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The implementation of cleaner production throughout various industries

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ABSTRACT
Background: The implementation of cleaner production (CP) has gained significant attention in recent years as a cost-effective strategy to address environmental challenges and improve resource efficiency. **Methods:** A literature review was conducted to examine the implementation of CP in various industrial sectors and the factors that influence its success. **Findings:** The review found that the successful implementation of CP is influenced by regulatory and policy frameworks, stakeholder involvement, the availability of technical and financial resources, and the level of awareness and understanding of CP among industrial firms. **Conclusion:** The adoption of CP practices can lead to significant environmental and economic benefits, including reduced energy and water consumption, reduced waste generation and pollution, and increased competitiveness and profitability. However, challenges to the implementation of CP were also identified, including a lack of awareness and understanding, a lack of financial and technical resources, and a lack of supportive policy frameworks.

KEYWORDS: cleaner; implementation; industries; production; various.

1. Introduction

Industrial activities have a significant impact on the environment, and the environmental challenges posed by these activities are becoming increasingly pressing. As a result, there is a growing recognition of the need to adopt more sustainable and resource-efficient practices in industry. One approach that has gained significant attention in recent years is cleaner production (CP), which is defined by the United Nations Environment Program (UNEP) as "the continuous application of an integrated preventive environmental strategy applied to processes, products, and services to increase efficiency and reduce risks to humans and the environment" (Programme, 1970).

CP aims to reduce the negative environmental impacts of industrial activities while simultaneously improving efficiency and competitiveness. It is based on the principle that it is more cost-effective to prevent pollution and waste at the source than to treat it after it has been generated (Programme, 1970). CP can be applied to a wide range of industrial sectors, including manufacturing, service industries, and resource extraction.

The implementation of CP has the potential to bring about significant environmental and economic benefits. It can lead to reduced energy and water consumption, reduced waste generation and pollution, and improved resource efficiency. These benefits can in turn lead to increased competitiveness and profitability for firms (Programme, 1970).

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Given the potential benefits of CP, there has been a growing interest in understanding how it can be effectively implemented in various industrial sectors. A literature review was conducted to examine the factors that influence the implementation of CP and the challenges and opportunities associated with its adoption. The review also aims to identify gaps in the existing literature and to provide recommendations for future research.

1.1 Background

Cleaner production (CP) is a proactive approach to environmental management that seeks to reduce the negative impacts of industrial activities on the environment. It aims to optimise the use of resources and minimise waste generation through the implementation of environmentally-friendly technologies and practices. CP has gained significant attention in recent years as a cost-effective strategy to address environmental challenges and improve resource efficiency in various industrial sectors.

Examples of CP practices include energy efficiency, resource conservation, pollution prevention, and life cycle thinking. Implementing energy-efficient technologies and processes can reduce energy consumption and greenhouse gas emissions (Nilsson, 2007). Optimising the use of resources such as water, raw materials, and chemicals can reduce waste and improve resource efficiency. Implementing processes and technologies that reduce or eliminate pollution at the source can prevent environmental degradation and improve the overall sustainability of industrial operations (Nilsson, 2007). Adopting a life cycle perspective can help to optimise resource use and minimise environmental impacts throughout the entire lifecycle of a product or service.

The successful implementation of CP is influenced by a range of factors, including regulatory and policy frameworks, stakeholder involvement, the availability of technical and financial resources, and the level of awareness and understanding of CP among industrial firms (Wu et al., 2019). Governments and regulatory bodies can play a crucial role in promoting the adoption of CP practices through the development of supportive policies and incentives (Wu et al., 2019). The involvement of stakeholders, such as employees, customers, and communities, can also contribute to the success of CP initiatives by providing valuable insights and support.

The adoption of CP practices can lead to significant environmental and economic benefits, including reduced energy and water consumption, reduced waste generation and pollution, and increased competitiveness and profitability (Nilsson, 2007). However, challenges to the implementation of CP were also identified in the literature review, including a lack of awareness and understanding, a lack of financial and technical resources, and a lack of supportive policy frameworks. These challenges can hinder the adoption and success of CP practices, and need to be addressed in order to achieve the full potential of CP in various industrial sectors.

2. Methods

To conduct this literature review, a comprehensive search of academic databases was carried out, including ScienceDirect, JSTOR, and PubMed. The search included articles published in English between 2010 and 2022 and used the following keywords: "cleaner production," "industrial sectors," "regulatory frameworks," "policy frameworks," "stakeholder involvement," "technical resources," "financial resources," "awareness," "understanding," "environmental benefits," "economic benefits," "energy consumption," "water consumption," "waste generation," "pollution," "profitability," "challenges," "lack of awareness," "lack of resources," "lack of policy support." The search was limited to peer-reviewed articles and excluded grey literature and conference proceedings.

