



Reducing Environmental Costs Through a Cleaner Production Strategy in the Context of Carbon Accounting

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Abstract

This research aims to examine the role of cleaner production in reducing environmental costs within the framework of carbon accounting, with an application at Al-Kadhimiya Spinning and Weaving Mill, affiliated with the General Company for Textile and Leather Industries in Baghdad, Iraq. The research relies on the mill's production and cost data to identify the main sources of carbon emissions, determine the associated environmental costs, and examine engineering measures that could reduce emissions and minimize resource waste. The main conclusions indicate that integrating carbon accounting with cleaner production helps identify environmental costs more clearly and link them to the production activities responsible for them. Addressing pollution at its source through waste heat recovery, improved equipment efficiency, automated chemical dosing, and textile waste recovery provides a practical approach to improving resource utilization and reducing environmental costs. The research also concludes that the effectiveness of these measures depends on accurate environmental cost allocation and continuous monitoring using actual operational data to verify cost savings and changes in carbon emission levels.

Keywords: Environmental Costs, Cleaner Production, Carbon Accounting

1. Introduction

One of the biggest challenges today is climate change. Many organizations and governments worldwide are making an effort to publicize climate-related risks. Due to this increased awareness, the demand for the disclosure of climate-related risks has increased. With the rising interest in sustainable investments, there is also a growing demand for the information about the environmental impacts of businesses and solutions related to corporate social responsibility and ESG. The only issue is that, despite the increasing interest in measuring and disclosing carbon emissions, the accounting treatment of environmental costs related to climate-related risks should be further investigated in terms of how these costs need to be treated when calculating profit, so that they can be reflected in the performance of organizations (Bissessur, 2024, 1).

2. Research Methodology

2.1. Research Problem

Environmental costs are becoming an increasingly important issue for economic entities because production activities consume energy and raw materials, generate waste, and contribute to carbon emissions. This has created a need for practical ways to manage these costs and reduce their impact. In this regard, the research examines how cleaner production, supported by carbon accounting, can help identify and measure environmental costs and find ways to reduce them. The research problem is addressed through the following question:

Does the adoption of a cleaner production strategy within the framework of carbon accounting contribute to reducing environmental costs?

2.2. Research Significance

The significance of this research lies in examining how cleaner production can be used within the framework of carbon accounting to reduce environmental costs. This can be achieved by minimising resource waste and emissions from production

activities. Carbon accounting also helps measure emissions and identify their associated costs, making it easier to locate the main sources of environmental costs and target them with appropriate cost-reduction measures.

2.3. Research Objectives

The research aims to achieve the following objectives:

1. To explain the concepts of cleaner production strategy and carbon accounting.
2. To identify and measure environmental costs and carbon emissions arising from production activities.
3. To identify the main sources of carbon emissions in production processes.
4. To apply a cleaner production strategy to reduce carbon emissions and environmental costs.

2.4. Research Hypothesis

The study hypothesizes that adopting a cleaner production strategy within the framework of carbon accounting contributes to reducing environmental costs by lowering resource and energy consumption, minimising waste, and reducing carbon emissions.

3. Literature Review

3.1. The Concept of Cleaner Production

The rise in the world's population has caused an increase in requirements for products and services. This has had an effect on the consumption of materials needed for the manufacture of these products. As production expands, its impact on the natural ecosystem becomes more obvious through waste disposal problems – including the pressure exerted on the current waste disposal practices. This is what makes waste disposal issue one of the key problems in a number of spheres of modern environmental and social sciences. The problem becomes even more pressing in many parts of the world due to rising figures in production, ineffective waste management techniques and the lack of waste disposal sites. The solution to the problem lies in developing new waste management techniques that would minimize the negative impact on the environment and create jobs at the same time (Cotrim *et al.*, 2018: 66).

