International Journal of Environmental Studies and Researches (2024), 3(2):57-65

Environmental Emissions Performance for Energy Transition in Cement Industrial Sector from Natural Gas to Energy Fuel Mix Case Study: Cement Company in Egypt

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Abstract

Since 2015, energy map in Egypt has shifted to energy transition, and type of fuel used in the Egyptian cement sector has undergone significant change. There has been a general shift toward coal, petroleum coke, and alternative wastes such as liquid and solid wastes, as well as a lessening dependence on natural gas. The cement production process currently uses a mix of alternative fuels and conventional fossil fuels. In this research, we studied the environmentalemissions performance of energy transition in a cement company as a case study .The company shifted from using natural gas as a mine fuel in cement production to coal and alternative fuels and discuss the environmental effects resulting from using new types of fuels, especially air emissions resulting from the combustion of different types of fuel as total suspended particulates (TSP), nitrogen oxides (NO_x), and sulfur dioxide (SO_2) between 2014 to 2020. The result showed that the use of an appropriate energy mix, appropriate operation control, and not relying on only one type of fuel leads to improved environmental performance in the cement company.

Keywords: Cement industry, Energy mix, Environmental performance.

Introduction

Cement production is an energy-intensive process that requires up to 110 kWh of electric energy and 2800–4000 kJ of thermal energy per kilogram of clinker **(Hosten and Fidan, 2012).** About 5% of the world's industrial sector and 2% of global energy consumption are accounted for the cement industry's energy use **(Pieper et al., 2020)**. The process of making cement consists of three main steps preparing the "meal," or raw materials, which entails grinding, preheating (drying), and mixing/homogenizing. Raw meal is burned in the kiln to produce cement clinker. In the pre-calciner and rotary kiln, the raw meal constituents react at temperatures between 900 and 15000^{O}C to produce cement clinker. After cooling, the clinker is further ground and mixed with additives. Grinding raw meal, mixing, pre calcining, burning clinker, and grinding cement are the steps in the cement manufacturing process. **(Kaantee et al., 2004).** In the cement industry, the most widely used type of energy are coal, fuel oil, and natural gas. The distribution of energy used in the manufacture of cement is 92.7% in pyro-processing, 1.9% for raw grinding and 5.4% for finishing grinding **(Choate, 2003).** In China, cement is made mainly from coal. In the future, alternative fuels might be an option **(Soule et al., 2002).** In India about 18% of coal consumption is used as the primary fuel in cement mills **(ZKG International, 2003)**. Recently, a variety of materials, including tires, oil waste, plastics, solvents, and industrial waste, are frequently used to make alternative fuels **(Galitsky and Price, 2007).** Cement companies across the globe are evaluating the potential replacement value of waste materials, such as waste oils, non-recycled plastic and paper mixtures, used tires, biomass wastes, and waste water sludge, in place of conventional fuels due to rising energy costs and environmental concerns **(Chatziaras et al., 2016)**. There has been discussion about the potential use of the highly calorific refused derived fuel (RDF) to lessen the amount of fossil fuels used in the production of cement and to protect the environment **(Chamurova et al., 2017).** Global cement manufacturers also use alternative fuel (AF) as a source of energy. Typically, these fuels are made from blends of municipal, industrial, and other wastes **(Mokrzycki et al., 2003**). Cement producers currently use a combination of conventional fossil fuels and alternative fuels to lower their energy and environmental costs.Various waste materials can be used in cement production in substitute for primary raw materials and/or fossil fuels, which will help conserve natural resources. Environmentally beneficial waste-to-energy and material recycling applications are essentially made possible **(Galitsky and Price, 2007**). Cement industry is a major contributor to environmental imbalances, specifically with regard to air quality. Grey dust, Sulphur dioxide (SO_2), and nitrogen oxides (NO_x) are the main environmental pollutants **(Madsenet al., 2004).** Egypt started producing cement in the early 20th century, with the establishment of the Torah Cement Company in 1927, making it one of the oldest countries in the region in this regard. The Helwan Cement Company was founded later in 1929, and was succeeded by the Alexandria Cement Company in 1948 and the National Cement Company in 1956. Nowadays**,** there are 19 operational cement companies with 42 producing lines.With an installed capacity of about 62 million tons of cement annually, the Egyptian cement industry is the most energy-consuming sector in the entire country. Cement consumption in the Egyptian market was 48.7 million tons in 2019 and 44.9 million tons in 2020, accounting for more than 9% of Egypt's totalprimary energy consumption. **(Ismail et al., 2014)**. In 2012, The Egyptian government diverted natural gas from heavy industrial users as cement.During 2013, The amount of cement produced in the country had decreased by 50%. The industry campaigned to replace natural gas with other fossil fuel-based substitutes, like coal and pet coke. In 2015 in response to this debate, the executive regulation Decree 964/2015 was drafted by the Egyptian government to address the mitigation options available to cement companies that use coal as a fuel **(Twidale and Bushra, 2014)**.

