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"A Proposed Accounting Framework For Reducing Water Pollution And Waste Management (Case Study - Sample Of The Cement Sector In Egypt)"

Author
Muhammad Muhammad Naguib Muhammad Abdelaal Zeyada

Abstract
The cement industry generates pollutants, including sulfur oxides, which have detrimental effects on the environment and human health. Wet Scrubber technology effectively controls air pollution by removing sulfur dioxide. However, this process results in polluted water, exacerbating water scarcity and environmental compliance challenges. Managing gaseous wastes and treating the polluted water incur additional costs.

This study proposes an accounting framework for the cement industry to reduce water pollution and waste management costs while achieving environmental compatibility. The focus is on managing sulfur dioxide emissions from cement production, ensuring compliance with legal standards and minimizing water pollution.

The hypothesis is that implementing an accounting framework for measuring and disclosing pollution reduction costs (wet scrubber unit and water treatment) will significantly decrease sulfur dioxide emissions, achieving environmental compatibility. A comparison is made between fines incurred due to gaseous waste and expenses associated with the scrubber unit.

The research methodology uses a descriptive and analytical survey approach at an Egyptian cement factory. Sulfur dioxide emission data is collected before and after installing the scrubber unit. An accounting framework is developed to facilitate economically and environmentally sound decision-making, monitoring, measuring, and disclosing costs related to environmental activities.

The research evident that the cost of installing the wet scrubber unit for sulfur dioxide gas, along with the attached water pollution control unit and related expenses, is lower than the fines incurred by the factory for air pollution caused by sulfur dioxide gas when the wet scrubber unit is not installed.

Keywords:*accounting framework - environmental compatibility - air pollution – waste management*

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I. Introduction

Cement is considered a fundamental material for construction (Schröfl et al., 2017). It refers to all substances that become plastic when mixed with water and gradually crystallize and solidify into a solid material called "cement" (Yin et al., 2018). Cement exhibits adhesive properties when mixed with water, making it widely used in various construction purposes in our current era due to increased urbanization, manufacturing processes, and infrastructure development (Shen et al., 2017). It acts as a binder for building materials such as bricks and stones and is also used as a protective material for covering walls and other structures. Additionally, it is used in columns, walls, and various construction materials (Mechtcherine et al., 2017). The cement industry is considered a strategic industry in Egypt and serves as a cornerstone of the Egyptian economy due to its essential role in constructing the necessary infrastructure for productive and service projects and implementing development programs. Moreover, the cement industry is a transformative industry that produces an intermediate product relied upon by the construction, building, and real estate sectors (Schneider, 2019). It is also an essential industry that is indispensable for implementing various development projects, leading to an increasing demand for cement, both locally and globally, year after year. The annual production of cement increases by approximately 2%, while the annual growth rate of cement demand in Egypt is approximately 8% (Mawgoud et al., 2023).

Despite the significant role of the cement industry in Egypt's recent progress (MO Mokhtar, 2020), it generates numerous pollutants that negatively affect the environmental balance, human health, and climate (Zeb et al., 2018; Akram et al., 2019; Prasad et al., 2021). The most important of these pollutants include gaseous waste such as sulfur oxides, nitrogen oxides, volatile organic compounds, particles of various sizes, as well as carbon monoxide and carbon dioxide (Shayegan et al., 2018; Nowak, 2019; Kumar et al., 2023). Previous studies have paid significant attention to these emissions through comprehensive reviews and thorough examination of the cement manufacturing process to identify the sources of harmful emissions (Zeb et al., 2018; Adeniran et al., 2019). This enables the necessary measures to be taken to combat these pollutants, which are major contributors to the formation of smog in urban areas, in addition to their impact on the global climate (Devi et al., 2017). One of the most significant pollutants produced by the cement industry is sulfur dioxide gas, which is generated from the use of raw materials with high organic sulfur content (Vyas &Waoo, 2019; Perera et al., 2020). The emissions of sulfur dioxide in cement manufacturing are primarily associated with the content of volatile or reactive sulfur in raw materials (Sadala et al., 2019), as well as the types of fuels used for energy generation. Therefore, proper management of sulfur dioxide gas can help avoid many environmental risks and achieve environmental compatibility (Shahsavari& Akbari, 2018).