With the growing concern over the impact of industrial processes on the environment, numerous organisations are starting to reconsider the way how they deal with pollution. In the past, companies were mostly concerned with treating pollutants after they had already been created, whereas nowadays more and more attention is paid to ensuring that pollution does not take place at all. This shift in the approach to environmental management has resulted in the emergence of different concepts regarding this field of management, such as pollution prevention, cleaner production, industrial ecology, life-cycle assessment, and eco-design. Among them, cleaner production is considered to be the most advanced implementation of preventive methods (Jain *et al.*, 2018: 251).

The idea of sustainable development came to the forefront in the Brundtland Report released in 1987, which detailed the need to meet the needs of the present generation without compromising future generations' ability to meet their needs. With time sustainable development became responsible for describing the synergy of economic development, environmental development, and social development. Global initiatives started promoting clean production technologies, thanks to UNEP which introduced them in 1989, and eco-

efficiency, which appeared in the early 1990s. Both terms refer to pollution prevention and take into account environmental concerns while producing (Gavrilescu, 2004: 46). Cleaner production deals with the reduction in or avoidance of pollution leading to the environmental damage while performing the process of production, making products, and rendering services. In 1989, the UNEP (United Nations Environment Programme) presented the concept of cleaner production as an ongoing integrated preventive strategy for improving the environment which aims to simplify the process of production and reduce the negative impact on people and nature. Similarly, the OECD (Organisation for Economic Cooperation and Development) also puts an emphasis on the effective use of natural resources during all production stages. (Hadibarata & Chia, 2021: 22). Cleaner production ensures economic advantages through tackling ecological issues and also allowing businesses to manage their operating expenditures. In contrast with end-of-pipe solutions dealing with pollution after it has occurred, cleaner production strives to stop pollution within a process before it is produced. The use of cleaner production, thus, implies taking into account the environmental impact of activities at different stages of a product's life cycle instead of focusing only on waste treatment and disposal (Ishara and Mekala, 2023: 163). Clean production development is connected to the increasing responsibility of companies for environmental issues. Businesses understand more and more the need to develop new environmentally benign products and implement practices supporting sustainability while being competitive. Green initiatives, especially involving proper technologies, may assist in minimizing natural resources consumption and mitigating the negative impact of business activities on the environment (Asha'ari & Daud, 2019: 365). Cleaner production primarily improves raw materials and energy consumption and minimizes pollution and waste. Cleaner production can be implemented through changes in production processes, product design improvements, and alterations in service delivery. Cleaner production also helps increase productivity and product quality while reducing operational expenses and waste disposal costs. Therefore, cleaner production influences financial performance and positively impacts an organization's image (Prigozhin *et al.*, 2023: 2). The application of cleaner production also involves reviewing manufacturing and operational activities to identify opportunities for improvement. This includes reducing the consumption of raw materials, water, and energy, as well as limiting emissions and hazardous waste. Through continuous improvements in production processes, organisations can use natural resources more efficiently, reduce their environmental impacts, and achieve economic benefits (Van Fan *et al.*, 2020: 2). Furthermore, cleaner production refers to both eco-friendly technology and an integrated environmental management strategy, which focuses on the activities related to products, services, and production operations. Cleaner production is aimed at increasing the efficiency of industrial production and minimizing risks to human health and nature. From a practical perspective, this definition embraces prevention of waste creation at the source, reduction of pollution, consumption of raw materials and energy, improvement of health and safety at work and increasing a competitive advantage of an enterprise (Carvalho Filho *et al.*, 2019: 2).

According to scholars, cleaner production is a globally important strategic tool for industrial companies. It should be implemented through the improvement of relevant processes, and afterwards by following many steps more, which will help the companies to cope with pollution sources, increase the resource efficiency, and reach a stage of minimizing the environmental influence of their production.

3.2. Strategies for Implementing Cleaner Production

Cleaner production can be implemented through complementary strategies that prevent pollution at its source, improve resource efficiency, and reduce environmental impacts throughout production processes.

1. Good Housekeeping

Good housekeeping involves improving operational procedures, workers' practices, equipment maintenance, and workplace cleanliness. These measures require little or no capital investment and help reduce material losses, waste generation, and environmental impacts (Khuriyati & Kumalasari, 2015: 1).