Materials and methods

The research methodology depends on assess the environmental emissions performance of Titan Alexandria Portland Cement Company (APCC) during using fuel energy mix as coal and different types of alternative fuel especially monitoring of air emissions like sulfur dioxide SO_2, Nitrogen Oxides NO_x, total suspended particulates TSP emits from stack kiln during fuel combustion and cement production.

Study area

The research was done in Titan Alexandria Portland Cement Company (APCC) which located in Wadi Al-Qamar region, west of Alexandria Governorate, on the Mediterranean coast of Egypt at 7º 24' 42.45"N and 8º 58' 31.28"E as shown in Fig. 1.

Fig. 1. Location of Titan Alexandria Portland Cement Company (APCC).

APCC is chosen in this study because it represents one of the most important and largest cement plants in Egypt that is concerned with applying local legal limits and regulations for environmental protection as one of the sustainable development goals. It also implements an online data monitoring system using multicomponent analyzer systems to measure and report air emissions.

Instruments and measurement

Titan Alexandria Portland Cement Company (APCC) had a continues emission monitoring system from kiln stack for sulfur dioxide (SO_2), Nitrogen Oxides (NO_x), suspended particulates (TSP). The system operates during 24 hours in seven days a week. These measurements are sent straight to the EEAA control room, allowing for close real-time monitoring of the emissions and appropriate action. The continues stack monitoring system isan online data monitoring system that measures and reports air emissions using SICK's MCS100E HW multicomponent analyzer systems in order to guarantee total control for environmental effects of cement production.

Applicable local laws and regulations for emission levels

The present study is concerned with the Egyptian air quality standards, specifically with regard to stack emissions from the cement industry. Specifically, the environmental law No. 4 of 1994, which was amended by Law 9/2009 and its executive regulations in 1995, as well as the amendments No. 1095 in 2011, 710 in 2012, and 964 in 2015 (annex 6 table no. 6 for the cement industry).

Table 1. Emissions AQL from cement kilne stack - Environment Law No. 4 /1994 (No, E. E. L. (4). for year 1994 and its Executive Regulations).

Pollutants	**Maximum limits (mg/m^3)**
Total suspended particulate (TSP)	50 for lines before Executive Regulations 2015
	30 for new lines after Executive Regulations 2015
SO2	400
Nitrogen oxides (NOx)	600 for lines before Executive Regulations 2015
	450 for lines before Executive Regulations 2015

Results and Discussion

Fuel mixused in cement production in (APCC)

Uses of fuels inTitan Alexandria Portland Cement Company (APCC) has changed significantly to coal, petroleum coke and alternative wastes as fuel mix and lessening dependence on natural gas. During 2014, the main fuels used in cement production was natural gas 97.3% and diesel 2.7%. In 2015 due to the shortage in natural gas the company start using different type of fuel such as coal, petcock with percentage 33.6% and Waste oil with percentage 23.3% and start to reduced depending on natural gas as min fuel with percentage 0.82 %. In 2016,2017 and 2018 the company used coal and pet coke as a main fuel with high percentage (70.99%, 83.36%, 81.01%) and start using alternative fuels as agriculture waste AW, refuse drive fuel RDF, and used Dried Sewage Sludge (DSS) in small percentage (0.5%, 0.01 %) as a trails. In 2019 and 2020 coal and pet coke keep using as primary fuels start using Tire-Derived Fuel (TDF) with various amount with counting using coal and agriculture waste AW, refuse drive fuel RDF (Fig. 2 and Table 2).

The fuels mix was changed every year in the company with different percentage of coal as main fuel and alternative waste fuels according to the availability of waste fuels and suitability of fuel specifications for the production process.