Furthermore, managing this type of waste contributes to providing sustainable solutions to reduce global greenhouse gas emissions (Yoro et al., 2020). Gas waste management involves developing solutions used by cement factories to dispose of gases generated during the manufacturing process and associated with each stage of production (Xu et al., 2017; Miller et al., 2021). It also involves assessing the inputs required for product manufacturing (Naqi & Jang, 2019), as reducing emissions of harmful substances relies on the use of alternative fuels (Ghenai et al., 2019), which cement manufacturers can manage by replacing traditional fuel sources such as coal with alternative fuels like waste-derived fuels (Richards &Agranovski, 2017; Chatterjee & Sui, 2019).

Focusing on the management of the studied gaseous waste, sulfur dioxide, modern technology has introduced the wet scrubber device (Elrafie et al., 2018) to control air pollution. It has proven its effectiveness in reducing air pollution (Hasanbeigi et al., 2017). Cement factories use it to scrub sulfur dioxide gas and discharge the contaminated water resulting from the scrubbing process into waterways (Palevi et al., 2019). This achieves gaseous waste management but at the expense of water resources, which are valuable resources for all living organisms and essential for sustaining life (Lisnic& Jinga, 2018).

Therefore, wet scrubbing technology cannot be considered an environmentally sustainable solution for managing this gaseous waste (sulfur dioxide) generated from cement manufacturing (Elrafie et al., 2018; Fungene et al., 2023) because it causes water pollution through the alteration of its physical or chemical properties (Jayadi et al., 2021), rendering the water unsuitable for desired uses (Naidu &Chelliapan, 2021). It also results in a deterioration in water quality due to the mixing of sulfur dioxide with water (Keiser & Shapiro, 2019; Singh et al., 2020; Ustaoğlu et al., 2020). Additionally, water becomes unsuitable for use due to the contamination of water bodies, including seas, rivers, oceans, as well as groundwater, wells, and rainwater, with water resulting from gas scrubbing. Consequently, using this water poses risks to human health (Abd-Elaty et al., 2022).

This water pollution affects the problem of water scarcity (Karaouzas et al., 2018), which is an important issue receiving significant attention at local, national, and international levels. Internationally, many countries face an increasing level of freshwater scarcity (Strokal et al., 2019). At the local level, Egypt has been included among the ten countries threatened by water scarcity by 2025 due to rapid population growth and a shortage of water resources needed to meet their demands (Gad, 2017).

Based on the above, it becomes clear that resorting to gas waste management through purification methods that have a negative impact on water resources is not viable (Lee et al., 2009). Water scarcity has become a global problem, and the use of wet scrubbing technology results in contaminated water, which affects the compliance of the facility with environmental regulations and imposes additional costs in the form of environmental fines (Dal Pozzo et al., 2023). However, not utilizing sulfur dioxide purification methods means a lack of environmental compliance with legally permissible gas emission limits (Ni et al., 2020). At the same time, the use of wet scrubbing units, along with the treatment of resulting contaminated water, entails additional costs for acquiring, installing, operating, and maintaining these units to ensure their continued efficiency in achieving environmental compliance with regulations (Sharif et al., 2021). Therefore, making decisions regarding environmental compliance requires considering the financial and accounting aspects as well (Han et al., 2020). This explains the difficulties faced by decision-makers in comparing pollution reduction methods and choosing the optimal ones, considering both the financial and environmental dimensions (Choi et al., 2020). Thus, proposing an accounting framework that reduces water pollution and waste management may significantly assist the cement sector in comparing different solutions to achieve environmental compliance while reducing costs.

Problem Statement

The cost of environmental pollution control is one of the most important cost elements in the cement industry (Benhelal et al., 2021; Dinga& Wen, 2022). With the increasing focus on environmental issues, there has been growing interest in addressing this problem and understanding its various aspects in order to measure and disclose the costs associated with environmental activities and their resulting benefits (Song et al., 2017; Schaltegger et al., 2017). However, due to the indirect effects and difficulties in measuring these costs, it can be challenging to make decisions regarding the implementation of pollution control technologies. There are two main reasons for this: first, the true cost of these technologies is often unclear, making it difficult to compare the results of their application with the results of non-application from an accounting perspective (Wang & Feng, 2021). Second, many of these technologies may achieve environmental compatibility in one aspect but have negative impacts on the environment in other ways (Čolaković&Hadžialić, 2018; Rasheed et al., 2020).

The economic and environmental aspects have a significant impact on the cement industry in the Arab Republic of Egypt, which aims to achieve positive industry goals by reducing negative environmental impacts and associated costs (Grunwald, 2018; Ahmed et al., 2021). Environmental protection is not a luxury but a necessity to avoid significant losses for society, as it provides returns to the community and reduces the costs of protecting against the negative effects of pollution on all organisms in the surrounding community (Jahanger& Usman, 2022; Mostafa et al., 2022).