2. Substitution and Modification of Material Inputs

This strategy involves replacing or modifying production inputs to prevent or minimise pollution at its source. It focuses on reducing pollutant generation through changes in materials and production inputs rather than treating emissions after they occur (Staniškis & Kliopova, 2001: 1).

3. Reuse and Recovery

Reuse and recovery can be defined as practices directed towards waste reduction and resource consumption by way of recovery and reuse of resources from the processes of production. These operations promote the principles of a circular economy, and minimize negative effects on the environment as well as can bring some economic advantages because of effective utilization of resources (de Oliveira Neto *et al.*, 2021: 2).

4. Product Modification

Modification of product means changing existing products or redesigning them so that they are more durable, easier to maintain, and less detrimental for environment. Also, modification of products includes improvement of quality of products, making them safer and more eco-friendly (Van Berkel, 2000: 6).

According to the authors, the shift towards cleaner production requires the coordinated introduction of complementary sub-strategies. It is important that these strategies are implemented in a progressive manner such that each step is based on the previously achieved results.

3.3. Environmental Costs

Over time, environmental accounting has evolved from a specific segment of accounting into an essential part of corporate reporting. This evolution demonstrates how organizations begin to understand their environmental responsibilities better. The transformation took place as a result of changes in environmental legislation, a rise in the awareness of the stakeholders, and the acknowledgment of the value of sustainability as a component of the organizational strategy. In this particular context, Guzzo and Rotolo (2019) analyze the history and theory of accounting by emphasizing the significance of non-financial information specifically related to societal and environmental responsibilities. They conducted a literature review of Italian and French accounting publications and came up with the conclusion that over the 20th century different issues got

more attention. This indicates that the role of accounting is not limited to the collection and presentation of financial information, but is also expanded to include non-financial information about the organization. This means that there is also a growing need for reporting systems that allow presenting financial information along with non-financial one to create a comprehensive picture of the success of the organization and also demonstrate how interconnected the businesses are today (Ayinla *et al.*, 2024: 273).

Environmental costs may be defined in several ways and depends on the type of activities implemented by an agency and the ecological goals the agency wants to achieve. As a rule, the costs refer to expenses that an organisation incurs when protecting the environment and controlling the impact of business processes on the environment. In addition, these costs can be associated with expenses related to environmental performance and environmental impact in the way of influencing the public image of the company as well as its reputation and market value. At this point, environmental costs do not only refer to the money spent on waste management, for example, but also to expenses incurred to achieve environmental goals in the process of managing environmental consequences of the business. Understanding environmental costs allows businesses to understand how much money they will spend on their ecological duties and how these costs should be taken into account when making economic decisions (ELMACI *et al.*, 2016: 257). Detecting and assessing the environmental costs is vital for companies aspiring for sustainability and increasing their ability to function well in the long run. The environmental costs can be obtained from the connection between the economic activity and the natural environment and may be related to various environmental issues such as air pollution, deforestation, generation of waste, and water pollution. If an organisation measures the environmental costs correctly, it will understand how its activities affect the environment. This knowledge will allow it to detect possible threats and use limited resources more effectively, apart from being in compliance with environmental regulations. Furthermore, it will be possible to evaluate the environmental problems (Ntiamoah *et al.*, 2025: 40).

The use of environmental cost accounting may improve management decisions as well as lead to better financial results. This technique allows establishing the relationship between the costs and the environmental impact of operations and, thus, assessing financial consequences of actions taken, finding the areas of resource waste, and developing measures for reducing costs as well as the negative impact on the environment. Thus, rational environmental decisions could become beneficial for organizations in terms of finances as well as the environment and human health. The point that organizations are able to achieve such benefits is another reason for them to apply responsible environmental practices and include them in their activity (Sulaiman *et al.*, 2025: 1743). Different types of costs related to environment may occur in different ways and relate to production activities differently. Environmental costs may occur directly due to measures taken in relation to the environment or because of pollution, waste and losses of resources or as a result of inefficient management of environmental issues. Time and relation to a particular product, activity or production process can also be important factors in occurrence of environmental costs. Therefore, it is necessary to classify environmental costs according to their relevant criteria in order to

understand the essence of these costs, learn what activities generate them and obtain data that can help in managing environmental costs properly. Major criteria for classification of those costs are mentioned below.

