

**COMPARATIVE ANALYSIS OF COAL, FUEL OIL AND NATURAL GAS
FOR CEMENT PRODUCTION**

BY

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CERTIFICATION

This is to certify that the project “COMPARATIVE ANALYSIS OF COAL, FUEL OIL AND NATURAL GAS FOR CEMENT PRODUCTION” was carried out by Akangumoh Mkpouto Joseph in accordance with the regulations governing the presentation of project for the award of Bachelor of Engineering degree (B.Eng) in Chemical Engineering, Caritas University, Enugu.

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APPROVAL

This project “COMPARATIVE ANALYSIS OF COAL, FUEL OIL AND NATURAL GAS FOR CEMENT PROODUCTION” has been approved by the board of internal and external examiners of the Department Of Chemical Engineering, Caritas University- Enugu.

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DEDICATION

I dedicate this project to Almighty God, who saw me through my academic struggle and by his mercy gave me sound health, understanding and inspiration to carry out this project work and to my darling parents Dr/Mrs. Joseph Akangumoh who were the financial backbone of my academic achievement.

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ABSTRACT

This study is a comparative analysis of the use of coal, fuel oil and natural gas for cement production noting their physical and chemical properties, cost and availability, impact on the environment and human health. Out of the seven cement manufacturing industries in Nigeria, three industries use these fuels were selected for the study. The industries are NigerCem –Ebonyi state, Dangote cement –Benue state and UniCem -Cross river state. Questionnaires were used to gather information on the three fuels. The likert 3- scale model was adopted, using 2.0 as the cut off mark. Based on the analysis of the study, it was observed out that amongst these three (3) fuels, fuel oil is presently expensive though available, while coal and natural gas are cheap but coal is not available due to the closure of Nigeria’s coal mine. In terms of environment and health, coal and fuel oil emit much harmful gases to the environment and cause more health problems to cement worker but natural gas emits less of these harmful gases to the environment and cause less health problems to workers. The study therefore shows that natural gas is the best fuel because it is cheap, readily available and creates fewer problems to the environment.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Energy is commonly defined as the ability to do work or to produce heat.

Normally heat could be derived by burning a fuel (i.e. a substance that contains internal energy which upon burning generates heat). (IEA, 2004).

The energy system today is highly dependent on fossil fuel with coal, fuel oil and natural gas accounting for about 80% of world primary energy demand. (Kul, 2001).

Fuels are the major source of energy for industries and cement industry is not an exception. However, the energy source to be adopted will have to meet the varying needs of different countries and at the same time enhance the security of each against the energy crisis that have taken place in the past. The selection/ choice of fuel type depend on various factors such as environmental pollution, ease in processing, storage and handling, availability and cost of the fuel.

Coal, fuel oil and natural gas are the most commonly used energy carrier in cement industries. The energy use for cement production is distributed as follows:-

- 92.7% for pyro-processing
- 5.4% for finishing grinding and
- 1.9% for raw grinding (Choate, 2003).

The choice of fuel use entails the level at which green house gases (GHG) are emitted, the cost of cement and the quality of the cement produced.

This research work will help in selecting the best fuel and techniques to be use in order to attain a high quality product at a lower cost with lesser green house gas emission to the environment.

1.2 STATEMENT OF PROBLEM

The choice of fuel is attained by comparative analysis of coal, fuel oil and natural gas in cement production. In comparing these fuels, the following problem arises:-

- Knowledge of the physio- chemical properties of coal, fuel oil and natural gas.
- Knowledge of the green houses gases (GHG) emitted by each of these fuel, their level of emission and their effects on the environment and humans health (esp. cement workers).
- Knowledge of the cost and availability of coal, fuel oil and natural gas.

1.3 AIMS AND OBJECTIVES OF STUDY

The aims of this research work is to;

- Study the physical and chemical properties of coal, fuel oil and natural gas.
- Gain knowledge on the green house gases (GHG) emitted, their effect on the environment and humans health and the level of emission from each fuel.
- Study coal, fuel oil and natural gas in relation to cost and availability.

1.4 SIGNIFICANCE OF THE STUDY

With the growth in industrialization today, this study will offer numerous values both to the cement industry and staff, the environment and society at large.

It will choose an economical and less hazardous fuel and techniques for cement production.

Also, it will help in the selection of techniques /fuel that will reduce the emission of green house gases (GHG) from cement industries to the environment. This gases emitted causes acid rain, smog etc. which can cause cancer to human and destroys plant lives.

In terms of infrastructural development, an economical fuel for production will lead to a reduction in the cost of cement, thereby encouraging the development of buildings and Government in development of roads, bridges, and other construction- oriented projects.

This study will also give students of chemical engineering and other related courses an insight of these fuels with their different environmental implications, properties and choice of fuel when combustion of fuel is required.

1.5 SCOPE AND LIMITATION

This study would have covered all the Nigerian cement industries but due to time and cost of analysis, it is limited to three(3) cement industries namely:- Dangote Cement in Gboko -Benue State, United Cement Company in Calabar - Cross River State(UniCem), and Nigerian Cement Company in Nkalagu -Ebonyi State

(NigerCem) of which each uses Fuel oil, natural gas and coal respectively as energy source.

The intention of the study is to cover the effects of coal, fuel oil and natural gas in the production of cement with reference to cost, storage and handling, availability, product quality and environmental impact.

CHAPTER TWO

LITERATURE REVIEW

2.1 ENERGY SOURCE

Fuels are the most important energy source in the world. Almost 80% of the energy which is used comes from fuel. (Kul, 2001). Fuels are the major source of energy for industries. Fossil fuel is used to collectively referred to coal, fuel oil and natural gas. Coal and natural gas are used in their natural forms, but petroleum requires distillation and refinement to give useable fuel.

2.1.0 Coal

Coal is the most abundant fossil fuel on the planet, with current estimates from 216 years global recoverable reserve. (IEA coal information, 2004). Coal provides 26% of global primary energy needs and generates 41% of the world's electrification. Total world electricity generation by coal projected for the year 2030 is 38%. (World coal institute report, 2005) Countries heavily dependent on coal for electric generation includes; China(78%), Israel(71%), Morocco(69%), USA(50%), South Africa(93%), Australia(80%) and Poland(93%). ins(World coal institute report, 2005)

Coal is formed by the partial decomposition of vegetable matter and is primarily organic in nature. It is a complex organic natural product that has evolved from

precursor materials over millions of years. It is believed that the formation of coal occurred over geological times in the absence of oxygen thereby promoting the formation of a highly carbonaceous product through the loss of oxygen and hydrogen from the original precursor molecules.

Coal is a dark, combustible material formed, through a process known as coalification, from plants growing primarily in swamp regions. (World coal institute, 2003). Layers of fallen plant material accumulated and partially decayed in these wet environments to form a spongy, coarse substance called peat. Over time, this material was compressed under sand and mud, and heated by the earth to be transformed into coal. Some scientists refer to coal as sedimentary rock. Coal is primarily composed of carbon, hydrogen, oxygen and nitrogen.