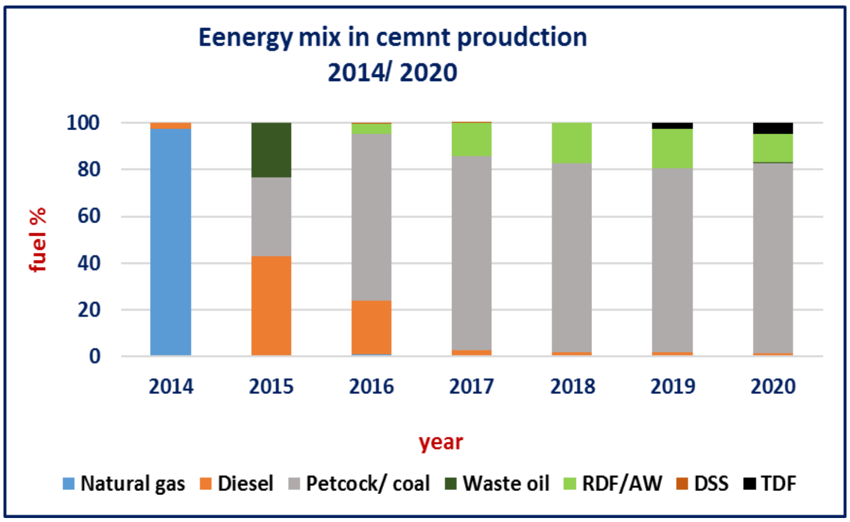

Fig. 2. Energy mix in cement production.

Air emissions monitoring

The air emissions resulting from the use of various fuel mixes are monitored using a continuous emission monitoring system from a kiln stack. The system operated for 24 hours, collecting data was then submitted online to the environmental affairs agency (EEAA). Total suspended particulates (TSP), nitrogen oxides (NO_x), and Sulphur dioxide (SO_2) are the main emissions parameters. Table 3 and Fig. 3 show how the energy transition from natural gas to a combination of coal and alternative fuels, affected the emissions results.

Table 2. Fuel type used in cement production during study period 2014-2020.

Year Fuel %	2014	2015	2016	2017	2018	2019	2020
Natural gas	97.3	0.82	0.9	0.67	0.28	-------	-------
Diesel	2.7	42.3	23.27	1.91	1.55	2.1	1.3
Petcock/ coal	------	33.6	70.99	83.36	81.01	78.4	81.6
Waste oil	-----	23.3	-------	------	------	------	0.1
RDF/AW	------		4.28	14.05	17.16	16.8	12.2
DSS	------	------	0.56	0.01	------	------	
TDF	-----	------	------	------	------	2.7	4.8

AW is Agriculture waste, RDF is Refuse drive fuel, DSS is Dried Sewage Sludgeand TDF is Tire-Derived Fuel.

Total suspended particulate (TSP)

During 2014 with using natural gas the concentrations of total suspended particulate (TSP) always below AQL (2.17 mg/m^3)as the company used the operation control and best available technology (BAT) as bag filters to control dust emissions from the kiln stack. After energy transition in 2015 to 2020 to fuel mix coal and alternative fuels the concentrations of total suspended particulate TSP start to increasethan in 2014 as in Table 3 and Fig. 3 but still lower than AQL even though using different types of wastes as fuels but due to the process of clinker production in kiln systems creates favorable conditions for use of alternative fuels. These include: high temperatures, long residence times, an oxidizing.

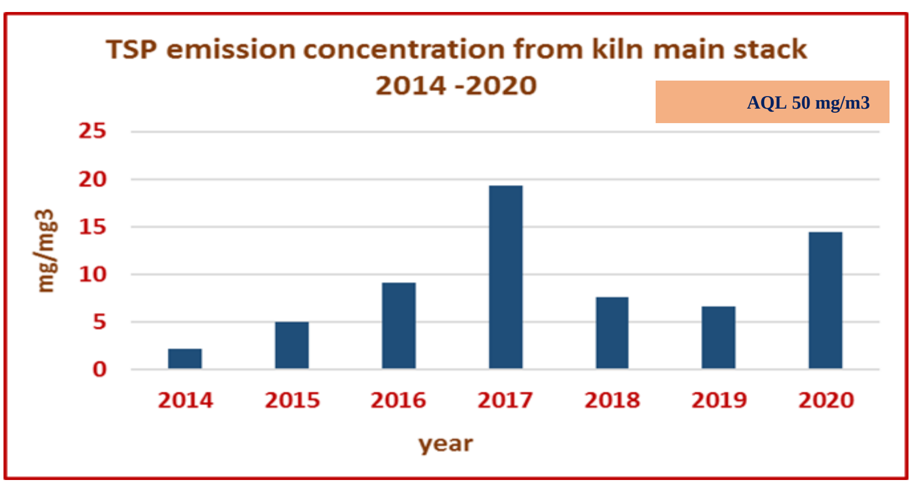

Fig. 3. TSP emission concentrations.