Reports and studies indicate that the air around cement factories is filled with gas emissions that exceed allowable limits by several times (Landrigan et al., 2018; Gonzalez-Martin et al., 2021). Previous studies have highlighted the health effects of air pollution in general (Wu & Zhang, 2017; Voicu et al., 2020), specifically related to emissions from cement manufacturing, such as sulfur dioxide gas (Etim et al., 2021). The impact of this pollution on human health poses a threat to the national economy, particularly in terms of human resources, and leads to health crises, labor absence, and economic losses in healthcare costs (Devi et al., 2017; Munsif et al., 2021).

To manage some of the gas emissions resulting from cement production, the wet scrubbing process is used for sulfur dioxide gas, which is considered one of the most efficient methods for managing gas waste. However, it causes pollution of the water used in the scrubbing process (Gu et al., 2018; Zhu et al., 2019). This comes at a time when Egypt is suffering from water resource scarcity, as it is located in semi-arid regions. The per capita share of water in Egypt does not exceed 500 cubic meters, while the international standard for water scarcity is set at 1,000 cubic meters per year per person (Tellioglu&Konandreas, 2017; Zhao et al., 2021). This confirms that Egypt faces a real water resource scarcity problem (Abdelhafez et al., 2020; Luo et al., 2020).

The scarcity and limited availability of water represent one of the most important current and future challenges for Egyptian economic policies. This is due to the increasing demand for water resulting from population growth and urban development that Egypt seeks to achieve, as well as sustainable development plans, which are among the current priorities. The Egyptian state, through all its institutions, is working to achieve water security in all productive and service sectors and to preserve it in the future (Gad, 2017; Odhiambo, 2017; Eid &Negm, 2019; Abdelhafez et al., 2020). Despite the current challenges, including the construction of the Ethiopian Renaissance Dam, one of the main reasons for intensifying this problem is the phenomenon of population growth. The population growth rate in Egypt during the first decade of the new millennium was about 2.5%, which is one of the highest rates globally (Yihdego et al., 2017; Negm et al., 2019). Although this rate has decreased recently in line with the economic reform program, with the combined efforts of various entities such as the Ministry of Health, the Ministry of Social Solidarity, and the Ministry of Religious Endowments, the aim is to reduce the population growth rate to about 1.5% annually (Makhaiel et al., 2018; Bush, 2019).

Therefore, this study focused on finding a mechanism that helps in decision-making by proposing an accounting framework for one of the techniques used in managing the gas waste generated from cement manufacturing processes, specifically sulfur dioxide gas, and how to manage it in an environmentally friendly manner. In order to make this accounting framework clearer, the study chose a technology that does not cause any environmental harm when used, which is a dedicated scrubbing unit for sulfur dioxide gas equipped with a water treatment unit to completely minimize water pollution in the gas purification process. The reduction of water pollution in the employed technology means that there are no harmful environmental impacts from using this technique, which makes the proposed accounting framework clearer.

Study Objectives

This study aims to:

1- Develop a comparative accounting framework that enables decision-making between available environmental solutions.
2- Study the environmental and economic impacts of the proposed environmental solutions.
3- Incorporate the accounting framework for the financial economic effects resulting from environmental decisions, allowing future researchers to further develop and include other dimensions, such as the social dimension, from an accounting perspective.
4- Manage sulfur dioxide gas emissions resulting from cement manufacturing processes by purifying it to achieve emissions below the legally allowed limits.
5- Minimize water pollution in the purification of sulfur dioxide gas.
6- Mitigate the negative effects of cement manufacturing through the application of environmentally friendly cleaner production techniques.

Importance of the Study

The cement industry is closely associated with modern construction and progress (Naqi & Jang, 2019; Liew & Akbar, 2020). However, the pollutants generated by this industry have a negative impact on the balance of the ecosystem, human health, and the climate, making it a major concern for numerous studies aiming to provide sustainable solutions for cement manufacturing (Zeb et al., 2018; Mishra et al., 2022).

Air pollution, particularly particulate matter of different sizes, as well as gaseous waste such as sulfur oxides and carbon dioxide, are among the most environmentally impactful pollutants (Sivaguru, 2019; Elehinafe et al., 2022). Previous studies have placed significant emphasis on these pollutants by conducting comprehensive reviews and detailed examinations of the cement manufacturing process to identify harmful gaseous pollutants and their sources, and subsequently search for necessary measures to combat them (Adeniran et al., 2019; Jiang et al., 2019).