Types of Coal

The degree of change undergone by a coal as it matures from peat to anthracite known as coalification – has an important bearing on its physical and chemical properties and is referred to as the ‘rank’ of the coal.

1. Low rank coals, such as lignite and sub-bituminous coals are typically softer, friable materials with a dull, earthy appearance. They are characterized by high moisture levels and low carbon content, and therefore low energy content.

2. Higher rank coals are generally harder and stronger and often have a black, vitreous lustre. They contain more carbon, have lower moisture content, and produce more energy.

Coal Classification

There are several classifications of coal, which are rated according to their Carbon content and heating value. The heating value of coal is expressed in British Thermal Unit per pound(BTU/lb) or Joules per kilogram (J/kg).

Coal is classified into three major types namely:-

- Anthracite
- Bituminous and
- Lignite.

However there is no clear demarcation between them and coal is also further classified as semi- anthracite, semi-bituminous, and sub-bituminous.

1. **Anthracite** is the oldest coal from geological perspective. It is a hard coal composed mainly of carbon with little volatile content and practically no moisture. It is the hardest and most expensive coal, with a heating value of approximately 13,600 BTUs (31,634.96 J/kg). It contains 92-95% carbon.
2. **Bituminous coal** is a more developed coal and the most common type. With a heating value that ranges from approximately 11,250 –14,350BTUs (26,168.6 – 33,379.54 J/kg), it contains about 85% carbon. **Sub-bituminous**

coal, with an approximate heating value of 9,300 BTUs (21,632.73J/kg) contains about 78% carbon.

3. **Lignite** is the youngest coal from geological perspective. It is a soft coal composed mainly of volatile matter and moisture content with low fixed carbon (70% carbon). it has a heating value of approximately 7,000BTUs(16,282.7 J/kg)

A precursor to the formation of coal is peat. Peat, with a heating value of approximately 4,500 BTUs(10,467.5 J/kg), contains up to 60% carbon when dried. Peat hardens over time and under pressure into lignite, a cheap brown coal, containing approximately 70% carbon.

TYPES OF NIGERIAN COAL DEPOSITS

Nigerian coal deposits are of three types;

- Bituminous
- Sub-bituminous
- Lignite

Outstanding characteristics are low sulphur, ash and moisture content while heating values are high. These qualities make them very suitable for fuelling coal- fired power plants and hence good potential to contribute significantly to energy mix of the nation.

Nigeria has coal deposits located in about 15 states of the federation. The coal deposit of Anambra basin, located in the south-east, appears to contain the largest and most viable coal resources.

Other significant coal deposits includes :- Lafia Obi, Inyi (Enugu state), Afrikpo (Ebonyi state), and Gombe(Gombe state).

According to (Chawla, 2003), the particular characteristics of coal that underpin its prevalent use and makes it an attractive component of energy mix for many countries are:-

- **Availability;** commercial reserves of coal in different parts of the world means that exploiting indigenous coal resources or importing coal economically are practical options for most countries.
- **Useability:-** coal is relatively easy and safe to handle and store, thereby enhancing its usefulness in mitigating both physical and commercial risks.
- **Affordability:-** coal is a low cost option in most markets, and therefore it can play an important role in supporting economic development in developing countries.

Preparation of Coal

After mining, the coal is usually subjected to some so of preparation or physical treatment. Preparation of coal prior to feeding into the boiler is an important step for achieving good combustion.

Large and irregular lumps of coal may cause the following problems:

1. Poor combustion conditions and inadequate furnace temperature.
2. Higher excess air resulting in higher stack loss.
3. Increase of unburnts in the ash.
4. Low thermal efficiency.

(a) Sizing of Coal

Proper coal sizing is one of the key measures to ensure efficient combustion. Proper coal sizing, with specific relevance to the type of firing system, helps towards even burning, reduced ash losses and better combustion efficiency.

Coal is reduced in size by crushing and pulverizing. Pre-crushed coal can be economical for smaller units, especially those which are stoker fired. In a coal handling system, crushing is limited to a top size of 6 or 4mm. The devices most commonly used for crushing are;

- The rotary breaker
- The roll crusher and
- The hammer mill.

It is necessary to screen the coal before crushing, so that only oversized coal is fed to the crusher. This helps to reduce power consumption in the crusher.

Recommended practices in coal crushing are:

1. Incorporation of a screen to separate fines and small particles to avoid extra fine generation in crushing.

2. Incorporation of a magnetic separator to separate iron pieces in coal, which may damage the crusher.

Table 2.1; Proper size of coal for various types of firing system.

S. No.	Types of Firing System	Size (mm)
1.	Hand Firing (a) Natural draft (b) Forced draft	25-75 25-40
2.	Stoker Firing (a) Chain grate i) Natural draft ii) Forced draft (b) Spreader Stoker	25-40 15-25 15-25
3.	Pulverized Fuel Fired	75% below 75 micron*
4	Fluidized bed boiler	< 10 mm

(b) Conditioning of Coal

The fines in coal present problems in combustion on account of segregation effects. Segregation of fines from larger coal pieces can be reduced to a great extent by conditioning coal with water. Water helps fine particles to stick to the bigger lumps

due to surface tension of the moisture, thus stopping fines from falling through grate bars or being carried away by the furnace draft. While tempering the coal, care should be taken to ensure that moisture addition is uniform and preferably done in a moving or falling stream of coal.

If the percentage of fines in the coal is very high, wetting of coal can decrease the percentage of unburnt carbon and the excess air level required to be supplied for combustion. Table 2.2 shows the extent of wetting, depending on the percentage of fines in coal.

Table 2.2; Extent of Wetting: Fines Vs Surface Moisture in Coal.

Fines (%)	Surface Moisture (%)
10 - 15	4 - 5
15 - 20	5 - 6
20 - 25	6 - 7
25 - 30	7 - 8

(c) Blending of Coal

In case of coal lots having excessive fines, it is advisable to blend the predominantly lumped coal with lots containing excessive fines. Coal blending may thus help to limit the extent of fines in coal being fired to not more than 25%.

Blending of different qualities of coal may also help to supply a uniform coal feed to the boiler.

Uses of coal

Coal is one of the cheapest and most important sources of fuel responsible for about 41% of electricity production worldwide.

Coal is an essential raw material and fuel for important global industries like steel and cement. Different qualities of coal are used for different purposes; example coking coal with higher carbon percentage is used in steel production. Thermal coal is used in production of electricity.

- a) Electricity production:- Coal is mainly used as fuel to generate electricity through the process of combustion. Steam coal known as thermal coal is used in power stations to generate electricity.
- b) Steel production:- Steel industry is the second largest user of coal after electricity industry. Coal is an essential raw material along with iron in the production of steel which is one of the useful metal products used by man today.

Coking coal is a solid carbonaceous residue derived from low-ash, low-sulphur bituminous coal. Metallurgical coke is used as fuel to melt iron in the furnace. This cast iron which is produced is further refined to make steel.