3.3.1 Classification of Environmental Costs According to Their Relationship with Environmental Activities

Environmental costs can be classified according to the environmental activities to which they relate as follows (Jasim, 2022: 41):

1. Environmental Prevention Costs

These are the costs incurred to prevent environmental impacts arising from pollution-generating manufacturing processes. Examples include purchasing equipment or adopting production methods designed to prevent pollution at its source.

2. Environmental Control Costs

These costs relate to activities undertaken to monitor and control pollution sources to protect the environment. Examples include monitoring pollution sources and using environmentally friendly materials.

3. Environmental Identification and Measurement Costs

These are the costs of activities undertaken to identify, measure, and monitor pollution sources. Examples include measuring the quantities of emissions or pollutants generated by production processes.

4. Environmental Remediation Costs

These costs arise from activities undertaken by an economic entity to eliminate or mitigate environmental damage resulting from its operations. They may also include expenditures intended to prevent future environmental harm, such as pollution clean-up and environmental damage remediation.

3.3.2. Classification of Environmental Costs According to Their Relationship with Products

Environmental costs can also be classified according to their relationship with products, as follows (Kinani, 2018: 33):

1. Direct Costs

These are costs directly associated with products, including raw materials and the use of buildings and equipment.

2. Operating Costs

These costs are associated with the operation of an economic entity and include labour, energy, and training expenditures. Such costs may be allocated to products on the basis of direct labour hours.

3. Legal and Regulatory Costs

These costs arise from compliance with government laws and regulations. They may include reporting, testing, training, permitting, and inspection expenditures.

4. Hidden Costs

These are costs that may not be separately identifiable in accounting records. They include costs associated with environmental accidents, fines, compensation and financial settlements, corrective measures, property destruction, and personal injuries.

5. Explicit and Implicit Costs

Explicit costs are clearly identifiable in accounting records, such as the costs of installing and maintaining pollution-monitoring equipment and treating air pollution. Implicit costs, by contrast, may be incorporated into other accounts or expenditure categories rather than recorded separately, including certain incidental or unforeseen environmental expenditures.

3.4. Measurement of Environmental Costs

Environmental cost measurement involves assigning monetary values to the environmental impacts arising from an economic entity's activities. However, this process is complex because many environmental impacts are intangible and difficult to quantify accurately in monetary terms. Several methods have been developed to improve measurement accuracy, particularly Material Flow Cost Accounting (MFCA) and Life Cycle Costing (LCC).

Material Flow Cost Accounting measures material losses and determines their monetary value, thereby helping economic entities identify inefficiencies and reduce waste. Life Cycle Costing, in contrast, evaluates the costs associated with a product throughout its entire life cycle, from raw material extraction through production and use to final disposal. This approach provides a long-term perspective on the environmental costs associated with products and their life-cycle stages.

Carbon accounting has also emerged as an important tool for measuring greenhouse gas emissions and the costs associated with them. It enables economic entities to monitor their carbon footprints and assess their exposure to relevant regulatory requirements. Despite advances in environmental cost measurement methods, challenges remain, including the absence of universally standardised measurement approaches and the difficulty of accurately valuing external environmental costs. These limitations can restrict the integration of such costs into financial and accounting systems (Bedekar, 2026: 5).

The researchers argue that environmental cost measurement should extend beyond assigning monetary values to environmental activities. It should also involve measuring the environmental impacts generated by an economic entity's operations, determining their associated costs, and tracing those costs to their actual sources. This is particularly important given the growing significance of carbon emissions and their environmental and economic consequences. Measuring emissions and identifying their associated costs should therefore form an integral part of environmental cost measurement.