Waste management, in its various forms, is also one of the most important environmental challenges hindering sustainable development in Egypt (Wahaab et al., 2020; Abou Taleb& Al Farooque, 2021). The research has addressed the issue of gaseous waste and its integrated management to mitigate the resulting pollution (Chen et al., 2019; Eckelman et al., 2020). The study has specifically focused on the cement sector, providing a detailed clarification of the economic value elements through comparative analysis. The research proposed an accounting framework that facilitates decision-making regarding pollution reduction methods, considering that implementing certain pollution reduction methods may lead to the emergence of other types of pollution, each with its environmental and accounting dimensions.

For example, flue gas desulfurization units contribute to the pollution of water used in washing operations (Dal Pozzo et al., 2019; Hanif et al., 2020), which affects one of the most important issues on the political agenda during the 1960s and beyond (Noll, 2017; Abul-Magd et al., 2020). The water resource crisis has become a significant topic of international negotiations and has attracted the attention of researchers seeking objective and innovative solutions to rationalize water usage and explore alternatives such as seawater desalination (Williams, 2018; Klimasauskaite& Tal, 2021). This is particularly important due to water scarcity crises in various regions worldwide resulting from water resource scarcity and increased climate fluctuations (Di et al., 2018; Flörke et al., 2018; Li & Qian, 2018), as well as the growing demand for water due to imbalanced demographic growth worldwide and the expansion of water-consuming economic sectors, leading to international conflicts over water resources (Garnier & Holman, 2019; Soligno et al., 2019). The problem intensifies in developing countries, taking a different turn considering that development and growth are paramount issues for these countries. Most developing countries suffer from structural issues, including unemployment, inflation, population growth, increased poverty rates, and other challenges that make achieving growth a strategic objective with no alternative (Meo et al., 2018; Nabi et al., 2020; Siddiqa, 2021).

Given the water pollution that occurs as a result of certain methods used in managing gaseous waste, such as installing flue gas desulfurization units and the associated financial costs, the importance of this study can be summarized as follows:

1-Finding integrated solutions to the problem of gaseous waste management through wet scrubbing technology, while reducing water pollution resulting from these methods.
2-Introducing a new accounting perspective that enables the cement sector to maximize the benefits of different solutions and make informed comparisons between them.

Therefore, the significance of this study lies not only in addressing gaseous waste management but also in mitigating water pollution. By treating the wash water resulting from the employed technology, the waste management process is completed by reducing the pollution of the water. However, the decision to use such technologies is often made under conditions of uncertainty or lack of certainty due to the difficulty of accurately estimating the actual costs incurred by the facility when implementing or not implementing these technologies. Hence, the comparative approach highlights the importance of this study in establishing an accounting framework to minimize water pollution and manage waste in a way that facilitates easy comparison between proposed solutions.

Study Assumptions

1-Reducing water pollution and managing waste leads to environmental compatibility.
2-Reducing water pollution and managing waste does not lead to cost reduction.

The study is based on the assumption that the accounting framework for measuring and disclosing the costs of environmental pollution reduction in the cement industry (through the installation of a wet scrubbing unit that treats the used water internally) leads to a significant reduction in sulfur dioxide emissions, thus contributing to environmental pollution reduction by the plant. Additionally, this accounting framework provides a comparative method that illustrates the costs incurred by the facility as a result of fines imposed on the plant for air pollution caused by those emissions prior to the installation of the wet scrubbing unit. It also considers other expenses associated with the procurement and operation of the scrubbing unit to reduce air pollution.

Methodological Framework

A- Study Method: The study adopted a descriptive and analytical survey method.

B- Target Research Population: Cement factories in the Arab Republic of Egypt.

C- Sampling Unit: One cement factory in the Arab Republic of Egypt.

D- Data Collection Tools: A prepared registration form was used for data collection purposes.

E- Sampling Method:

Simple random sampling was applied in selecting the sampling unit. Additionally, systematic random sampling was used for the study variables (readings before and after the installation of the wet scrubbing unit).

F- Data Collection Method:

Primary data related to the research topic was collected using prepared tables. The date, sulfur dioxide emissions readings during the day, and the schedule for regular and emergency maintenance during the study period were recorded for both the period before and after the installation of the wet scrubbing unit.

G- Sample Size:

The study sample size was 1,318 observations (including 659 observations before the installation of the wet scrubbing unit and 659 observations after its installation in the same factory). This was after excluding days of emergency maintenance, shutdowns, and the installation period.