- c) Cement industry:- Coal is used as energy source in the industry. Large amount of energy are required to produce cement. Kilns usually burn coal in the form of powder and by-product generated from burning coal in coal-

fired power plant such as fly ash, bottom ash, boiler slag and flue gas desulphurization gypsum are also used to replace cement in concrete.

- d) Paper industry and aluminum:- Both industries require large amount of fuel and energy. Coal being the cheapest energy resource forms an essential input to these industries. The price and availability of coal is an important factor in the growth of these industries.
- e) Chemical and pharma industry:- Several chemical products can be produced from the by-products of coal. Refined coal tar is used in the manufacture of chemicals such as creosote oil, naphthalene, phenol and benzene. Thousands of different product have coal or coal by-products as components:- Soap, aspirins, solvents, dyes, plastics and fibers' such as rayon and nylon.
- f) Coal gas and coal liquid s transport fuel:- Current transportation industry does not make much use of coal as fuel. However the increasing cost of oil gas and liquid which can be used to power vehicles, ships etc.

2.1.1 FUEL OIL

Fuel oil is a fraction obtained from petroleum distillation, either as a distillate or a residue. Broadly speaking, fuel oil is any liquid petroleum product that is burned in a furnace for the generation of heat or used in an engine for the generation of power. Fuel oil is made of long hydrocarbon chains, particularly alkanes, cycloalkanes and aromatics. Factually and in a stricter sense, the term fuel oil is used to indicate the heaviest commercial fuel that can be obtained from crude oil, heavier than gasoline and naphtha. (Narayan, 1998).

Fuel oil is classified into six classes, according to its boiling temperature, composition and purpose. The boiling point ranges from 175°C to 600 °C.

In terms of industrial use of fuel especially in cement kiln firing, heavy fuel oil or low pour fuel oil (LPFO). Heavy oil are long residue obtained from the atmospheric distillation column. Heavy fuel oil is used mainly too produce electricity, to fire boiler and furnance in industry, notable the cement, pulp and paper and to power large marine and other vessels.

2.12 NATURAL GAS

Natural gas is a fossil fuel like oil and coal, thus it is essentially the remains of plants, animals and microorganisms that lived millions and millions of years ago. Over the years, natural gas has secured its vital role in every aspect of the world development, particularly its role to replace coal and oil. Due to its different

characteristics from other types of petroleum, natural gas has been well accepted as the energy for the world of today and tomorrow. Nowadays, the public do not only need the energy for their livings but most of all, they also want a better choice for environment.

Natural gas is a mixture of various hydrocarbon gas known in scientific names i.e. methane, ethane, propane, and butane. Over 70% of natural gas is formed by methane, the major component.

Natural gas is a high calorific value fuel requiring no storage facilities. It mixes with air readily and does not produce smoke or soot. It has no sulphur content and is lighter than air and disperses into air easily in case of leak. It is colorless and odorless but due to security reasons, a commercial odorant known as mercaptan is added to allow users to detect the gas.

Industrial Utilization Of Natural Gas

Manufacture of pulp and paper, metals, chemicals, stone, clay, glass, and to process certain foods are various fields in which natural gas is effectively utilized. Gas is also used to treat waste materials, for incineration, drying, dehumidification, heating and cooling, and CO generation. It is also a suitable chemical feedstock for the petrochemical industry. Natural gas has a multitude of industrial uses, including providing the base ingredients for such varied products as plastic, fertilizer, anti-freeze, and fabrics. In fact, industry is the largest consumer of natural gas,

accounting for 43 percent of natural gas use across all sectors. Natural gas is the second most used energy source in industry, trailing behind only electricity.

Power Generation

Natural gas works more efficiently and emits less pollution than other fossil fuel power plants. Due to economic, environmental, and technological changes, natural gas has become the fuel of choice for new power plants.

Natural gas can be used as a motor fuel in two ways:-

- As compressed natural gas (CNG) and
- As liquefied natural gas (LNG).

Cars/ vehicles using natural gas are estimated to emit 20% less green house gases than gasoline or diesel cars. (Energy information administration (EIA))

2.2 CEMENT

Cement is the general term given to the powdered material which initially have plastic flow when mixed with water or other liquid but has the property of setting to a hard solid structure in several hours with varying degree of strength and bonding properties (European Cement Association,1996).

Cement production is a capital intensive activity and requires complex plants that are expensive to install and maintain.

Cement, a common and essential constituent of mortar and concrete, serves as the most common and widely used building material in the world.

2.2.0 Cement Manufacturing Process

1. Quarry

Most plants rely on a nearby quarry for ready access to limestone. The most common combination is limestone (for calcium) plus much smaller quantities of clay and sand (for silica, alum, iron).

Other sources such as mill scale, shale, bauxite, and fly ash are brought in from outside sources when necessary.

2. Proportioning, Blending, and Grinding

Raw materials are analyzed in the plant laboratory, blended in the proper proportion and then finely ground. Plants grind the raw materials with heavy wheel type rollers that crush these materials into powder against a rotating table. After grinding, the material is now ready for the kiln or pre-heater; depending on plant type.

3. Pre-heating

The pre-heater tower supports a series of vertical cyclone chambers through which the raw materials pass on their way to the kiln. To save energy, modern cement plants pre-heat the materials before they enter the kiln. Rising more than 200 feet, hot exit gases from the kiln heat the raw materials as they swirl through the cyclones.

4. Kiln

Raw materials now enter the huge rotating furnace called a kiln, which is the heart of the cement making process- a horizontally sloped steel cylinder, lined with fire brick, turning from about one to three revolutions per minute. Typically, a kiln is the world's largest piece of moving industrial equipment. The raw material enters the kiln at the upper end and slides/tumbles down the kiln through progressively hotter zones towards the flame. At the lower end of the kiln, fuels such as powdered coal and natural gas feed a flame that reaches 1870 °C (3400 °F) – one third of the temperature of the earth's surface. This is the hottest part of the apparatus and the raw materials reach about 2700°F (1480°C) and become partially molten.

5. Calcination

Intense heat triggers chemical and physical changes. Expressed at its simplest, these series of chemical reactions converts the calcium and silicon oxides into calcium silicates, cement's primary constituent, through a process known as *calcination*. At the lower end of the kiln, the raw materials emerge as a new substance; red-hot particles called clinker.

6. Clinker Cooler and Finish Grinding

The clinker tumbles out on to a grate that is cooled by forced air. Once cooled, the clinker is ready to be ground into the gray powder known as Portland cement.

Re-circulate: to save energy, heat recovered from this cooling process is circulated back through to the kiln or pre-heater tower.

7. Ball-mill and Finish Grinding

The clinker is ground in a ball mill (a horizontal steel tube filled with steel balls). As the tube rotates, the steel balls tumble and crush the clinker into a superfine powder considered as Portland cement. The cement is so fine it will easily pass through a sieve that is fine enough to hold water. A small amount of gypsum is added during the final grinding to control the set. Gypsum is a mineral that slows down the hardening process of the powder after it has been mixed with water and makes it moldable before application.

