A Perception Analysis of Environmental Sustainability Processes in Industry: A Prospective Eco-Innovation Strategy Implementation in An Electrical Motor Manufacturing Plant

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Abstract

This study focuses on the implementation of eco-innovation strategies in an electrical motor manufacturing plant to promote environmental sustainability. The evaluation process for cleaner product implementation in the plant involves gathering technical and environmental data, identifying pollution sources, and implementing cleaner production tactics. Electrical motor manufacturers can reduce their environmental impact, enhance operational efficiency, and increase cost-effectiveness by adopting cleaner production techniques. The study examines the planning phase of ISO 14001 implementation processes and its integration with environmental requirements in the electrical motor manufacturing industry. The findings highlight the importance of environmental consequences and regulatory requirements in the design phase and overall organization of environmental management systems.

Keywords: environmental management system; environmental sustainability; green practices; eco-friendly technology; cleaner production

Introduction

The idea of cleaner products is seen as a viable strategy that benefits the environment, consumers, and labor, while also enhancing industrial efficiency and increasing economic gains (Mylan, 2015).

Key benefits of implementing cleaner products include increased production efficiency, reduced raw material usage, decreased emissions, minimized waste generation, enhanced work environment, and improved product quality. The cleaning product will contribute to covering the expenses of operation, waste treatment, and accident rates (Giannetti et al., 2020).

Implementing cleaner production tactics is crucial in manufacturing facilities (Sharma & Gupta, 2024). These facilities are typically linked to substantial environmental effects, such as greenhouse gas emissions, resource depletion, and the production of hazardous waste (Almeida et al., 2013; Issa, 2014). Electrical motor manufacturers can reduce their environmental impact, enhance operational efficiency, and increase cost-effectiveness by adopting cleaner production techniques (Amienyo et al., 2016).

Among the many things that fall under the umbrella of "cleaner production strategies" are the following: using renewable energy sources; reducing waste; minimizing raw material consumption; and most importantly, reducing the consumption of water, which is a scarce resource (Issa, 2018; Mohanty et al., 2021). Moreover, implementing environmentally friendly methods such as cleaner production helps reduce the release of dangerous solid wastes containing heavy metals that can lead to significant soil pollution (Issa & Alshatteri, 2020). These measures not only contribute to the preservation of the environment, but they also give economic benefits in the form of decreased exploitation of resources, decreased costs associated with disposal, and reduced costs associated with energy consumption (Rajput & Singh, 2020). This study aims to enhance a manufacturing process for an electrical motor manufacturing facility by investigating the possible outcomes that could be attained from implementing more environmentally friendly production methods. In addition to raising awareness about the importance of environmental protection, this could lead to a competitive edge in the development of environmentally friendly production methods.

Methodology

This process involves consultancy through exploratory qualitative investigation, specifically action research. Using literary and documentary research as a foundation, it centers on cleaner manufacturing practices, following the cleaner production program and ISO 14001 environmental management systems (ISO 14001, 2015). The primary case studies of this research is a an electrical motor manufacturing plant stiuated in Baghdad, Iraq, where the current research cycle was consistently implemented during the consultancy. This study's methodology centred on the two-step process of diagnosis, which included extensive research, preparation, and assessment execution. The plant's air emissions, water discharges, waste output, and resource consumption were assessed in an initial environmental study (Issa, 2019). The manufacturing plant's ISO 14001 environmental management system application technique. Then the outcomes arised from this phase will asisst toward establishing environmental policies, goals, and targets as well as an environmental management system with recorded processes and controls in order to adhere to environmental rules and regulations (Fatimah et al., 2020; Lutfi et al., 2023). Allocating resources and integrating it into plant business processes are top management commitments to the environmental management system.

Process Description for electrical motors plant

The industrial process for electrical motors includes several steps, which can be classified as essential steps as follows:

1. The mechanical steps:

1-1. transferring works for elementary materials like metal parts to the production site.

1-2. welding, cutting, punching, and drilling work for the metal parts.

1-3. assembles the outer structure of the motor from metal parts.

2. Painting steps:

2-1. outer part painting operation (called phosphatizing), where the parts to be painted are cleaned and transferred to the paint division in the plant, where paint particles are sprayed on the parts, then washed and dried by passing into a thermal furnace.

2-2. internal parts painting (called painting with chromatic zinc), where the internal parts are transferred to the paint division and putted in special mixers, then crossed into several acidic and alkaline pools in order to remove oils, dirt, and corrosion. After this process comes the painting step, where the mixer is putted in the painting pool, then washed and putted in the chromic solution pool to give the internal parts their color.