H- Data Sources:

The research relied on primary data collected through monitoring and recording the emissions per day of sulfur dioxide (SO2). It also utilized secondary data from books, research papers, and studies related to the research topic, as well as some online sources.

Research Boundaries

A- Spatial Boundaries: One cement factory in Egypt. The selection of the factory as a research sample was driven by the need to measure and disclose the costs of environmental pollution reduction.

B- Temporal Boundaries: The period from November 16, 2018, to September 12, 2022.

Study Variables and Measurement Methods:

The study variables (readings of sulfur dioxide emissions before and after the installation of the wet scrubbing unit) were measured using a relative measurement level ("Ratio").

Statistical Methods Used:

- Frequencies, means, and standard deviations.
- Repeated measures t-test.
- One-sample Kolmogorov-Smirnov test.
- Wilcoxon Signed-Rank test.

II. Research Results

Results of the descriptive analysis of the study sample:

A. Before the installation of the wet scrubbing unit:

Table 1: Descriptive analysis of the study sample data before the installation of the wet scrubbing unit for sulfur dioxide gas.

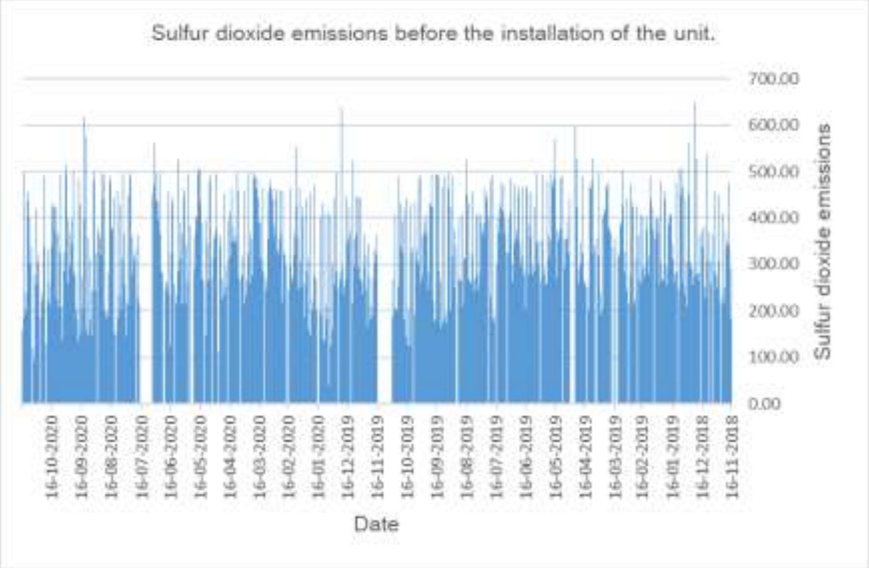
Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Before	659	40.00	651.38	342.4787	105.04539
Valid N (listwise)	659				

Source: Results of data analysis from the registration form using SPSS ver. 27 software.

From the results of Table 1 below:

The study sample size was 659 readings. The maximum value recorded was **651.38 measurement units**, while the minimum value was **40.0 measurement units**. The mean value was approximately **342.48 measurement units**, with a standard deviation of approximately 105.05. Figure 1 illustrates the levels of sulfur dioxide emissions before the installation of the unit.

Figure 1: Levels of sulfur dioxide emissions before the installation of the wet scrubbing unit.



Source: Registration form data.

B. After the installation of the wet scrubbing unit:

Table 2: Descriptive analysis of the study sample data after the installation of the wet scrubbing unit for sulfur dioxide gas.