The data from the selected articles were extracted and analysed using thematic analysis. The themes that emerged from the analysis were used to organise the findings of the review and to identify key trends and patterns in the literature.

3. Results and Discussion

3.1 Cleaner Production in the Textile Industry

The textile industry is a major contributor to water and air pollution, largely due to the poor handling of chemical waste and toxic metals used in traditional production methods (Guo et al., 2019; Jin et al., 2013). This puts the textile industry as one of the industries where CP needs to be emphasised and applied. On this table below is a list of 31 CP practices that were identified in the textile industry (Oliviera et al., 2020).

Table 1. CP practices

CP practices		Concepts
P1	Environmental issues are considered during the selection of suppliers	Establish rules for the development of partnerships between companies and suppliers that result in environmental performance
P2	Environmental issues play a role in factory layout	The integration of layout with environmental issues improves the organisation of processes and directs the company toward actions that reduce environmental impacts
P3	Energy efficient technologies and technologies for minimising energy consumption	The use of energy in a rational way and choose to acquire and configure equipment considering the use of energy, reduces the consumption to perform the same activity
P4	Environmental issues are considered in the selection of equipments for producing the products	Production is less polluting and more efficient when new machines produce fewer off-spec products
P5	Possibilities of recyclability of packages are evaluated	Having and maintaining waste reuse materials flows from production and recycling of materials to improve environmental performance and production efficiency
P6	The replacement of the materials with the materials that are non-toxic and non-polluting is evaluated	Eliminating the toxicity of the products results in not generating toxic waste, simplifies the treatment of effluents and brings benefits to health and environment

P7	The possibilities of reducing the use of packages are considered	Reducing the amount of packaging in product design and considering packaging recycling reduces environmental impact
P8	For increasing the recyclability of the products, the possibilities of the changes in the composition of the products are evaluated	Considering recyclability through changes in composition or replacement of materials is possible without affecting product performance
P9	The ease of disassembly of products is evaluated in the design of products	Facilitating the dismantling of products makes maintenance more agile, increases the useful life and improves the recycling capacity
P10	Environmental issues are evaluated in the selection of manufacturing systems	Using mechanical rather than physical-chemical processes and simplifying the entire production processes improves environmental performance
P11	Environmental issues are considered in materials handling	Integrating environmental issues with the movement of materials brings benefits to the health and safety of employees
P12	Possibilities for consumers and end-users to access the recycling centres are evaluated	Direct interactions that encourage the participation of employees, suppliers, and end customers in recycling programs increase environmental awareness
P13	Reducing the usage of natural resources is considered in the manufacturing processes	Improving efficiency in the extraction of natural resources, choosing renewable sources, and using them rationally improves environmental performance
P14	Environmental issues are considered in the processes of production planning and control	Integrating environmental issues with production planning and control results in the rational use of materials and reduction of rework and waste
P15	While evaluating the production schedules, environmental problems, that may be created by the schedules, are also considered	The realisation of environmental risk analysis integrated to the production schedule allows the taking of preventive actions and increases the environmental awareness

P16	Possibilities of using energy efficient and clean technologies are considered in capacity decisions	The use of clean technology and investment in innovation minimises environmental damage, reduces waste, and improves operational efficiency
P17	The forward logistics and reverse logistics are considered in stock planning	The implementation of reverse logistics by the company reduces the environmental impact when considering the entire product life cycle in relation to the correct destination
P18	Increasing the durability of the products is considered	Increasing durability and life cycle through repairs and component replacement prevents premature discarding
P19	The possibilities of the disposal of the products are evaluated in the design of products	Consider methods of disposal and disposal of materials from the design of the product reduces the emission of waste
P20	The environmental effects, that may occur while usage of the products by the consumers, are evaluated	Creating or improving the product together with the customer considering the environmental effects minimises the environmental risks
P21	Environmental issues are considered in the design of logistic networks	The transformation of production residues into by-products or feedstock that can be marketed to other companies improves environmental performance
P22	The collection and distribution of the products and components that will be recycled, remanufactured, or reused are designed and planned	Considers in product design the reuse, remanufacturing, and recycling of materials, from planning and collection to the production process
P23	The participation of customers and end-users in recycling programs through programs such as education and information sharing are encouraged	Environmentally friendly products stand out from competitors and collaborate to protect the environment
P24	The possibilities of using renewable resources are considered	The use of renewable resources contributes to the reduction of environmental impact
P25	Projects the products for the opportunity to reduce the use of packaging and/or use of recyclable packaging	Reducing the amount of packaging in the product design and considering recycled materials to produce the packaging reduces the environmental impact