8. Bagging and Shipping

Silos: From the grinding mills, the cement is conveyed to silos where it awaits shipment.

Transportation: Most cement is shipped in bulk by trucks, rail, or barges.

Bagging: A small percentage of the cement is bagged for customers who need only small amounts or for special uses such as making mortar. Most cement is shipped to ready-mixed concrete producers. There it is combined with water, sand, and gravel to make concrete delivered in the familiar trucks with revolving drums. Cement is also used for a wide variety of pre-cast concrete products.

(Portland Cement Association (PCA)).

There are four(4) main process routes for the manufacturing of cement namely:-

- a) **Dry process**:- The raw materials are ground and dried to raw meal in the form of a flow- able powder. The dry raw meal is fed to the pre-heater or pre-calciner kiln or, more rarely, to a long dry kiln.
- b) **Semi-dry process**:- Dry raw meal is palletized with water and fed into a grate pre-heater before the kiln or to a long kiln equipped with crosses.
- c) **Semi-wet process**:- The slurry is first dewatered in filter presses. The filter cake is extruded into pellets and fed either to a grate pre-heater or directly to a filter cake drier for raw meal production.
- d) **Wet process**:- The raw materials (often with high moisture content) are ground in water to form pump-able slurry. The slurry is either fed directly into the kiln or first to slurry drier.

The choice of process is to a large extent determined by the state of the raw materials (dry or wet). Wet processes are more energy consuming, and thus more expensive. Plants using semidry processes are likely to change to dry technologies whenever expansion or major improvement is required. Plants using wet or semi-wet processes normally only have access to moist raw materials. The dry process consumes less energy and runs at a lower cost.

Currently, the production technology employed most commonly is the dry process technology.

Factors affecting production quality are:

- The composition of limestone.
- Particle size
- Degree of calcining/ burnability
- Degree of homogeneity.

2.2.1 Major Characteristics of Cement Industry

- **Homogenous Product:-** Cement is considered as a standard product because of its homogeneity status, all kinds of Cement are considered to be homogenous when they are perfect substitute and consumers perceived no actual or real differences between the products offered by different firms. The only instrument for competition in a cement industry is price where if Company A lowers its price to gain market share, company B may follow suit so as to retain its customers.
- **Capital Intensive:-** The high cost of constructing a cement plant has ranked the industry among the most capital intensive industries in any country. Long time periods are therefore needed before investments can be recovered and plant modifications have to be carefully planned and must take account of the long-term nature of the industry. This makes cement industry to be low labour intensive due to the development of modern automated machinery and continuous material handling devices. In the Europe, the cement factory

represents 58, 000 direct jobs but a modern plant is usually manned by less than 150 people.

- **High Energy Usage:-** Cement manufacturing requires high consumption of fuel from the first stage of production till the last stage. Each tonne of cement produced requires 60 to 130 kilogrammes of fuel oil or its equivalent, depending on the cement variety and the process used, and about 105 KWh of electricity may be used which also means high cost.
- **Heavy Material Input and Output:-** Cement production requires heavy material input such as limestone, transportation of limestone as a major raw material in cement production is cumbersome and this is the reason while cement factories are located very close to limestone deposit. The finished good, cement, is also very heavy and requires huge cost of transportation which impacts on price of cement.

2.2.2 Energy challenge in the industry

The high cost of manufacturing cement is a global phenomenon, mainly because of the large amounts of energy utilized during the production process. Power supply (electricity) is essential for operating the machines, while fuel (LPFO, coal and natural gas) is required for firing the kilns. Each tonne of cement requires 60-130kg of fuel oil or its equivalent, depending on the cement variety and process used, and about 105kwh of electricity. Energy supply continues to pose challenges for cement operators in Nigeria. The estimated annual power requirement for Manufacturers is

25000/30000 MW, however, the Power Holding Corporation of Nigeria (PHCN) generates only about one-tenth of this requirement. The inconsistency in the supply of energy during the first half of 2008 hampered the rate of production and led to loss of production days in some cement production plants. In order to maintain or increase their production output, manufacturers have to generate alternative power, thereby increasing production costs and reducing their profits. On a five-year average basis, the ratio of cost of sales to turnover is 60% (an improvement from 80-90% recorded in the early 2000s due mainly to technological improvements. (Companies Annual Reports, AIS Research)

In addition, high fuel prices and shortages in supply are twin challenges faced by cement manufacturers.

The price of diesel and LPFO has increased by over 100% in the last three years, while militant activities in the oil-rich Niger Delta region of Nigeria continues to hinder the steady supply of natural gas. Consequently, many production plants have seen their production outputs fall drastically and their profitability.

Cement companies are facing up to this challenge in various ways. For instance, as a substitute to the expensive and erratic supply of low pour fuel oil (LPFO),

AshakaCem switched to the use of coal and embarked on a coal-mining project.

This is expected to reduce its overall energy costs, and guarantee supply in the long-run. It also embarked on roller press refurbishment to reduce power consumption on cement grinding and increase efficiency of the cement mill. Lafarge

WAPCO has also embarked on the installation of gas fired power plants to cut energy costs and guarantee power supply to its plants. But for its erratic supply, natural gas is considered one of the more efficient energy sources for Nigerian cement production.

2.2.3 Demand for cement

It is fairly challenging task to estimate demand for cement. The best practice approach is to estimate demand through actual consumption.

The demand for cement is a function of construction activity spurred by growth and development of an economy, and the continuous inflow of investment into the development of both residential and commercial estates by government, corporate, and private developers.

Recently, it has been noticed that cement consumption in Nigeria has grown significantly. Nigeria is an emerging economy with growth potential in several economic and social sectors. Rapid urbanization has become a major challenge with the intensification of rural – urban migration. The situation has put pressure on the already inadequate social infrastructure including roads , housing, and other social overhead capital. There is therefore great need for cement. In terms of infrastructure development, government is currently entering into various forms of partnership with the private sector to develop roads, bridges, fly-over and other

construction-oriented projects. These projects contribute to the rising demand of cement.

2.2.4 Emissions from cement manufacturing

The clinker burning is the most important part of the cement manufacturing process in terms of the key environmental issues of energy use and emissions to air. Clinker making accounts for up to 90% of the total energy consumption of cement manufacturing. Further key environmental emissions are nitrogen oxides (NO_x), sulphur dioxide (SO_x), carbon dioxide(CO₂) and dust.

The production process is energy intensive, resulting in emission /release of environmental pollutants at almost all it stages of process.

The pollution outputs from cement manufacturing plants include;

- Dust (stack emission and fugitives source)
- Gaseous atmospheric emission (NO_x, SO_x, CO_x, VOC etc)
- Other emissions (noise and vibration, odour, process waste water, production waste etc)
- Plant maintenance waste such as waste oil from equipment lubrication, and research and laboratory waste.