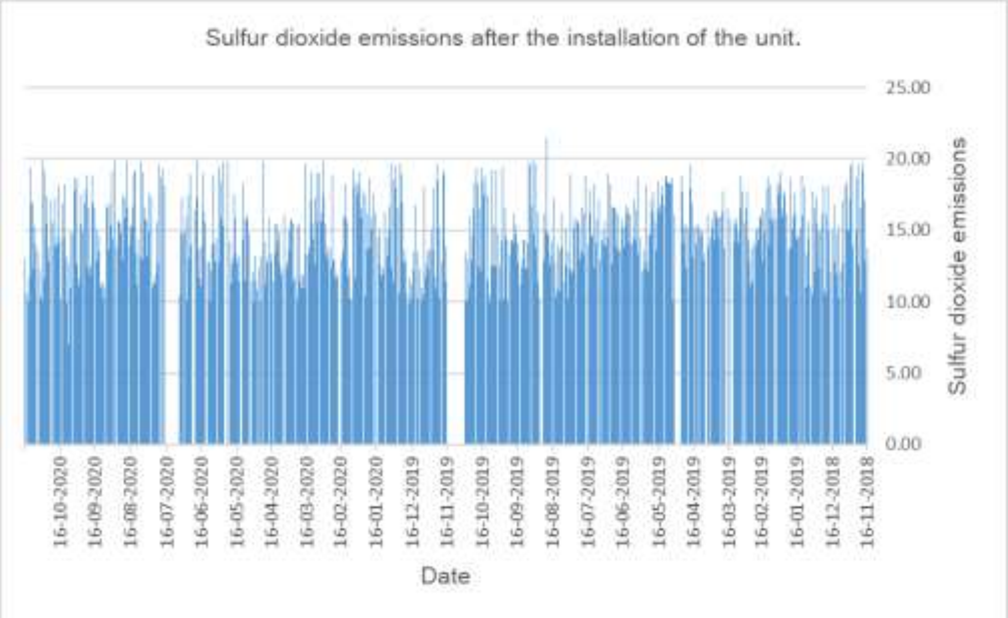
Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
After	659	7.00	21.53	14.8743	2.64827
Valid N (listwise)	659				

Source: Results of data analysis from the registration form using SPSS ver. 27 software.

From the results of Table 2 below:

The study sample size was 659 readings. The maximum value recorded was **21.53 measurement units**, while the minimum value was **70.0 measurement units**. The mean value was approximately **14.87 measurement units**, with a standard deviation of approximately 2.65. Figure 2 illustrates the levels of sulfur dioxide emissions after the installation of the wet scrubbing unit.

Figure 2: Levels of sulfur dioxide emissions after the installation of the wet scrubbing unit.



Source: Registration form data.

2- Repeated measures t-test:

* Null Hypothesis: H0: d=0 (The difference between the two samples "d" is not significant).
* Alternative Hypothesis: H1: $d \neq 0$.

Verification of test assumptions:

1. The researcher used the t-test to compare the difference between two independent samples, which is known as the repeated measures t-test. Since the t-test relies on several assumptions that must be met before conducting the test (Sheridan, 2005), they are as follows:
2. Scale of Measure: The unit of measurement used for the data should be either an interval or a ratio scale.
3. Random sampling: The sample should be selected randomly, which ensures independence between the individuals within the sample (internal independence of the sample data).
4. Normality of the data: The sample data or the samples involved in the test should follow a normal distribution.
5. Normality of population difference scores: Due to the large sample size, violations of this assumption are not of significant concern.

The fulfilment of the first and second conditions was ensured during the experiment and data recording.

Regarding the normality of the data: The normality of the sample data was verified through the Kolmogorov-Smirnov test, where the significance value was less than 0.05 (See Table 3), indicating that the data distribution does not follow a normal distribution. Therefore, the Wilcoxon Signed-Rank test, which is a non-parametric test, was used (See Table 4).

Table 3: Results of the Kolmogorov-Smirnov statistical test

Tests of Normality			
	Kolmogorov-Smirnov[a]		
	Statistic	**DF**	**Sig.**
Before	.055	659	.000
After	.043	659	.006
a. Lilliefors Significance Correction			

Source: Results of data analysis from the registration form using SPSS ver. 27 software.

The data in Table 3 illustrates the results of the Kolmogorov-Smirnov statistical test with the significance level corrected using Lilliefors. It is observed that the significance level is less than 0.05, indicating that the data does not follow a normal distribution.

Table 4: Wilcoxon test results
Wilcoxon Signed Ranks Test

Ranks				
		N	**Mean Rank**	**Sum of Ranks**
After – Before	**Negative Ranks**	659[a]	330.00	217470.00
	Positive Ranks	0[b]	.00	.00
	Ties	0[c]		
	Total	659		

a. after < before.
b. after > before.
c. after = before.

Test Statistics	
	After - Before
Z	-22.240-[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test
b. Based on positive ranks.

The results (SeeTable4) indicate that there are significant differences in sulfur dioxide emissions before and after the installation of the wet scrubbing unit. This confirms the hypothesis of the study.

The Proposed Accounting Framework for Water Pollution Reduction and Waste Management

Referring to the above, it becomes evident that the installation of the wet scrubbing unit leads to achieving environmental compliance. This is due to the reduction in sulfur dioxide emissions before and after the unit's installation (See Table1&Table2), resulting in a reduction in the costs incurred by the factory. Previously, these costs took the form of fines imposed on the facility due to non-compliance with legal limits for sulfur dioxide emissions.