Table 3. Air emission monitoring for (TSP, SO_2, NO_X) during study period 2014- 2020.

Years / Items	2014	2015	2016	2017	2018	2019	2020	AQL mg/m^3
(TSP)	2.17	5.03	9.09	19.34	7.63	6.62	14.46	50
NOx	613.3	688.34	576.70	567.84	554.97	399	548.25	600
SO2	38.48	17.37	23.91	23.95	11.05	17.07	44.18	400

Atmosphere, alkaline environment, ash retention in clinker, and high thermal inertia, these conditions ensure that the fuel's organic part is destroyed and fuel ash is incorporated into the clinker and combined in the product which reduced the dust emissions in addition of using best available technology (BAT) as bag filters to control dust emissions.

Nitrogen oxides NO_x concentrations

During 2014 and 2015 the concentration was 613.3 mg/m^3 and 688.34 mg/m^{3}higher than AQL 600 mg/m$_3$ and that is due to using only one fuel type as natural gas in 2014andcoal 2015 and with high temperature of cement production process in kiln the NO_x is emits with high concentrations and that is one of the big challenging in choosing fuel type. During 2016 to 2020 the concentration of NO_x was lower than AQL 600 mg/m^{3}and that is due to start using energy mix especiallyusing agriculture waste AW, refuse drive fuelRDF which leads to reduce the NO_x concentrations as in Table 3 and Fig. 4.

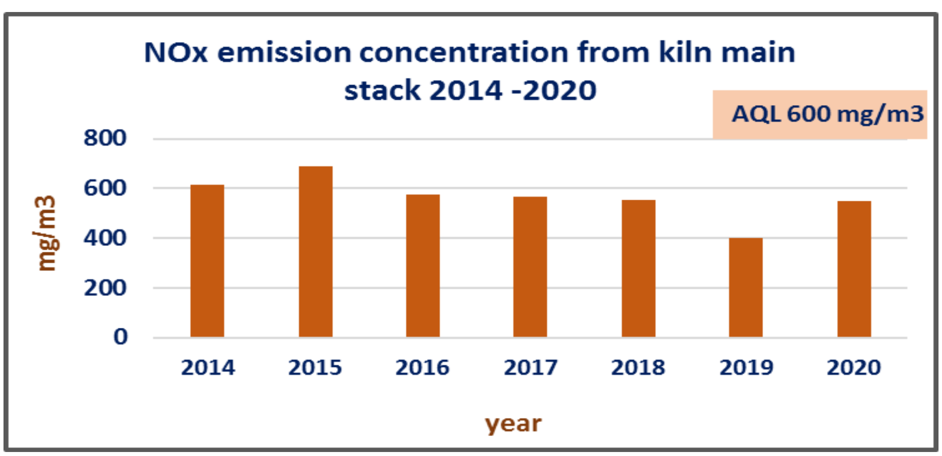

Fig.4. NO_X emission concentrations

Sulfur dioxides (SO_2) concentrations

For Sulfur dioxides (SO_2) the concentrations in 2014 when using natural gas was below AQL also during 2015 to 2020 when energy transition occurred by using coal and alternative fuels as fuel mix the concentrations was below AQL as in Table 3 and Fig. 5 that is due to the cement kiln system's extremely alkaline internal environment provides favorable conditions for SO_2 to directly absorb into the product, reducing the amount of SO_2 emissions in the exhaust stream.