Dust and gaseous atmospheric emission during operation of the cement plant are the main pollutant. Dust is generated at all stages in cement manufacturing process. The

dust generation is basically from the stack of various sections like crusher, raw mill, kiln system, clinker cooler, cement mill and packing plant. These are known as process dust or point stack source. While dust arising from material handling, storage and transportation etc. is known as fugitive source. Fugitive dust emission can arise during the storage and handling of materials and solid fuels and also from road surface. The emission of odour may be mainly traced to emission from the burning of sulphur containing fuel and/or use of sulphur containing raw material.

Green House Gas (GHG) Emissions

Cement production is an energy intensive process that results in greenhouse gas emissions from both fuel combustion and the chemical process of calcination that occurs during clinker production. As a result, the global cement industry is a major contributor to anthropogenic greenhouse gas (GHG) emissions (Soares, 2006).

Practically all fuel is used during pyroprocessing during the production of the clinker. The pyroprocess removes water from the raw meal, calcines the limestone at temperatures between 900 and 1000°C and finally clinker the kiln material at about 1500 °C. The amount of gases emitted during this process is influenced by the type of fuel used (coal, fuel oil, natural gas).

The emission of NO_x, SO_x, CO₂, etc. occurs during the production of clinker.

The main environmental challenges facing the cement manufacturing industry are:-

- Release of air of oxides of Nitrogen (NO_x), Sulphur oxide(SO_x), particulates and Carbon-dioxide(CO_2)
- Use of resources, especially primary raw materials and fossil fuel
- Generation of waste

Nitrogen oxide(NO_x), is formed during fuel combustion by oxidation of the molecular nitrogen of the combustion air as well as the nitrogen compounds in the fuels and raw materials.

NO_x formation is an inevitable consequence of the high temperature combustion process, with a smaller contribution resulting from the chemical composition of the fuels and raw materials.

Sulphur oxide (SO_x), is formed during fuel combustion, releases of SO_2 in the burning zone of the kiln (from sulfates, e.g. CaSO_4) and oxidation of pyrite/marcasite (sulphide) and organic sulphur in the preheater or in the kiln inlet. Sulphur entering the kiln system through raw materials and fuels is largely captured in the kiln products. However, sulphur contained in raw materials as sulphides (or organic sulphur compounds) is easily volatilized at fairly low temperatures (i.e. 400- 600 °C) and may lead to considerable SO_x emissions in the stack.

Due to the dominant use of carbon intensive fuels, e.g. coal, in clinker making, the cement industry is a major emitter of CO₂ emissions. Besides energy consumption, the clinker making process also emits CO₂ due to the calcining process. The cement industry contributes 5% of total global carbon dioxide emissions. The total CO₂ emission during the cement production process depends mainly on;

- Combustion of fuel and
- Calcination of limestone in raw mix($\text{CaCO}_3 \longrightarrow \text{CaO} + \text{CO}_2$)
- Types of production process(Dry/ Wet process)

Thus, Carbon dioxide emissions in cement manufacturing come directly from combustion of fossil fuels and from calcining the limestone in the raw mix.

Emissions of carbon dioxide can be reduced by:

- Improvement of the energy efficiency of the process
- Shifting to a more energy efficient process (e.g. from wet to dry process)
- Replacing high carbon fuels by low carbon fuels.
- Removal of CO₂ from the flue gases

The combustion of fossil fuels releases harmful emissions into air which influence the greenhouse effect as well as direct health problems of human beings. Major emissions of NO_x, SO_x, CO₂ and particulate matter are the cause of majority of the

concern for pollution of the environment resulting in the increase of ozone level in the lower atmosphere, acid rain and warming of the atmosphere.

Effect of pollutants on human beings includes; CO causes heart disease, strokes, pneumonia, tuberculosis and congestion of brain and lungs. SO_x causes Acute respiratory infection (chronic pulmonary or cardiac disorders). and NO_x causes Chronic respiratory infection. Emissions such as SO_x and NO_x contributes to the formation of smogs and acid rain. Mercury is linked to various neurological and productive impairment and CO₂ emission is one of the leading causes of global warming. [Energy Information administration (EIA)]

2.3 Conceptual framework

Independent variables

Dependent variable

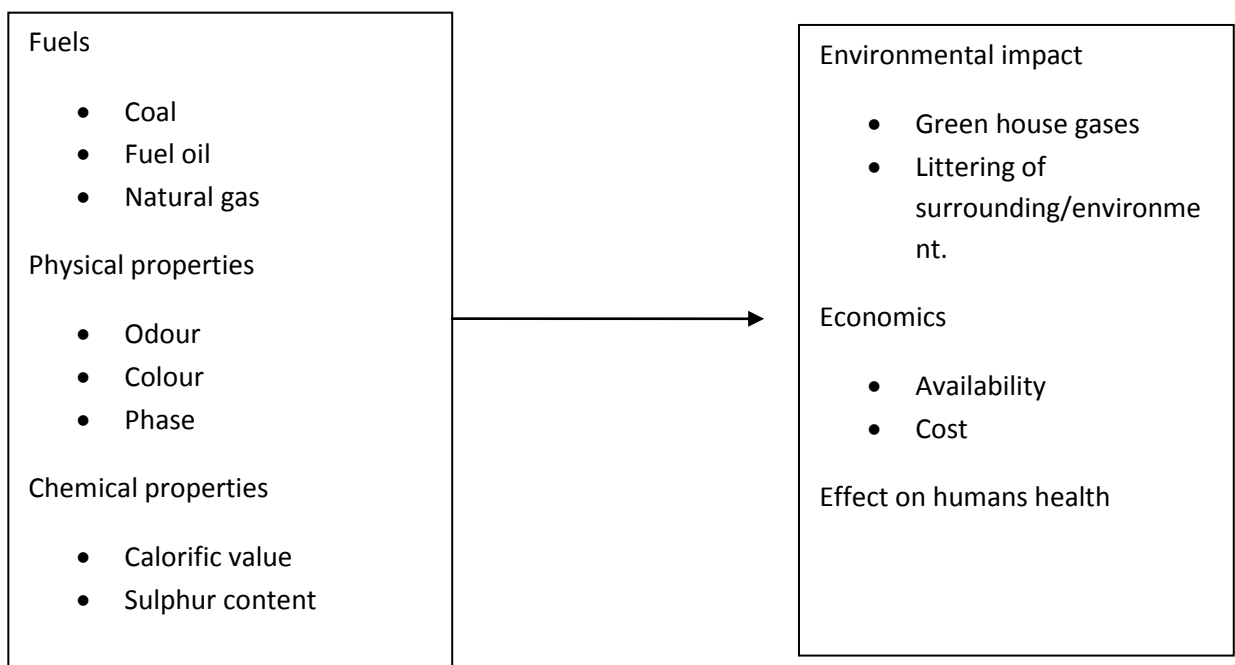


Fig 2.1:-The schematic diagram of the study.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 RESEARCH METHOD

In conducting this research, the researcher employed the quasi- experimental design, using particularly the cross sectional design of questionnaire and interview was administered to study subjects in the normal state of life so as to assess their responses about specific variables under study.