However, the cost reduction achieved by avoiding these fines is offset by other expenses related to the purchase of the wet scrubbing unit and the necessary spare parts. Additionally, there are costs associated with regular maintenance throughout its assumed lifespan to maintain its performance quality. Furthermore, there is the cost of purchasing a water treatment unit for treating the wastewater generated from the gas scrubbing process, along with related expenses.

The following section presents the proposed accounting framework for comparing the costs before the installation of the wet scrubbing unit and the water treatment unit, and the costs after their installation.

Statement	Before Installation of Wet Scrubber (SO2 Scrubber)	After Installation of Wet Scrubber (SO2 Scrubber)
Annual Depreciation of Wet Scrubbing Unit	………	165.000EGP
Maintenance of Wet Scrubbing Unit	………	30.000EGP
Spare Parts for Wet Scrubbing Unit	………	12.000 EGP
Depreciation of Water Treatment Unit	………	35.000EGP
Maintenance of Water Treatment Unit	………	5.000 EGP
Air Pollution Fines	716.702EGP	………
Water Pollution Fines	………	………
Total Annual Cost	716.702 EGP	247.000EGP

Explanations

- The price of the SO2 scrubber unit is 775,000 EGP, in addition to installation expenses amounting to 50,000 EGP.
- The assumed lifespan of the unit is 5 years.
- The installation expenses are necessary expenses for operating the asset, so the value of the asset will be increased by these expenses, making the value of the asset 825,000 EGP (775,000 + 50,000 = 825,000 EGP).
- Since the unit operates with equal efficiency throughout its assumed lifespan, the straight-line depreciation method will be followed, resulting in an annual depreciation of the wet scrubbing unit of 165,000 EGP (825,000 / 5 years).
- To maintain the efficiency of the wet scrubbing unit, maintenance work is required, estimated to cost 30,000 EGP annually.
- The wet scrubbing unit includes some spare parts that need to be replaced annually, and it costs the cement factory 12,000 EGP per year to purchase and install these spare parts.
- The price of the water treatment unit for the sulfur dioxide gas wash water is 150,000 EGP, in addition to installation expenses amounting to 25,000 EGP.
- The assumed lifespan of the water treatment unit is 5 years.
- The installation expenses are necessary expenses for operating the asset, so the value of the asset will be increased by these expenses, making the value of the asset 175,000 EGP (150,000 + 25,000 = 175,000 EGP).
- Since the unit operates with equal efficiency throughout its assumed lifespan, the straight-line depreciation method will be followed, resulting in an annual depreciation of the water treatment unit of 35,000 EGP (175,000 / 5 years).
- The cement factory incurs approximately 25,000 EGP over the five years for the maintenance of the unit (equivalent to 5,000 EGP annually).

Fines for exceeding the legally allowed limits for air emissions:

The Egyptian legislator stipulated in Chapter II of the Environment Law No. 4 of 1994, as amended by Law No. 9 of 2009, the protection of the atmospheric environment from pollution. Articles "35, 40, 43" provide for penalties for emissions from various facilities, whether external or within the work environment, when they exceed the maximum limits prescribed by law. The details are as follows:

1- Article 35 obliges facilities to not exceed the maximum air pollutants limits, stating that "facilities subject to the provisions of this law in their activities shall comply with not emitting or leaking pollutants into the air beyond the maximum limits allowed by the applicable laws, decisions, and the executive regulations of this law."

2- Article 40 requires that emissions resulting from fuel combustion for any purpose be within the allowed limits, stating that:

"When burning any type of fuel or other materials, whether for industrial, power generation, construction purposes, or any other commercial purpose, the smoke, harmful gases, and vapors resulting from the combustion must be within the allowed limits. The person responsible for this activity must take all precautions to reduce the amount of pollutants in the combustion products referred to. The executive regulations of this law specify these precautions, the allowed limits, and the specifications of chimneys and other means of controlling the smoke, gases, and vapors emitted from the combustion process".

3- Article 43 obligates the facility to take necessary precautions to prevent the emission of air pollutants within the work environment. The article states:

"The owner of the facility is committed to taking necessary precautions and measures to prevent the leakage or emission of air pollutants within the workplace, except within the allowed limits, as determined by the executive regulations of this law, whether resulting from the nature of the facility's activities or from malfunctioning devices. The owner should provide necessary protection for workers in compliance with occupational health and safety conditions, including the selection of suitable machinery, equipment, materials, and types of fuel. Consideration should be given to the duration of exposure to these pollutants, and it is required to ensure adequate ventilation, installation of chimneys, and other means of air purification."