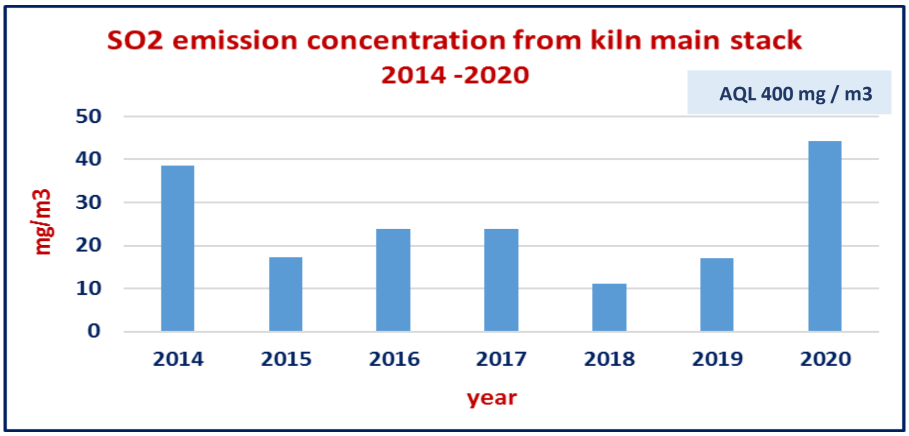

Fig. 5. SO_2 emission concentrations.

Conclusion

In 2012 the Egyptian government diverted natural gas from cement industrial sectors, the executive regulation Decree 964/2015 was drafted by the Egyptian government to address the mitigation options available to cement companies that use coal as a fuel. The cement company (case study) start using coal as primary fuel and different types of alternative fuels as secondary source of energy like waste oil, refuse derived fuels, tiers, dried sewage sludge. The rustles showed that concentrations of total suspended particulate (TSP) and Sulfur dioxides (SO_2) was lower than AQL during study period 2014 to 2020 while the concentration of Nitrogen oxides NO_x was higher than AQL. During 2014 and 2015 due to using only one fuel type as natural gas in 2014 and coal 2015 and with starting using big amount of alternative fuels the concentration was lower than AQL. The result also showed that the using of appropriate energy mix and appropriate operation control and not relying on only one type of fuel leads to improvement environmental performance in the cement company.

References

Chamurova, I., Stanev, R., & Deliyski, N. 2017. RDF as an alternative fuel for the cement plants in Bulgaria. Journal of chemical technology and Metallurgy, 52(2), 355-361.

Chatziaras, N., Psomopoulos, C.S. and Themelis, N.J. 2016. "Use of waste derived fuels in cement industry: a review "Management of Environmental Quality, An International Journal, 27(2), 178-193.

Choate, W. T. 2003. Energy and emission reduction opportunities for the cement industry. BCS Inc., Laurel, MD (United States).

Galitsky, C. & Price, L. 2007. Opportunities for Improving Energy Efficiency, Reducing Pollution and Increasing Economic Output in Chinese Cement Kilns. Proceedings of the 2007 ACEEE Summer Study on Energy Efficiency in Industry. Washington, DC: American Council for an Energy-Efficient Economy.

Hosten, C. & Fidan, B. 2012. An industrial comparative study of cement clinker grinding systems regarding the specific energy consumption and cement properties. Powder Technology Journal 221: 183–188.

Ismail, I., Abdel Hafiez, H. E., Hamouda, A. &Soliman, A. 2014. Solutions and potentials to overcome the energy crises in Egyptian cement sector. In AUCBM 19th conference on cement technology.

Kääntee, U., Zevenhoven, R., Backman, R. & Hupa, M. 2004. Cement manufacturing using alternative fuels and the advantages of process modelling. Fuel processing technology, 85(4), 293-301.

Madsen, H., Thyregod, P., Popentiu, F., & Albeanu, G. 2004. Computer Aided Modeling and Pollution Control in Cement Plants. In Fourth Annual Meeting of ENBIS–20–22, Copenhagen, Denmark.

Mokrzycki, E., & Uliasz-Bocheńczyk, A. 2003. Alternative fuels for the cement industry. Applied Energy, 74(1-2), 95-100.

Egyptian Environment Law No. 4/1994. and its Executive Regulations, Promulgating a law concerning Environment', 1st Edn (Al matbaElAmeraya, Egypt, 1994).

Pieper, C., Liedmann, B., Wirtz, S., Scherer, V., Bodendiek, N., & Schaefer, S. 2020. Interaction of the combustion of refuse derived fuel with the clinker bed in rotary cement kilns: A numerical study. Fuel, 266, 117048.

Soule, M. H., Logan, J. S., Stewart, T. A. 2002. Trends, challenges, and opportunities in China's cement industry. Available from: http://www.wbcsdcement.org/final, Conches- Geneva, Switzerland, World Business Council for Sustainable Development, 51 pp (Mar 2002).

Twidale, S., & Bushra, S. 2014. Egypt's cement firms overcome gas shortages by importing coal. http://www.reuters.com/article/2014.

ZKG International, 2003. (Changes in the Indian cement industry). cement industries; 56 (1); 12-20.