P26	Minimises waste generation and emissions in the production system	Opportunities to reduce and eliminate waste in a preventive way considering all steps in the process reduce pollution at source and are one of the initial CP practices
P27	Efficient use of raw materials and inputs, avoiding waste	The rational use of the raw material is also related to the practices of continuous improvement and reduction of the variations of the processes, besides the environmental performance
P28	Considers the CP intrinsic to the environmental management system, with periodic audits, aiming at continuous improvements	The application of CP practices collaborates with the implementation of an environmental management system
P29	Improve employee environmental awareness through capacity building	Environmental education requires the training of all employees and activities related to environmental impacts, environmental management, and recycling
P30	Improve working conditions to reduce waste	Integrating environmental issues into jobs improves health and safety, as well as reducing waste
P31	Efficient use of water	Preventive actions that stimulate the rational use of water make it possible to identify opportunities for reuse and mitigate risks of pollution of effluents, reducing environmental impacts

Cleaner production practices identified in the textile industry
(Oliveira et al., 2020)

Among the 31 identified practices of CP, all of them aim to reduce its impact to the environment. All of the practices reduce the amount of materials and resources used in the production and also tries to use a less toxic chemical whenever possible. Disposability, durability and the efficiency of the product are also likewise considered in the pursuit of CP.

The article discusses the implementation of corporate practices (CP) related to sustainability in small, medium, and large multinational companies in the textile sector in Brazil. The study found that small companies often implement CP practices solely for cost reduction purposes, while medium-sized companies are motivated by economic benefits and the ability to supply their products to large supply chains and export to developed countries. Large companies also prioritise economic benefits, but also consider environmental and social benefits and invest in employee training and environmental certifications. The study found that the level of implementation of CP practices was much higher in large companies compared to small and medium-sized enterprises, indicating a gap in sustainability practices between different sizes of companies. This highlights another advantage of CP where improving overall efficiency not only means reducing overall waste that’s bad for the environment, but also bad for business.

3.2 Cleaner Production in the Leather Industry

Similarly to the textile industry, the traditional methods still widely used in the leather industry are quite inefficient in its use of chemicals. Furthermore, some of the most widely used chemicals are toxic and are harmful when released to the environment. In the leather industry, the adoption of CP practices can help to address the environmental challenges associated with traditional leather production methods, which can be resource-intensive and generate significant amounts of waste and pollution (Al-Jabari et al., 2021).

One example of a CP practice in the leather industry is the use of more environmentally-friendly chemicals and technologies, such as closed-loop tanning systems. These systems recycle and reuse the chemicals used in the tanning process, reducing the amount of waste and pollution generated (Al-Jabari et al., 2021). Other CP practices in the leather industry can include the implementation of waste minimization and recycling programs, the use of renewable energy sources, and the optimization of energy use in manufacturing processes.

The adoption of CP practices in the leather industry can bring a range of benefits, including reduced environmental impact, improved economic efficiency, and enhanced reputation and sustainability credentials. By implementing CP practices, leather companies can demonstrate their commitment to sustainability and reduce their environmental footprint, which can be attractive to consumers and stakeholders who prioritise environmentally-friendly products (Padda & Asim, 2018). Additionally, the adoption of CP practices can help leather companies to reduce costs by optimising resource use and reducing waste, improving their competitiveness in the marketplace.

Overall, the implementation of cleaner production practices in the leather industry can contribute to a more sustainable and efficient future for the sector. By adopting these practices, companies can help to reduce the environmental impacts of leather production and contribute to a more sustainable future for the industry.

3.3 Cleaner Production in the Electronics Industry

Cleaner production (CP) practices in the electronics manufacturing industry can involve the use of more environmentally-friendly materials and technologies in the production process. For example, companies can use recycled materials and more energy-efficient production processes, such as using renewable energy sources and optimising energy use in manufacturing processes. The use of these practices can help to reduce the environmental impacts of electronics production, such as the generation of greenhouse gases and the consumption of non-renewable resources (Tseng et al., 2013).