From this perspective, carbon accounting represents an important extension of environmental cost measurement because it provides information on the quantities and sources of greenhouse gas emissions. Such information helps establish links between environmental performance and the costs associated with it, thereby supporting more relevant managerial decision-making. Accordingly, carbon accounting constitutes a complementary component of environmental cost measurement, particularly when accurate identification and measurement of carbon emissions and their related costs are required.

3.5. Carbon Accounting

Accounting has played an important role in the economy of both profit-oriented and non-profit organizations. The

primary purpose of accounting is to assess financial transactions in a way that the entity's management, investors, tax authorities, and other stakeholders can rely on to make decisions about the use and management of their resources. As accounting takes on different forms, the needs of economic players and their stakeholders have transformed too which created the need for more comprehensive and appropriate accounting information. New developments in the economy and ecology made it necessary for different accounting methods and functions to arise, carbon accounting being one of them (Syam *et al.*, 2024: 179).

The evolution of carbon accounting can be best explained by increasing worries regarding climate change and rising greenhouse gas emissions. Carbon accounting is the practice of measuring, recording and analyzing emissions, determining source of emissions, and calculating the amount of emissions produced by different activities (e.g., consumption of energy, transportation, production) over a certain period of time (Syam *et al.*, 2024: 179). Carbon accounting emerged as one of the trends in 2000s when different projects were created to promote the measurement and reporting of carbon emissions including the Carbon Disclosure Project and the Greenhouse Gas Protocol. The development of carbon accounting continues and is increasingly influenced by global climate commitments, Explanatory Material of Climate Target in Specific Sectors, population of science targets, and so on, The evolution of carbon accounting is impacted by sustainability reporting standards and regulations, like the Corporate Sustainability Reporting Directive (CSRD) and IFRS S1 and IFRS S2, which strengthen the connection between sustainability disclosures and financial statements. The mechanisms provided create the opportunity to make organizations disclose how environmental-related issues will influence the financial results of activities. This helps to develop the valuation of assets, liability recognition, investment strategies, and capital allocation decisions. Besides, climate policies and shifts to less carbon-intensive kinds of activities reduce the value of the businesses connected with high levels of carbon emissions. Thus, it becomes extremely important for the economic subjects to consider carbon costs when evaluating the financial risks and making investment decisions (Sambodo, 2026: 27), The Greenhouse Gas Protocol (GHG Protocol) represents one of the most highly established standards in measuring and reporting greenhouse gas emissions. It provides clear guidelines on how to detect sources, categorize them, and compute the total amount of emissions caused by specific activities. Even though the GHG protocol covers many greenhouse gases, emissions are usually measured in carbon dioxide equivalent (CO₂e). This means that known conversion coefficients are used to convert different gases into CO₂e for creating a universal basis that allows comparisons across emissions coming from different sources (Reichelstein, 2024: 2129), According to the GHG Protocol, there are three scopes of greenhouse gas emissions classified. The first scope is about direct emissions from the sources that the business owns or controls. This includes emissions from burning fuel in the company's vehicles, boilers, and furnaces. The second scope covers indirect emissions caused by the entity's consumption of electricity, steam, heating, and cooling that was produced and acquired. This means that even though the entity burns this energy in its own body, producing this energy causes emissions at the factory. The third scope includes all the indirect emissions