Results and discussion

The study's findings primarily focus on the first of two stages of production—the planning phase of ISO 14001 implementation processes and its integration with environmental requirements—that lead up to the finished product becomes an eco-feindly. Both the design phase and the overall organization of environmental management systems are based on the specified regulatory requirements, which operate as a filter to evaluate the importance of environmental consequences (Ahmed & Mathrani, 2023).

The evaluation process for cleaner product implementation includes the practical steps for cleaner product implementation in plants. This process is based on information gathered about environmental parameters followed in the plant, as well as site visits and direct observation of production steps from beginning to end. Electric motors and waste treatment operations' technical aspects are part of this evaluation process.

Here are some concrete actions that electrical motor plants can do to adopt cleaner products:

1. Gathering technical and environmental data, including details on potential solutions to waste reduction and their effectiveness.

2. As stated in Table 1, there are different categories of pollution sources for gaseous, liquid, and solid industrial waste, therefore you'll need to find them in the electrical motor plant.

Table 1
The Sources and Sorts of Waste Produced by the Electrical Motor Plant

Waste Type	Source
1. Gaseous Emissions	
Emission of paint particles	Painting process of motor parts
Emission of various solvent vapors	Paint dilution Motor parts cleaning
Various gases and vapors	Various metals work like welding
2. Liquid Wastes	
Used Solvents	Paint dilution Painting process Motor parts cleaning
Industrial Waste Water	Water formed during various industrial processes like cooling hot surfaces
Industrial Washing Waters	Production wholes and treatment unit cleaning process
3. Solid Wastes	
Metal Sludge	Treatment Unit
Motors Parts	Quality control monitoring
Metal Rasp	Various mechanical actions like welding and metal cutting
4. Oils and Grease Wastes	Maintenance or leakage of equipment

When it comes to liquid industrial wastes, it almost always originates from the use of a variety of solvents, either in the process of dissolving and dilution of paint or in the process of cleaning and removing contamination, as shown in Figure 1.

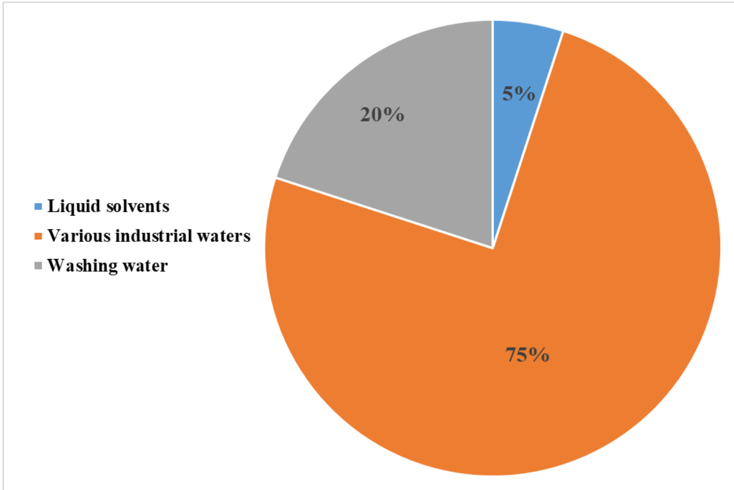

Figure 1. Distribution of generated liquid wastes percentage from electrical motors plant, calculated on the basis (100 m^3/day)

When it comes to the solid industrial wastes that are formed throughout the treatment process, there are numerous sources. The majority of these wastes are the sludge that is generated at the treatment unit for the wastes and contains high ratios of metals. As can be seen in Figure 2, further types of solid waste include the oils and grease that are generated during the process of performing maintenance repairs on the equipment.