All these provisions are subject to punishment under Article 87 of the Environmental Law, with a fine ranging from a minimum of one thousand pounds to a maximum of twenty thousand pounds.

Criminal Reconciliation Procedures:

Article 18 of the repeated Law of Criminal Procedures No. 150 of 1950 establishes the general rule for reconciliation regarding offenses and misdemeanors punishable by fines or punishable by imprisonment for a maximum period not exceeding six months. The value of the reconciliation amount is determined based on the maximum fine prescribed by law, distinguishing between reconciliation before filing a criminal lawsuit by setting its value at one-third of the maximum fine, and reconciliation after filing a criminal lawsuit by setting its value at two-thirds of the maximum fine or the value of the minimum fine, whichever is higher. The article states:

"The accused person may reconcile in offenses, as well as in misdemeanors that are not obligatory to be punished by a fine, or those punishable by imprisonment for a maximum period not exceeding six months."

The record officer or the public prosecution, as the case may be, is responsible for presenting the reconciliation to the accused person or their attorney and documenting it in the record. It is the responsibility of the accused person who wishes to reconcile to pay, before filing the criminal case, an amount equivalent to one-third of the maximum fine prescribed for the crime. The payment shall be made to the court treasury, the public prosecution, or to a person authorized by the Minister of Justice.

The right of the accused person to reconcile does not expire with the filing of the criminal lawsuit before the competent court, if they pay two-thirds of the maximum fine prescribed for the crime or the value of the minimum fine, whichever is higher, before a judgment is issued in the matter.

The criminal lawsuit is dismissed upon payment of the reconciliation amount, and this dismissal does not affect the civil lawsuit.

Calculation of the Reconciliation Amount:

When a facility violates one of the articles "35, 40, 43" by exceeding the legally prescribed maximum limits for air pollutants, reconciliation is made for this violation according to Article 87 of the Environmental Law, which is punishable by a fine of not less than one thousand pounds and not exceeding twenty thousand pounds.

Reconciliation is carried out in accordance with the procedures stipulated in Article 18 of the repeated Law of Criminal Procedures mentioned above. In the case of reconciliation before filing the criminal lawsuit, the value of the reconciliation is calculated by paying one-third of the maximum fine, which is 20,000 pounds, equivalent to 6,667 pounds as a fine for reconciling the violation.

Referring to the study period from November 16, 2018, to November 15, 2020 (the two years prior to the installation of the unit) and extracting a sample consisting of 659 violations, 215 violations were recorded during the two years.

Multiplying the number of violations (215) by 6,667 pounds results in the amount of 1,433,405 EGP, and to determine the amount to be borne by one year in terms of these fines, this amount is divided by 2 (two years) to make the fines for one year equal to 716,702 EGP.

- Due to the quality of the attached processing unit to the wet scrubber unit used in the illustrative example, the water produced from it remains within the allowed limits, and there are no fines resulting from water pollution. This clarifies the role of this unit, which is not limited to managing the gaseous pollutant -SO2- and eliminating its emissions into the atmosphere but also includes limiting water pollution because the water resulting from gas scrubbing is treated in the processing unit and reused in cleaning operations.

Based on the above, it is evident that the cost of installing the wet scrubber unit for sulfur dioxide gas and the attached water pollution control unit, along with their related expenses, is lower than the cost incurred by the factory in case the wet scrubber unit is not installed, which is represented by the fines paid by the factory due to air pollution caused by sulfur dioxide gas.

III. Recommendations And Results

- Reducing water pollution and waste management contribute to achieving environmental compatibility for the facility, as well as reducing costs.
- Monitoring, measuring, and disclosing the costs of environmental activities and comparing them to the costs incurred by the facility in case these activities are not implemented help in making economically and environmentally appropriate decisions for the facility.
- It is necessary to work towards achieving comprehensive environmental balance by tracking the environmental impact of solutions used to mitigate any negative effects. This is important to mitigate any harmful negative effects on other environmental elements resulting from these solutions.
- The proposed accounting framework in this study should be applied to all industries with harmful environmental impacts, especially those with multiple proposed solutions to mitigate the pollution resulting from these industries.
- This study included both the environmental and economic dimensions in the proposed accounting framework, but it also aimed to make it a nucleus that enables researchers to include other future dimensions, such as the social dimension from an accounting perspective.
- The proposed accounting framework in this study should be used to achieve environmental integration in addressing waste management issues, including various types of waste, not just gaseous waste such as plastic waste, solid waste, organic waste, agricultural waste, and others.

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