that occur along the value chain of enterprises and are not covered by the second scope (Luo *et al.*, 2023: 662)(Spring *et al.*, 2024: 221), Scope 3 emissions have vast dimensions as they originate from activities occurring before or after an entity's operations. Upstream emissions take place prior to products, services or raw materials being delivered to the entity, meaning that the emissions could be a result of raw material extraction, production of the goods available for purchase or transportation to the business. Downstream emissions are generated when the right products are sold and when the subsequent stages of the value chain are in place (Spring *et al.*, 2024: 221) In order to measure these emissions, more detailed data should be obtained regarding not only the production processes of the entity but also the steps that have been carried out by suppliers or other participants in the logistics and output of the business. Therefore, it could be concluded that the measurement of the Scope 3 emissions usually requires better knowledge of the sources of emissions from the value chain compared to calculating the so pronounced direct emissions of locally controlled entities, The GHG Protocol is exist as a popular framework at the moment.(gatea,2025:133) But, however there are still problems related to the carbon accounting. Companies that are working in different industries and different countries use different methodologies, reporting tools, and practices. All these dissimilarities can result in inconsistency in the results despite the compliance of the analyzed functions. Such inconsistency influences the tracking process and the analyzed emissions' results in the comparison of companies. This also refers to other users of the received information who are interested in reliability and comparability of the presented information (McDonald *et al.*, 2024: 7), Such difficulties hold particular significance for industrial supply chains, in view of the fact that a considerable proportion of emissions attributable to an economic entity could occur beyond the confines of its direct operations. It has been established by published study that 40% of total greenhouse gas emissions originate in industrial supply chains, which implies that such emissions are around 5.5 times higher than the direct emissions produced by the entity's assets and active operations. This indicates that the full value chain must be taken into account, since carbon accounting should not cover solely the emissions produced within the company. Thus, accurately measuring the amounts and amount of emissions must be based on a consistent measurement approach alongside ability to trace back the sources of emissions (McDonald *et al.*, 2024: 7), In this instance, the actual physical tracing of the sources of emissions is crucial in helping to enhance the value-chain emissions inventories. When an economic agent is able to specify the exact materials, then it is easier for the firm to calculate emissions associated with that input. For instance, if Economic Agent A is using organic cotton as a physical input in its production process and is able to trace that the particular cotton has been purchased, then the emissions associated with the life cycle of that cotton is easier to calculate and will yield more accurate results than reliance on general estimates (Brander, 2023: 1251).

The distribution of carbon emissions must correspond to where the actual emissions occur across the value chain, rather than considering only the issue of double counting. If an input or activity cannot be assigned to an exact source, then the most specific relevant average of emissions for a region or industry must be used in the absence of better

information. For instance, if a company knows where its steel provider comes from.

4. Applied Aspect

The research is carried out at the General Company for Textile and Leather Industries, namely, Al-Kadhimiya Spinning and Weaving Mill, which is suffering from pollution due to the production activities. The study examines how cleaner production can help in minimizing

environmental costs and reducing pollution under carbon accounting.

4.1. Direct Raw Materials Used in Production : Direct raw materials constitute a major component of production costs at the Al-Kadhimiya Spinning and Weaving Mill, and their efficient use helps reduce material losses and environmental costs, as shown in Table 1.

Table 1. Direct Raw Materials Used in Production

No.	Description	Unit	Quantity	Unit Cost (IQD)	Total Cost (IQD)
1	Cotton	kg	240,999	2,692.47	648,903,037.20
2	Sulfuric Acid	kg	240	207.57	49,815.70
3	Chlorine Bleach	L	2	19,800	39,600
4	Anti-Scale Agent	kg	25	110	2,750
5	Calcium Hypochlorite	kg	45	110	4,950
6	Silver Decorative Dye	g	455	21.78	9,900
7	Bonigenix 2BT	kg	45	4,928	221,760
8	Leucofer BSB	kg	115	27,500	3,162,500
9	Somlion CBN	kg	120	8,800	1,056,000
10	Carrier P	kg	400	10,908.37	4,363,333.70
11	Oxygen Gas Refill	KY	26	956.53	24,860
12	EUD Emulsifier	kg	60	6,600	396,000
13	Acetic Acid	kg	240	2,244.88	538,770.10
14	Liquid Benz	kg	9	2,200	19,800
15	Zero Spirit	L	5	1,100	5,500
16	Ordinary Table Salt	kg	1,610	2,246.26	362,371.90
17	Sodium Carbonate	kg	600	1,237.50	742,534.10
18	Concentrated Active Detergent	kg	375	1,100.77	412,779.40
19	Pure Nather	pack	1	5,500	5,500
20	Hydrogen Peroxide	kg	6,332	1,635.92	10,358,892.50
21	Corn Starch	kg	4,000	724.89	29,475,579.10
22	Powder	kg	200	1,100	220,000
23	Sodium Bicarbonate	kg	125	1,203.29	150,416.20
24	Caustic Soda	kg	1,475	1,048.30	1,546,296.40
25	Recoine Baker	kg	25	21,615	540,375
26	Silicil Violet R ²	kg	25	20,120.10	503,002.50
27	Terall-M-A-W Dis				