In addition to using more environmentally-friendly materials and technologies, electronics manufacturing companies can also implement waste minimization and recycling programs to further reduce their environmental impact (tseng et al., 2013). This can involve the implementation of systems to collect and recycle waste materials, such as circuit boards and plastic casings, as well as the reuse of production by-products and the adoption of closed-loop systems that recycle and reuse process water and chemicals.

The adoption of CP practices in the electronics manufacturing industry can bring a range of benefits, including reduced environmental impact, improved economic efficiency, and enhanced reputation and sustainability credentials. Companies that implement CP practices can demonstrate their commitment to sustainability and reduce their environmental footprint, which can be attractive to consumers and stakeholders who prioritise environmentally-friendly products (Yusup et al., 2015). Additionally, the adoption of CP practices can help electronics companies to reduce costs by optimising resource use and reducing waste, improving their competitiveness in the marketplace.

The implementation of cleaner production practices in electronics manufacturing can contribute to a more sustainable and efficient future for the sector. By adopting these practices, companies can help to reduce the environmental impacts of electronics production and contribute to a more sustainable future for the industry (Yusup et al., 2015).

Repairability is a key aspect of sustainable product design and production, as it enables products to be used for longer periods of time and reduces the environmental impact of manufacturing new products. In the electronics manufacturing industry, repairability can be achieved through the use of standard components and modular design, which makes it easier to repair and replace individual parts of a product (Hernandez et al., 2020).

The adoption of repairability principles can also help to reduce waste and improve resource efficiency in the electronics manufacturing industry. By designing products that are easier to repair and reuse, companies can reduce the amount of waste generated and extend the lifespan of their products (Hernandez et al., 2020). This can lead to cost savings for both the manufacturer and the consumer, as well as reducing the demand for new materials and resources.

In addition to the environmental and economic benefits, repairability can also enhance the reputation and sustainability credentials of electronics manufacturing companies. Consumers and stakeholders who prioritise sustainability are often willing to pay a premium for products that are designed to be durable and repairable, as it reflects the company's commitment to environmental responsibility. By designing products that are easy to repair and reuse, companies can reduce their environmental impact, improve resource efficiency, and enhance their reputation and sustainability credentials.

3.4 Cleaner Production in the Food and Beverage Industry

Cleaner production (CP) practices in the food and beverage industry can involve the use of more sustainable raw materials, the adoption of energy-efficient and water-saving technologies, and the implementation of waste minimization and recycling programs. For example, food and beverage companies can source ingredients from suppliers that follow sustainable practices, such as using organic farming methods or promoting biodiversity. They can also use energy-efficient equipment, such as refrigeration units and lighting systems, and implement energy-saving measures, such as optimising the use of process heat and using renewable energy sources (Espinosa et al., 2021). Additionally, they can implement systems to collect and recycle waste materials, such as packaging and food waste, and reuse production by-products, such as spent grain in brewing and distilling operations. They can also use water-saving technologies, such as efficient irrigation systems and water recycling systems, and implement water-saving measures, such as optimising process water use and implementing closed-loop systems to recycle and reuse process water (Espinosa et al., 2021). In addition, they can use sustainable packaging materials and implement packaging designs that reduce waste and are easier to recycle.

By adopting these and other cleaner production practices, food and beverage companies can reduce their environmental impact, improve their resource efficiency, and enhance their reputation and sustainability credentials. Additionally, the adoption of these practices can help companies to reduce costs by optimising resource use and reducing waste, improving their competitiveness in the marketplace. Overall, the implementation of cleaner production practices in the food and beverage industry can contribute to a more sustainable and efficient future for the sector. By adopting these practices, companies can help to reduce the environmental impacts of food and beverage production and contribute to a more sustainable future for the industry.

3.5 Cleaner Production in the Construction Industry

Cleaner production (CP) practices in the construction industry can involve the use of sustainable materials, the adoption of energy-efficient technologies, and the implementation of waste minimization and recycling programs (Wu et al., 2019). For example, construction companies can use materials that are sourced from sustainable sources, such as certified wood or recycled steel, and implement design strategies that reduce the overall environmental impact of the building, such as using natural lighting or optimising the orientation of the building to maximise energy efficiency (Wu et al., 2019). They can also adopt energy-efficient technologies, such as LED lighting and energy-efficient appliances, and implement energy-saving measures, such as optimising the use of process heat and using renewable energy sources. Additionally, they can implement systems to collect and recycle construction waste, such as concrete, wood, and drywall, and reuse production by-products, such as recycled concrete aggregate. They can also use water-saving technologies, such as efficient irrigation systems and water recycling systems, and implement water-saving measures, such as optimising process water use.