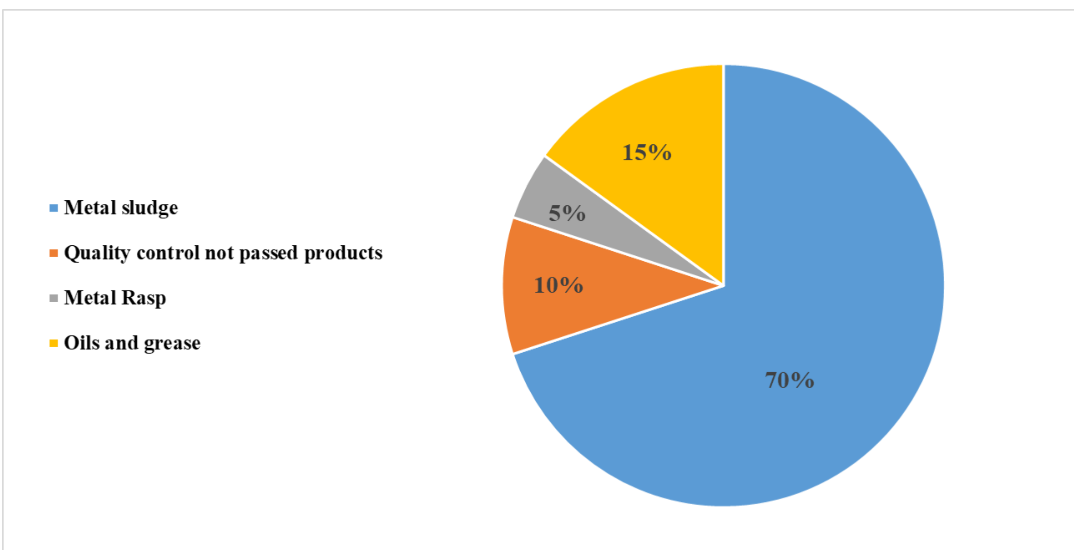

Figure 2. Distribution of generated solid and oils wastes percentage from electrical motors plant, calculated on the basis (40 Kg/day).

As shown in Figure 3, the primary sources of air pollutants emission at the plant site are the emission of paint particles along with the vapors of solvents that are used for the purposes of paint dilution and cleaning. These solvents typically have a high level of toxicity, which causes contamination of the air inside the plant, particularly in the production areas of the plant, where the concentration of these solvent vapors is increased to the point where it is harmful to the health of the workers.

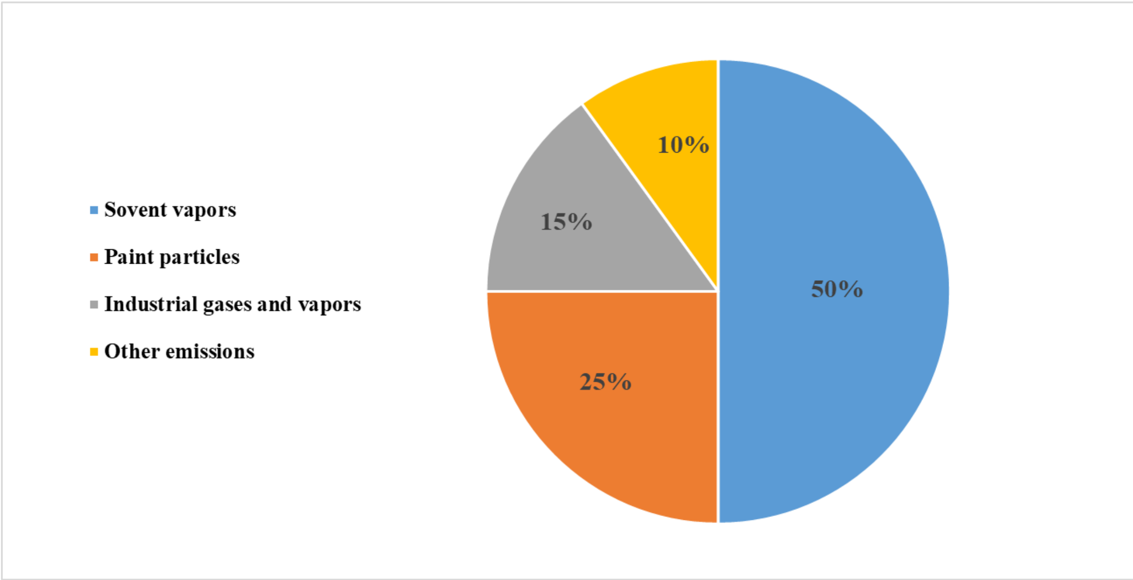

Figure 3. Distribution of Generated Gaseous Wastes Percentage from Electrical Motors Plant, Calculated on the Basis (10 m3/day)

According to the data presented in Table 2, it was established that the painting stage is the most significant contributor to pollution and the generation of elements that have unfavorable effects on the environment. This study was carried out with the purpose of determining the impact that the painting process has on the surrounding environment. Despite the fact that they contain pollutants, the paints that were used to coat the metal pieces are distinct from one another in terms of color and characteristics, as demonstrated in Figure 3. Because of this, there are limitations on the alternatives to traditional paints that may be used with the cleaners that are being used for painting purposes (Granadero et al., 2023).