3.2 SAMPLE PROCEDURE/ SAMPLE SIZE DETERMINATION

The sample is composed of 52 respondents randomly drawn from three cement industries namely Nigerian cement company (NigerCem) - Ebonyi state , Dangote cement- Benue state and United cement company (UniCem) – Cross river state in Nigeria. These three companies were chosen because it was fit that each of them uses coal, fuel oil or natural gas as energy source in production of cement from which the economical and environmental impact of these fuels on cement can be comparatively analyzed with the anticipated population of 60, the sample size was determined using Yaro Yamari technique.

$$n = \frac{N}{1 + N(e)^2}$$

Where N = population = 60

e = margin of error (0.05)

1 = constant and

n = sample size.

$$\text{Therefore, } n = \frac{60}{1 + 60(0.05)^2}$$

$$= \frac{60}{1 + 60(2.5 \times 10^{-3})}$$

$$= \frac{60}{1 + 0.15}$$

$$= 52.17 \approx 52$$

3.3 DATA COLLECTION

The main instrument for data collection was the use of questionnaire. This instrument contained two types of questions namely:-

- Structured questions; which offered the respondents optional answers from which they were required to choose from.
- Unstructured question; which is the opened ended type that allowed the respondents to answer the question by themselves.

The researcher paid personal visit to three(3) Nigerian cement industries in their various locations and obtained permission from the managing directors (MDs) to conduct the study by administering the questionnaire.

3.4 OPERATIONAL MEASURES OF THE VARIABLES

To ensure the criteria for evaluating sufficiency of criterion measures, the researcher adopted the use of the Yaro Yamari formula as the operational measure of variables so as to enhance the viability and reliability of the dependent and independent variables considering the population size under study.

3.5 RESEARCH ANALYSIS

To analyze the data that should be generated, the three (3) Nigerian cement industries were used to access the extent to which coal, natural gas and fuel oil contributes to the cost of cement and their effect on the environment and humans health.

The scores was demarcated according to the variable of technology process employed (wet or dry) and choice of fuel. The data obtained will be analyzed using likert's opinion scale model. In line to this approach, construction of statement will be done on scale basis. The respondent options are weighted, that is, high/most economical (3 points), low/ economical (2 points), and unknown/ not economical(1 point).

The mean deviation of the likert's scale will be used to evaluate the responses of the individuals to the questions. A mean score will be chosen. Scores above the mean score will be high/ economical and that below the mean score will be low/not economical .This method is chosen for simple interpretation and analyzation of the data that are normative

CHAPTER FOUR

PRESENTATION AND ANALYSIS OF DATA

This chapter presents the data that were collected and analysed in order to proffer solutions to the statement of problems. The study was carried out in three(3) Nigerian cement industries namely; Nigeria Cement Company- Ebonyi state(NigerCem), Dangote Cement Company – Benue state and United Cement Company- Cross River State (UniCem). The questionnaire distributed and returned was 60. 20 copies of the questionnaire was distributed to each of the three (3) cement industry. However, the Yaro Yamani formula was used to collect the sample size of 52 of which 18, 17 and 17 questionnaires were drawn out from NigerCem, Dangote cement and UniCem respectively. The likert’s 3-scale model was adopted as an instrument for data analysis with 2.0 as cut-off mark.

Weighing scale

Responses	Scale
High/Most Economical	3.0
Low/ Economical	2.0
Unknown/ Not Economical	1.0

1. What is your company's name, which of these fuel is used and what technological process is employ?

Table 4.1; Company's name, the type of fuel used and the process employ in production.

CEMENT INDUSTRIES	FUEL USE	PROCESS EMPLOY
Nigerian cement industry- Ebonyi state.	Coal	Wet process
Dangote cement industry- Benue state	Fuel oil	Dry process
United cement industry- Cross River State.	Natural gas	Dry process

Table 4.1 above shows that NigerCem uses coal as its source of energy and employs the Wet process technology in cement production whereas, Dangote cement and Unicem uses fuel oil and natural gas as energy source respectively and the two (2) companies employs the dry process technology.

2. Describe the fuel in terms of colour, odour and phase.

Table 4.2: Physical Properties of Fuels

Criteria	Coal	Natural gas	Fuel oil
Colour	Black	Colourless	Black
Odour	Odourless	Odourless	Pungent odour
Phase	Solid	Gaseous	Liquid

Table 4.2 shows the physical properties of coal, fuel oil and natural gas basically on the fuel's colour, odour and phase. The table shows that coal is a black, odourless and solid fuel, *fuel oil* is a black liquid fuel with a pungent smell and natural gas is an odourless, colourless, gaseous fuel

3. What are the chemical properties of these fuels?

Table 4.3(a); The level of calorific value in coal, fuel oil and natural gas.

(a) What is the level of calorific value of the fuel?

Fuels	Scale (x)	Frequency (f)	Fx	Mean deviation = $\Sigma fx/N$	Recommendation
Coal	3.0	9	27	$\Sigma fx = 38$ and N= 18. $\therefore 38 \div 18 = 2.1$	High
	2.0	2	4		
	1.0	7	7		
Fuel oil	3.0	3	9	$\Sigma fx = 32$ and N=17 $\therefore 32 \div 17 = 1.9$	Low
	2.0	9	18		
	1.0	5	5		
Natural gas	3.0	7	21	$\Sigma fx = 34$ and N=17 $\therefore 34 \div 17 = 2.0$	Moderate
	2.0	3	6		
	1.0	7	7		

This table shows the mean deviation for coal's calorific value level is high, while that of fuel oil and natural gas are low and moderate respectively.

3(b). What is the level of sulphur contained in the fuel?

Table 4.3(b); The level of sulphur contained in coal, fuel oil and natural gas

Fuels	Scale (x)	Frequency (f)	fx	Mean deviation = $\Sigma fx/N$	Recommendation
Coal	3.0	6	18	$\Sigma fx = 39$ and N= 18. $\therefore 39 \div 18 = 2.2$	High
	2.0	9	18		
	1.0	3	30		
Fuel oil	3.0	12	36	$\Sigma fx = 42$ and N=17 $\therefore 42 \div 17 = 2.5$	High
	2.0	1	2		
	1.0	4	4		
Natural gas	3.0	1	3	$\Sigma fx = 31$ and N=17 $\therefore 31 \div 17 = 1.8$	Low
	2.0	12	24		
	1.0	4	4		

This table shows that the sulphur content in coal and fuel oil is high while that of natural gas is low.

4. Which of these fuel is most economical?

(a). How availability of the fuel?

Table 4.4(a); The level of availability of coal, fuel oil and natural gas.