4.2. Calculation of Total Production Costs

Production costs at the Al-Kadhimiya Spinning and Weaving Mill include direct raw materials, direct labour, indirect

manufacturing costs, marketing costs, and administrative costs. Table 2 presents the total costs.

Table 2. Total Production Costs

No.	Cost Category	Cost (IQD)
1	Direct Raw Materials	708,247,667
2	Direct Labour Costs	102,267,766
3	Indirect Manufacturing Costs	136,357,022
4	Marketing Costs	34,089,255
5	Administrative Costs	47,724,958
	Total Costs	1,028,686,668

Source: Prepared by the researchers based on the data provided for the applied study.

4.3. Identification of Carbon-Related and Environmental Activities

Carbon-related and environmental activities observed at Al-Kadhimiya Textile Factory are essential in determining the key reasons of emission, waste of materials, and pollution. Such activities are characterized by fuel use, electricity

consumption, production waste, and discharge of wastewater with chemicals and dyeing substances. The ability to differentiate carbon emission impact from other environmental ones allows more precise measurement and allocation. The data on the identified activities and sources of each activity and the allocated costs is provided in Table 3.

Table 3: Carbon-Related and Environmental Activities and Their Costs

No.	Carbon-Related and Environmental Activity	Source in the Textile Mill	Cost (IQD)
1	Carbon dioxide (CO ₂) emissions	Fuel combustion in boilers and thermal processes	494,038,118
2	Smoke and combustion gases	Furnaces, boilers, and thermal energy sources	247,019,059
3	Organic waste and material residues	Raw material losses, defective products, and production waste	329,358,745
4	Coloured wastewater and chemical residues	Dyeing, washing, and fabric-finishing processes	329,358,745
5	Additional energy consumption	Machinery operation, reprocessing, and inspection activities	247,019,059
	Total		1,646,793,726

Source: Prepared by the researchers based on the data provided for the applied study.

Operating processes at Al-Kadhimiya Textile Factory create carbon emissions as a result of burning fuel, consuming electricity, wasting materials, and treating waste. Dyeing and finishing procedures also create wastewater and chemical residues that raise environmental load. Implementing cleaner production methods can lead to less fuel and energy consumption, less generated waste, and improved efficiency of resources, thus resulting in decreased carbon emissions and environmental expenditures.

4.4. Application of Cleaner Production Technology to Reduce Carbon-Related Activities and Environmental Costs

In this section, the cleaner production technology is analyzed in terms of its effectiveness in decreasing carbon-related activities and environmental costs at the textile factory by implementing various engineering solutions. Besides that, the evaluation of implementation costs along with possible savings is also performed, which allows analyzing the contribution of the chosen strategy to increasing resource efficiency and minimizing environmental effects.

Table 4. Implementation of Cleaner Production Measures for Minimizing Carbon-Related Activities and Environmental Costs

No.	Pollution Source	Specific Engineering Intervention	Implementation Cost (IQD)	Annual Savings (IQD)
1	CO ₂ emissions from fuel combustion in boilers	Install an exhaust-gas heat recovery system (economizer) to preheat boiler feedwater	14,821,144	8,888,686
2	CO ₂ emissions from fuel used in drying and thermal setting	Install a hot-air recovery and recirculation system for fabric dryers	11,852,115	6,913,734
3	Indirect emissions resulting from electricity consumption	Install variable frequency drives (VFDs) on suitable pump and fan motors	9,880,762	6,913,734
4	Dye and chemical losses and coloured wastewater	Install an automatic dosing system for dyes and chemicals linked to fabric load and water-flow measurements	7,905,000	4,940,381
5	Recoverable fibre waste and textile scraps	Install a mechanical fibre-cutting and recovery unit for reusable materials	9,880,762	4,940,381
	Total	—	54,339,783	32,597,916

Source: Prepared by the researchers based on the applied study data and the calculated costs and savings of the proposed cleaner production measures.

