarova AS, Jia X, Kruchina EB, et al. Environmental performance assessment of the chemical industries involved in the responsible Care®Program: case study of the Russian Federation. J Clean Prod. 2019;222:971–85. https://doi.org/10.1016/J.JCLEPRO.2019.02.218.
41. Alfarsi A, Jagtap S, Salonitis K. An assessment of environmental related key performance indicators of the chemical industries. Adv Transdiscip Eng. 2022;25:342–7. https://doi.org/10.3233/ATDE220614.
42. Plugge H. ChemESI (Chemical environmental sustainability index)—a KPI (key performance indicator) for standardizing environmental metrics for chemical sustainability. Front Sustain. 2022;3: 834849. https://doi.org/10.3389/FRSUS.2022.834849/BIBTEX.
43. Unified National Platform. Sustainable development goals and the Saudi efforts to achieve them; 2023. https://www.my.gov.sa/wps/portal/snp/content/SDGPortal. Accessed 13 Mar 2024.
44. Saudi Gazette. Saudi Electricity unveils framework for issuing green bonds—Saudi Gazette; 2020. https://saudigazette.com.sa/article/597710. Accessed 13 Mar 2024.
45. United Nations. First voluntary national review towards Saudi Arabia's sustainable tomorrow. New York: United Nations; 2018.
46. Saudi Electricity Company. Enlightening the path towards a sustainable future. Saudi Electricity Company; 2022.
47. Saudi Telecom Company. Sustainability report 2022 from ambition to action and beyond. Saudi Telecom Company; 2022.
48. Al-Alqam MS, Rehman AU, Alsultan M. Study of Saudi Arabian manufacturing and service organization sustainability and future research directions. IOP Conf Ser Earth Environ Sci. 2022;1026: 012004. https://doi.org/10.1088/1755-1315/1026/1/012004.
49. Hamieh A, Rowaihy F, Al-Juaied M, et al. Quantification and analysis of CO2 footprint from industrial facilities in Saudi Arabia. Energy Convers Manag X. 2022;16: 100299. https://doi.org/10.1016/J.ECMX.2022.100299.
50. Alsabri A, Tahir F, Al-Ghamdi SG. Environmental impacts of polypropylene (PP) production and prospects of its recycling in the GCC region. Mater Today Proc. 2022;56:2245–51. https://doi.org/10.1016/J.MATPR.2021.11.574.
51. Saudi Basic Industries Corporation. SABIC's UN SDG roadmap. Saudi Basic Industries Corporation; 2019.
52. Fattouh B, Sen A (2016) Saudi Arabia's vision 2030, oil policy and the evolution of the energy sector. The Oxford Institute for Energy Studies. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2016/07/Saudi-Arabias-Vision-2030-Oil-Policy-and-the-Evolution-of-the-Energy-Sector.pdf
53. Kahia M, Omri A, Jarraya B. Does green energy complement economic growth for achieving environmental sustainability? Evidence from Saudi Arabia. Sustainability. 2021;13:180. https://doi.org/10.3390/SU13010180.
54. Mosly I, Makki AA. Current status and willingness to adopt renewable energy technologies in Saudi Arabia. Sustainability. 2018;10:4269. https://doi.org/10.3390/SU10114269.
55. O'Rourke D, Connolly S. Just oil? The distribution of environmental and social impacts of oil production and consumption. Annu Rev Environ Resour. 2003;28:587–617. https://doi.org/10.1146/ANNUREV.ENERGY.28.050302.105617.
56. Alshahrani MM, Albogami HA, Asiri AA, et al. Epidemiological trends of acute chemical poisoning among children over a recent three-year period in Saudi Arabia. Children. 2023. https://doi.org/10.3390/CHILDREN10020295.
57. Taher N, Hajjar B. Energy and environment in Saudi Arabia: concerns and opportunities. Energy Environ Saudi Arabia Concerns Opportunities. 2014. https://doi.org/10.1007/978-3-319-02982-5/COVER.
58. Saudi Arabia. Kingdom of Saudi Arabia/Updated Nationally Determined Contribution, UNFCCC; 2021.
59. Alshehry AS, Belloumi M. Energy consumption, carbon dioxide emissions and economic growth: the case of Saudi Arabia. Renew Sustain Energy Rev. 2015;41:237–47. https://doi.org/10.1016/J.RSER.2014.08.004.
60. Singh HP, Singh A, Kowalska A, et al. Impact of sustainable development goals on economic growth in Saudi Arabia: role of education and training. Sustainability. 2022;14:14119. https://doi.org/10.3390/SU142114119.
61. Alghamdi B, Khadawardi H, Alghamdi B, et al. Key performance indicators for measuring sustainable performance: a case study of implementing Saudi Arabia's vision 2030 strategy. Perform Improv Q. 2022;34:491–519. https://doi.org/10.1002/PIQ.21359.