Fuels	Scale (x)	Frequency (f)	fx	Mean deviation = $\Sigma fx/N$	Recommendation
Coal	3.0	2	6	$\Sigma fx = 34$ and N= 18. $\therefore 39 \div 18 = 1.9$	Low
	2.0	12	24		
	1.0	4	4		
Fuel oil	3.0	12	36	$\Sigma fx = 43$ and N=17 $\therefore 43 \div 17 = 2.5$	High
	2.0	2	4		
	1.0	3	3		
Natural gas	3.0	10	30	$\Sigma fx = 41$ and N=17 $\therefore 41 \div 17 = 2.4$	High
	2.0	4	8		
	1.0	3	3		

From the table above, coal is low in availability but fuel oil and natural gas are high in availability.

4b. How economical is the fuel?

Table 4.4(b) The economics of coal, fuel oil and natural gas

Fuels	Scale (x)	Frequency (f)	fx	Mean deviation = $\Sigma fx/N$	Recommendation
Coal	3.0	10	30	$\Sigma fx = 43$ and N= 18. $\therefore 43 \div 18 = 2.4$	High
	2.0	5	10		
	1.0	3	3		
Fuel oil	3.0	1	3	$\Sigma fx = 25$ and N=17 $\therefore 25 \div 17 = 1.5$	Low
	2.0	6	12		
	1.0	10	10		
Natural gas	3.0	13	39	$\Sigma fx = 46$ and N=17 $\therefore 46 \div 17 = 2.7$	High
	2.0	3	6		
	1.0	1	1		

From the table above, coal and natural gas are highly economical but fuel oil is lowly economical.

5. The level of difficulties encountered in processing the fuel.

Table 4.5; The level of difficulties encountered in processing coal, fuel oil and natural gas.

Fuels	Scale (x)	Frequency (f)	fx	Mean deviation = $\Sigma fx/N$	Recommendation
Coal	3.0	9	27	$\Sigma fx = 43$ and N= 18. $\therefore 39 \div 18 = 2.4$	High
	2.0	7	14		
	1.0	2	2		
Fuel oil	3.0	8	24	$\Sigma fx = 36$ and N=17 $\therefore 36 \div 17 = 2.1$	High
	2.0	3	6		
	1.0	6	6		
Natural gas	3.0	5	15	$\Sigma fx = 35$ and N=17 $\therefore 35 \div 17 = 2.1$	High
	2.0	8	16		
	1.0	4	4		

This table shows that coal, fuel oil and natural are difficult in processing but coal happens to be more difficult in processing.

6. The level at which the fuel litters the surrounding/factory.

Table 4.6; The Level at which coal, fuel oil and natural gas litter the surrounding/factory.

Fuels	Scale (x)	Frequency (f)	fx	Mean deviation = $\Sigma fx/N$	Recommendation
Coal	3.0	12	36	$\Sigma fx = 46$ and N= 18. $\therefore 46 \div 18 = 2.6$	High
	2.0	4	8		
	1.0	2	2		
Fuel oil	3.0	3	9	$\Sigma fx = 33$ and N=17 $\therefore 33 \div 17 = 1.9$	Low
	2.0	10	20		
	1.0	4	4		
Natural gas	3.0	1	3	$\Sigma fx = 32$ and N=17 $\therefore 32 \div 17 = 1.8$	Low
	2.0	13	23		
	1.0	3	3		

The table shows that coal litter the surrounding at a higher rate compared to fuel oil and natural gas.

7. The level at which cement workers encounters health issues due to inhalation from the industry.

Table 4.7; The level at which cement workers encounters health problem.

Fuels	Scale (x)	Frequency (f)	fx	Mean deviation = $\Sigma fx/N$	Recommendation
Coal	3.0	9	27	$\Sigma fx = 41$ and N= 18. $\therefore 41 \div 18 = 2.3$	High
	2.0	5	10		
	1.0	4	4		
Fuel oil	3.0	11	33	$\Sigma fx = 41$ and N=17 $\therefore 41 \div 17 = 2.4$	High
	2.0	2	4		
	1.0	4	4		
Natural gas	3.0	2	6	$\Sigma fx = 31$ and N=17 $\therefore 31 \div 17 = 1.8$	Low
	2.0	10	20		
	1.0	5	5		

From table 4.7, the health of workers is highly affected in coal and fuel oil utilization industries compared to natural gas utilization industries.

8. The level of Green house gases emission from coal, fuel oil and natural gas.

8a. The level of NO_x emission from the fuel.

Table 4.8a; The emission level of Nitrogen oxides (NO_x)

Fuels	Scale (x)	Frequency (f)	Fx	Mean deviation = $\Sigma fx/N$	Recommendation
Coal	3.0	10	30	$\Sigma fx = 43$ and N= 18. $\therefore 43 \div 18 = 2.4$	High
	2.0	5	10		
	1.0	3	3		
Fuel oil	3.0	11	33	$\Sigma fx = 41$ and N=17 $\therefore 41 \div 17 = 2.4$	High
	2.0	2	4		
	1.0	4	4		
Natural gas	3.0	2	6	$\Sigma fx = 32$ and N=17 $\therefore 32 \div 17 = 1.9$	Low
	2.0	11	22		
	1.0	4	4		

Table 4.8a shows that coal and fuel oil emits a high level of nitrogen oxides and natural gas emits low level of nitrogen oxide.

8b. The level of SO_x emission from the fuel.

Table 4.8b; The emission level of Sulphur oxides (SO_x)

Fuels	Scale (x)	Frequency (f)	Fx	Mean deviation = $\Sigma fx/N$	Recommendation
Coal	3.0	11	33	$\Sigma fx = 43$ and N= 18. $\therefore 43 \div 18 = 2.4$	High
	2.0	3	6		
	1.0	4	4		
Fuel oil	3.0	10	30	$\Sigma fx = 40$ and N=17 $\therefore 40 \div 17 = 2.4$	High
	2.0	3	6		
	1.0	4	4		
Natural gas	3.0	1	3	$\Sigma fx = 29$ and N=17 $\therefore 29 \div 17 = 1.9$	Low
	2.0	10	20		
	1.0	6	6		

Table 4.8b shows that coal and fuel oil emits a high level of sulphur oxides and natural gas emits low level of sulphur oxide.

8c. The level of CO₂ emission from the fuel.

Table 4.8c; The emission level of Carbon dioxides (CO₂) from coal, fuel oil and natural gas

Fuels	Scale (x)	Frequency (f)	Fx	Mean deviation = $\Sigma fx/N$	Recommendation
Coal	3.0	8	24	$\Sigma fx = 37$ and N= 18. $\therefore 37 \div 18 = 2.1$	High
	2.0	3	6		
	1.0	7	7		
Fuel oil	3.0	7	21	$\Sigma fx = 36$ and N=17 $\therefore 36 \div 17 = 2.1$	High
	2.0	5	10		
	1.0	5	5		
Natural gas	3.0	4	12	$\Sigma fx = 35$ and N=17 $\therefore 35 \div 17 = 2.1$	High
	2.0	10	20		
	1.0	3	3		

Table 4.8c shows that coal and fuel oil and natural gas emits high level of Carbon dioxide to the environment.