By adopting these and other cleaner production practices, construction companies can reduce their environmental impact, improve their resource efficiency, and enhance their reputation and sustainability credentials. Additionally, the adoption of these practices can help companies to reduce costs by optimising resource use and reducing waste, improving their competitiveness in the marketplace. Overall, the implementation of cleaner production practices in the construction industry can contribute to a more sustainable and efficient future for the sector. By adopting these practices, companies can help to reduce the environmental impacts of construction and contribute to a more sustainable future for the industry.

3.6 Factors Influencing the Application of Cleaner Production

In addition to reducing environmental impacts and improving resource efficiency, the implementation of cleaner production (CP) practices can also help companies to reduce production costs. This can be achieved through a variety of mechanisms, including the optimization of resource use, the reduction of waste, and the use of more efficient technologies and processes. For example, companies that adopt CP practices may be able to reduce their energy and water consumption, leading to cost savings on utility bills. They may also be able to reduce the cost of raw materials by using more sustainable and recycled materials, and they may be able to reduce the cost of waste management by implementing recycling and reuse programs. Additionally, the use of more efficient technologies and processes can help companies to reduce production costs by increasing productivity and reducing downtime.

The implementation of CP practices can bring a range of benefits to companies, including reduced environmental impacts, improved resource efficiency, and reduced production costs. By adopting these practices, companies can improve their competitiveness in the marketplace and contribute to a more sustainable future for their industry.

3.7 Challenges and Opportunities Associated with the Adoption of CP Practices

The adoption of cleaner production (CP) practices can present both challenges and opportunities for companies. Some of the challenges that companies may face when implementing CP practices include: [a] Initial costs: The implementation of CP practices can often involve significant upfront costs, such as the purchase of new equipment or the development of new processes. These costs can be a barrier to the adoption of CP practices, especially for smaller companies with limited financial resources. [b] Lack of expertise: Implementing CP practices may require specialised technical expertise, such as engineering or process optimization skills. Companies that lack this expertise may struggle to implement CP practices effectively. [c] Resistance to change: The implementation of CP practices can involve significant changes to existing processes and systems, which can be met with resistance from employees and other stakeholders. This resistance can be a barrier to the successful implementation of CP practices.

On the other hand, the adoption of CP practices can also present a range of opportunities for companies, including: [a] Cost savings: The implementation of CP practices can lead to cost savings through the optimization of resource use, the reduction of waste, and the use of more efficient technologies and processes. [b] Improved reputation and sustainability credentials: Companies that adopt CP practices can enhance their reputation and sustainability credentials, which can be attractive to consumers and other stakeholders who prioritise environmentally-friendly products and practices. [c] Competitive advantage: The adoption of CP practices can give companies a competitive advantage in the marketplace, as they can demonstrate their commitment to sustainability and resource efficiency.

Overall, the adoption of CP practices can present both challenges and opportunities for companies. By addressing the challenges and taking advantage of the opportunities, companies can successfully implement CP practices and achieve their sustainability goals.

4. Conclusions

In conclusion, implementation of cleaner production (CP) practices can bring a range of benefits companies in various industries, including the textile, leather, electronics, construction, and food and beverage sectors. These practices involve the adoption of sustainable materials, the use of energy-efficient technologies, and the implementation of waste minimization and recycling programs. By adopting these practices, companies can reduce their environmental impacts, such as the generation of greenhouse gases and the consumption of non-renewable resources, and improve their resource efficiency, such as through the optimization of energy and water use. The adoption of CP practices can also enhance the reputation and sustainability credentials of companies, making them more attractive to consumers and other stakeholders who prioritize environmentally-friendly products and practices. Additionally, the implementation of CP practices can help companies to reduce costs by optimizing resource use and reducing waste, improving their competitiveness in the marketplace.

However, implementation of CP practices can also present challenges for companies, such as initial costs, lack of expertise, and resistance to change. For example, the adoption of new technologies or processes may require significant upfront investments, which can be a barrier to the implementation of CP practices, particularly for smaller companies with limited financial resources. Additionally, implementing CP practices may require specialized technical expertise, such as engineering or process optimization skills, which companies may not have in-house. Finally, the implementation of CP practices can involve significant changes to existing processes and systems, which can be met with resistance from employees and other stakeholders.

Despite these challenges, companies that successfully implement CP practices can reap a range of benefits and contribute to a more sustainable future for their industries. By addressing the challenges and taking advantage of the opportunities presented by CP, companies can successfully adopt these practices and achieve their sustainability goals.

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