62. Al-Alqam MS, Rehman AU, Alsultan M. Sustainability indexing model for Saudi manufacturing organizations. Sustainability. 2023;15:953. https://doi.org/10.3390/SU15020953.
63. Tripathi A, Singh MP. Determinants of sustainable/green consumption: a review. Int J Environ Technol Manage. 2016;19:316–58. https://doi.org/10.1504/IJETM.2016.082258.
64. Trianni A, Cagno E, Neri A, Howard M. Measuring industrial sustainability performance: empirical evidence from Italian and German manufacturing small and medium enterprises. J Clean Prod. 2019;229:1355–76. https://doi.org/10.1016/J.JCLEPRO.2019.05.076.
65. Dun & Bradstreet Find Basic Chemical Manufacturing Companies in Saudi Arabia; 2024. https://www.dnb.com/business-directory/company-information.basic_chemical_manufacturing.sa.html. Accessed 13 Mar 2024
66. U.S. Census Bureau. North American Industry Classification System (NAICS); 2007. https://www.census.gov/naics/?year=2007&input=325&details=325. Accessed 13 Mar 2024
67. Susanto TD, Diani MM, Hafidz I. User acceptance of e-Government citizen report system (a Case Study of City113 App). Procedia Comput Sci. 2017;124:560–8. https://doi.org/10.1016/J.PROCS.2017.12.190.
68. Nawaz R, Hussain I, Noor S, et al. The significant impact of the economic sustainability on the cement industry by the assessment of the key performance indicators using Taguchi signal to noise ratio. Cogent Eng. 2020. https://doi.org/10.1080/23311916.2020.1810383.
69. Collins LM. Research design and methods. Encyclopedia of gerontology. Elsevier; 2007. p. 433–42. https://doi.org/10.1016/B0-12-370870-2/00162-1.

70. Kacan E. Renewable energy awareness in vocational and technical education. Renew Energy. 2015;76:126–34. https://doi.org/10.1016/J.RENENE.2014.11.013.
71. Barinova GM, Gaeva DV, Krasnov EV. Hazardous chemicals and air, water, and soil pollution and contamination. Springer; 2020. p. 255–66. https://doi.org/10.1007/978-3-319-95681-7_48.
72. Minck GH. Creating platforms for environmental technology development. In: IEE Conference Publication. IEE; 1995. p. 25–27
73. Sofia D, Gioiella F, Lotrecchiano N, Giuliano A. Mitigation strategies for reducing air pollution. Environ Sci Pollut Res. 2020;27:19226–35. https://doi.org/10.1007/S11356-020-08647-X/FIGURES/2.
74. Zapata-Jaramillo CM, Castro-Rojas LF. Pre-conceptual-schema-based patterns for deriving key performance indicators from strategic objectives. Ingeniería e Investigación. 2017;37:120–8. https://doi.org/10.15446/ing.investig.v37n2.62252.
75. Maté A, Trujillo J, Mylopoulos J. Specification and derivation of key performance indicators for business analytics: a semantic approach. Data Knowl Eng. 2017;108:30–49. https://doi.org/10.1016/J.DATAK.2016.12.004.
76. Prézélus F, Chabni D, Barna L, et al. A metrics-based approach to preparing sustainable membranes: application to ultrafiltration. Green Chem. 2019;21:4457–69. https://doi.org/10.1039/C9GC01178A.
77. Brack W, Dulio V, Ågerstrand M, et al. Towards the review of the European Union Water Framework Directive: recommendations for more efficient assessment and management of chemical contamination in European surface water resources. Sci Total Environ. 2017;576:720–37. https://doi.org/10.1016/J.SCITOTENV.2016.10.104.
78. Rodriguez RD, Medini K, Wuest T. A DMAIC framework to improve quality and sustainability in additive manufacturing—a case study. Sustainability. 2022;14:581. https://doi.org/10.3390/SU14010581.
79. Venkataraman M, Csereklyei Z, Aisbett E, et al. Zero-carbon steel production: The opportunities and role for Australia. Energy Policy. 2022;163: 112811. https://doi.org/10.1016/J.ENPOL.2022.112811.
80. Malokani DKAK, Qureshi AA, Inayat A, Mahar Q. Impact of reduction of waste and waste, green employee behavior and reduction of resource use on environmental strategy: manufacturing companies top management's perception. J Soc Sci Rev. 2023;3:27–39. https://doi.org/10.54183/JSSR.V3I2.221.
81. Chiapella AM, Grabowski ZJ, Rozance MA, et al. Toxic chemical governance failure in the United States: key lessons and paths forward. Bioscience. 2019;69:615–30. https://doi.org/10.1093/BIOSCI/BIZ065.
82. Xia T, He J, Ye Y, et al. Controlling chemical industrial pollution with regulatory tools: the case of Yichang, Hubei, China. IOP Conf Ser Earth Environ Sci. 2019;307: 012014. https://doi.org/10.1088/1755-1315/307/1/012014.