8d. The level of CO emission from fuels.

Table 4.8d; The emission level of Carbon monoxides (CO)

Fuels	Scale (x)	Frequency (f)	Fx	Mean deviation = $\Sigma fx/N$	Recommendation
Coal	3.0	10	30	$\Sigma fx = 42$ and N= 18. $\therefore 42 \div 18 = 2.3$	High
	2.0	4	8		
	1.0	4	4		
Fuel oil	3.0	10	30	$\Sigma fx = 41$ and N=17 $\therefore 41 \div 17 = 2.4$	High
	2.0	3	6		
	1.0	5	5		
Natural gas	3.0	1	3	$\Sigma fx = 31$ and N=17 $\therefore 31 \div 17 = 1.8$	Low
	2.0	12	24		
	1.0	4	4		

Table 4.8d shows that coal and fuel oil emits high level of Carbon monoxide while natural gas emits less of CO to the environment.

9. The level at which the fuel affects the quality of the cement produced.

Table 4.9;The level of fuel’s effect on the product quality.

Fuels	Scale (x)	Frequency (f)	fx	Mean deviation = $\Sigma fx/N$	Recommendation
Coal	3.0	9	27	$\Sigma fx = 40$ and N= 18. $\therefore 40 \div 18 = 2.2$	High
	2.0	4	8		
	1.0	5	5		
Fuel oil	3.0	2	6	$\Sigma fx = 33$ and N=17 $\therefore 33 \div 17 = 1.9$	Low
	2.0	12	24		
	1.0	3	3		
Natural gas	3.0	1	3	$\Sigma fx = 23$ and N=17 $\therefore 23 \div 17 = 1.6$	Low
	2.0	9	18		
	1.0	7	7		

Table 4.9 shows that the use of coal for production highly affects the quality of cement produced whereas fuel oil and natural gas affects the product at a lower rate.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY OF FINDINGS

Based on the findings, it has been discovered in the course of study that coal is an odourless, black solid fuel with high calorific value and sulphur content, fuel oil is a black liquid fuel with pungent smell, low calorific value and high sulphur content and natural gas is an odourless, colourless gaseous fuel with a moderate calorific value and low sulphur content.

Also, green house gases mostly emitted during the combustion of coal, fuel oil and natural gas includes Nitrogen oxides (NO_x), Sulphur oxides (SO_x), carbon dioxide (CO_2), and carbon monoxide (CO). The level of these green house gases emission is high in combustion of coal and fuel oil but low in natural gas combustion.

Green house gases are pollutants and threat to the environment. These pollutant causes heart disease, pneumonia, congestion of the brain and lungs, chronic pulmonary or cardiac disorders, chronic respiratory infections, etc. in humans. The use of coal and fuel oil highly exposes cement workers to some of these diseases while natural gas exposes cement workers to these diseases at a low level.

Finally in terms of cost and availability, coal is highly economical but is low in availability. Fuel oil is lowly economical but highly available and natural gas is highly economical with high availability.

5.2 CONCLUSION

In conclusion, from the analysis of the work, coal is one of the fossil fuel used in the production of cement. It is the cheapest amongst the three fuel used in production of cement but it is not available due to the closing down of Nigeria's coal mine and it poses too much threat to the environment and human's health. Fuel oil is one of the fuel used in cement production, it is available but as at now it is the most expensive fuel used in Nigerian cement industries and it also poses high threat to the environment and human health. Then Natural gas is available, cheap and emits lesser green house gases to the environment , thereby , lowering its effect on human health.

5.3 RECOMMENDATION

Energy sources have direct impact on the market price of cement, environment and human health.

Natural gas which happens to be a cheap, available and most environment friendly energy source compared to coal and fuel oil is recommended so as to cut down

energy costs, guarantee power supply to the power plant and minimizes the emission threat caused by cement industries to the environment.

Also, since coal is also cheap though not available due to no coal mine at work, its use can be possible only if the industries embark on a coal – mining project, this is expected to reduce the overall energy cost. In terms of environmental and health impact, the exhausted gases can be made to pass through an air pollution control device such as Bio-scraper, Bio-filter, Electrostatic precipitators, Cyclone, Wet/Dry scrubber etc. The adoption of modern technology machineries would also be a forward step to diminishing green house gas emission from industries, eliminating the dust emitted from the factory chimneys and producing suitable environmental situation.

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APPENDIX

Chemical Engineering Dept.,
Faculty of Engineering,
Caritas University, Emene
Enugu State.

Dear Sir/Madam,

In fulfillment of the requirement of the award of bachelor of engineering degree(B.Eng.), I am currently carrying out a research work on “Comparative Analysis of Coal, Fuel oil and Natural gas for cement production”. You are therefore requested to please respond to the questions contained in this questionnaire.

Please note that this is strictly an academic exercise towards attainment of the above purpose. You are hereby assured that the information will be treated confidentially and strictly for academic purpose.

Thanks for your anticipated kind response.

Yours sincerely,

Akangumoh Mkpouto.J

Questionnaire

Section A: Personal Data

Instruction: Please fill in the appropriate column to indicate your response.

1. Sex:-----
2. Age:-----
3. Educational Qualification:-----
4. Department/ Section:-----
5. Rank/Position:-----
6. Years in present position:-----
7. Years spent in the company:-----

SECTION B

Instruction: Please tick in the appropriate box and list/ itemize where needed to indicate your response.

1. Which of these process do you employ in production?

(a) Dry process

(b) Wet process

2. Which of these fuels do you use for cement production?

(a) Coal

(b) Fuel oil

(c) Natural gas

3. Describe the fuel in terms of colour, phase and odour produced

a) -----

b) -----

c) -----

4. What quantity of fuel do you use per kg of raw material?

5. How much kg fuel do you use per kg of clinker?

6. Cement production is a complex industrial activity that can potentially affect environment with high impact. The gases emitted during kiln firing are mostly GHG and even dust. How do you manage this emission? Itemize please

a)-----

b)-----

c)-----

d)-----

e)-----

SECTION C

Instruction; You are please required to indicate your response by ticking (√) the level of the criteria in the appropriate space given.

Note:

- A represents **High/ most economical**
- B represents **Low/economical** and
- C represents **Unknown/not economical**

S/No.	Questions	A	B	C
1	How economical is the fuel?			
2	How is the availability of the fuel?			
3	Indicate the level of difficulties encountered during processing			
4	Indicate the level at which this fuel litters the working environment			

5	What can you say about the level of health problem encountered due to inhalation from the industry			
6.	What is the level of calorific value in the fuel?			
7.	Indicate the level of sulphur contained in the fuel			
8	What is the level of NO _x emitted by the fuel?			
9	What level of SO _x is emitted by this fuel?			
10	What is the level of CO ₂ emission caused by this fuel?			
11	Indicate the level of CO emitted by the fuel			
12	Indicate the extent at which the fuel affects the final product			