Evaluate potential options for lowering pollution levels through the use of other manufacturing processes. What this means is that we should look into any possible alternative industrial procedures, such as adding more separating units to reuse the discarded solvents, and try to improve the industrial process without the current technological and economic limitations. Large amounts of sludge with high concentrations of metals like nickel, chromium, and zinc are accumulated at the plant site as a result of treatment unit operations, according to the evaluation that follows the aforementioned approach. Various sources of paint particles emissions are very hazardous and can have significant impacts on workers' health, especially when they collect at high concentrations in enclosed areas of the plant site. Existence high quantities of liquid wastes that contains used solvents (i.e. toluene, tri chloro ethyl, --- etc.) from cleaning operations of electrical motors metal parts. Industrial waste water is chemically treated by adding resins to neutralize ionic salts (cations and anions). The generated ionic water is recyclable within a closed system.

Table 2
Spent Chemicals Used in Painting Processes

Chemicals	Unit	Quantity [b]	Usage	Toxicity [c]
Epoxy powder	Kg	12	Paint powder	
Poly ester powder	Kg	12	Paint powder	
Radulene [a]	Kg	15	Outer parts cleaning before painting	
Di oxalates	Kg	2	Outer parts cleaning before painting with powder	Toxic
Toluene	ml/liter [d]	7.2	Paint solution dilution	Toxic and Carcinogenetic
Tri ethyl chloride	ml/liter	19.2	Paint solution dilution	Toxic and Harmful
Thinner solution	ml/liter	19.2	Paint solution dilution	
Soda ash	gm/liter	80	Internal parts cleaning from oils	Harmful
Sodium carbonate	gm/liter	50	Internal parts cleaning from oils	
Sodium phosphate	gm/liter	60	Internal parts cleaning from oils	
Hydrochloric acid	ml/liter	400	Internal parts cleaning from corrosion	Toxic
Aluminum chloride	gm/liter	250	Electro-painting solution	
Zinc chloride	gm/liter	60	Electro-painting solution	
Nitric acid	ml/liter	10	Painted internal parts polishing	
Chromic acid	ml/liter	750	Painted internal parts fixing solution	Toxic
Sulfuric acid	ml/liter	150	Painted internal parts fixing solution	Toxic and Carcinogenetic
Nitric acid	ml/liter	10	Painted internal parts fixing solution	Toxic
Potassium di chromate	ml/liter	500	Painted internal parts fixing solution	Toxic

[a] Chemical trade name; [b] Required quantities per day of work; [c] according to the toxic and dangerous chemicals of World Health Organization (WHO, 2019); [d] Liter of used industrial solution.

To develop environmentally friendly procedures and address present environmental challenges, various alternative methods can be implemented. To manage leftover oils from equipment maintenance or leaks, building a system that manages operations by collecting, filtering, and securely disposing of the oils. The filtered oils will be prepared for reuse after testing their operational characteristics. To efficiently reuse liquid industrial waste with high levels of solvents such as toluene, a separator can be added to the treatment unit. This will help separate the solvents from other liquid waste, reducing the need to purchase more solvents and minimizing the amount of hazardous waste disposed of into the environment. Used solvents containing chlorine should be handled separately using a specialized equipment capable of neutralizing and eliminating hazardous elements to prevent their spread in the environment. An extraction unit can be established to extract the collected sludge from the treatment unit, which has a high concentration of metals such as nickel, chromium, and zinc. The paint used for the outer cover of the electrical motors has poor adhesion capabilities, leading to significant quantities being wasted as they drop to the floor and spread across the painting division, resulting in economic losses and increased process waste. The answer to this problem involves employing high-quality paints known as electrostatic epoxy paint particles, which have superior industrial features such as strong adhesion to surfaces. Secondly, set up a control system comprising appropriate filters to capture paint particles, making production areas more user-friendly for workers and allowing for the reuse of the collected paint particles.

Conclusion

Within the context of an electrical motor manufacturing facility, the study places an emphasis on the application of eco-innovation strategies in order to better enhance environmental sustainability. Obtaining technical and environmental data, determining the causes of pollution, and implementing efficient waste reduction solutions are all necessary steps in the process of implementing cleaner products in manufacturing facilities. Increased production efficiency, fewer emissions, decreased raw material utilization, less waste creation, and enhanced product quality are all outcomes that result from the implementation of cleaner goods in the electrical motor business. When it comes to the process of creating and arranging environmental management systems in the electrical motor manufacturing business, the planning phase of ISO 14001 implementation processes and the integration of environmental criteria play a vital role. Industrial efficiency and economic gains are both improved when environmental repercussions and regulatory requirements are taken into consideration during the design phase of the adoption of cleaner products at the same time.

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