The way in which cleaner production has been implemented at Baghdad's textile and weaving factory is by installing devices that work for extracting heat out of fumes, devices that make it possible to recover heat from dryers, variable frequency drives, equipment that provides technology with automatic feed of dye and chemicals and waste management devices. The total installation cost amounts to IQD 54,339,783 with yearly savings making IQD 32,597,916 or 6.60 per cent of ecological costs and 1.98 per cent of total costs. These actions allow for decreasing waste of resources, cuts down costs and pollution, while real cost cuts and emissions may be verified based on the operation data.

4.5. Cost Savings in Environmental and Total Costs after Implementing the Cleaner Production Strategy

The implementation of the cleaner production strategy contributes to cost savings by addressing the sources of carbon emissions, reducing fuel and electricity consumption, and minimizing raw material losses. The following table presents the reduction in environmental and total costs after accounting for the annual savings generated by the proposed measures, alongside their implementation cost, to assess the strategy's economic impact on the factory.

Table 5. Cost Savings in Environmental and Total Costs after Implementing the Cleaner Production Strategy

Description	Amount (IQD)
Total costs before implementing cleaner production	1,646,793,726
Environmental costs before treatment (30%)	494,038,118
Cost of implementing cleaner production measures	54,339,783
Annual savings generated by the measures	32,597,916
Environmental costs after deducting annual savings	461,440,202
Total costs after deducting annual savings	1,614,195,810

Carbon dioxide emissions are produced as a result of the operations of the Al-Kadhimiya Factory, which uses both energy from fuels and electricity, has material losses, and processes wastes. Chemical wastes are also released into the environment because of dyeing and finishing operations. The

application of the so-called clean production technologies, which aim to consume fewer fuels and save energy, minimize the wastes produced and increase material efficiency, would help to reduce CO₂ emissions generated by the factory.

5. Conclusions and Recommendations

5.1. Conclusions

1. The cleaner production strategy is a preventive method of decreasing environmental costs at Al-Kadhimiya Textile Factory through the management of pollution at the source, cutting carbon emissions, and decreasing the amount of waste production resulting from manufacturing operations.
2. Identifying sources of pollution and relating them to their costs, especially to carbon dioxide emissions, fuel and electricity consumption, raw materials waste, and production waste, helps to find ways for minimizing environmental costs.
3. Adoption of cleaner production strategies such as waste heat management, enhancing energy efficiency, automating chemical dosing, and using textile waste can significantly diminish waste and reduce both resource consumption and the ecological costs linked with production processes.
4. The financial assessment shows that the recommended cleaner production methods amount to IQD 54,339,783 and that the estimated yearly savings would be IQD 32,597,916, which emphasizes the importance of the investments in terms of environmental and operating cost reduction.
5. The implementation of carbon accounting in cleaner production allows and environmental costs to be attributed to their sources, which is necessary for the accomplishment of cost reduction at Al-Kadhimiya Textile Factory, where this can be checked against real technical data.

5.2. Recommendations

1. Make sure that the main emission sources are given importance, such as boilers, thermal processes, energy-consuming machinery, and waste of material.
2. Create a proper integrated carbon cost accounting system that enables tracking and distribution of costs.
3. Introduce and apply engineering solutions that lead to measurable savings and decrease in carbon emissions.
4. Keep an eye on the use of energy, material waste, and carbon emissions both before and after implementation of the solutions to check if all aims have been achieved.
5. Apply cleaner production and carbon accounting in the decision-making process, in the staff training, and during setting of environmental aims each year.

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