Overview of Industrial Pollution Activities and its Curbing Mechanisms

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Abstract. Pollution is a global phenomenon, which has been proven responsible for countless untold havoc to the environment and ecosystem at large resulting into global warming, climate change, deterioration of the ecosystem, and scarcity of resources. Industrial activities have as a whole been proven to be an ardent contributor to the global menace of environmental pollution worldwide, with a contribution percentage of 61%, and the cement industry in particular has been ranked as the third most polluting in the industrial sector. As countries look towards a more sustainable future, radical gains and changes have been necessitated in the industry, and though strides have been made in terms of energy consumption with 6% gains and emission reduction between 20-40% gains, yet pollution is still on the rise in the industry. This review paper delves into the subject matter and examines the underlying links between pollution rise and industrialization and then the cement industry; key correlations, the current and potential gains made, current and future projections and the factors facilitating the increased rate of pollution in the cement industry.

Keywords: Pollutions, industrial activities, CO₂ emission, energy

1. Introduction
Pollution in its many forms, is characterized by the introduction of harmful contaminants into the biological ecosystem, of which have negative adverse effects on the environment and its ability to naturally sustain itself and carry out its normal regenerative processes, as well as support living organisms [1, 2]. Human activity has been identified as the key indicator for pollution increase and instability of ecosystems, which have led to loss of life, as a result of manufacturing operations, industrialization and the ever increasing
need to increase the standard of living. A report provided by the World Health Organization in 2018 (WHO), identified air pollution resulting from industrial activities (waste pollutant) as a cause of one in nine deaths worldwide [3]. Among the diverse instigators of pollution worldwide, 61% is generated a result of industrialization related activities, which include from: transportation mechanisms, power generation, industrial activities, and urbanization etc., three have been identified to hinge as factors of economic growth [4-6]. Thus, pollution as an entity is seen by many scholars, as a consequence of industrialization and economic development, and numerous attempts have been made to clarify and explain the relationship that exists between pollution and industrialization [7, 8]. Studied by [9, 10] has identified pollution as a key consequence of industrialization and economic growth in developed countries. [11] established that industrial operations in fields of construction, energy generation and production all utilize equipment and processes that evolve one form of waste (pollutant) effluent or another; and the increase in the amount of greenhouse gases, depletion of natural resources and deforestation can be alluded to human activities of development and expansion. [12] Also identified in their work that industrialization is the primary factor responsible for deforestation and loss of habitat for different species due to its associated pollution. A case study was provided of the Doon valley in India, where industrial mining operations by quarries for limestone (CaCO3) a key ingredient for cement manufacture, as well as the actions of paper and wood industries, have severely threatened the ecological balance of the region. [13] credits this trend of unsustainable industrial practices in developing countries to a lack of control and policy from government, leading to environmental degradation and pollution as a consequence of this neglect, citing a case study analysis carried out in Bangladesh.

[14], also carried out a research study that supported this findings in his work, citing a case study carried out in Pakistan which investigated the relationship between industrialization, GDP per capita increase, energy consumption and ecological degradation, using data for a period between 1975-2011, and it was observed that the increasing the scale of both industries and energy consumption inversely affects the natural environment, depletes resources and leads to environmental pollution, this in in correlation with the study carried out by [15, who stated that industrial growth is a key determining factor of environmental quality as economic growth occurs and estimated that a 1% increase in industrial output appropriates a 11.8% increase in emission per capita, in his analysis, using data obtained from 157 countries between 1970-2000.

[16, in his work identified that the industrial revolution of the 18th century, which led to a sudden increase in standard of living through increased industrial activities, also characterized the height of environmental pollution, as policies for emission standards and industrial operations were lax and non-existent, industries exploited this and operated without checks and balances. This had detrimental effects on the immediate natural environment and lead to the adoption and implementation of the SDGs and MDGs by countries [17], which were aimed in part at reducing pollution levels associated with industrialization to tolerable levels. [18], also affirmed this trend of increasing industrialization to have an reverse effect on environmental growth, and that if economic growth occurs too rapidly, it tends to overwhelm pollution abatement efforts leading to pollution increase. However, it is important to note that the impact of industrialization in our modern day 21st century, cannot be understated as the high standard of living, communication and information facilities were attained through it, other benefits of economic growth such as: the creation of employment opportunities, provision of utilities (transportation, energy) are made available through industrialization [19]. Despite the compelling evidence linking industrialization to the deterioration of the ecosystem, there is no current forecast of it being halted, however the key element here to pacify the continued practice of industrialization is ensuring sustainability, i.e. in ensuring minimal negative impact to the environment, not depleting natural resources and reserves [20-23], concluded that the current economic growth model is not sustainable as pressure is continually mounted on environmental and natural resources which would eventually lead to depletion.
According to [24], the pursuit of attaining sustainable development in countries and societies have been discovered to hinge on three critical foundational pillars, which are: economic growth, social growth and ecological balance, and as such an index of sustainability can’t be effectively measured if even one of these identified pillars is annexed, but rather in the co-integration of all three, this was also confirmed by [26], in his work, and stated that focus on attaining ecological sustainability without considering the other pillars jeopardizes sustainability as a whole, and poses an enormous challenge, therefore all three aspects must be considered in dealing with the issue of pollution increase, which arises as a causality from economic growth and development, leads to issues relating to ecological imbalances (natural habitat destabilization), and hindering of social growth (in the form of hazards and various risks to human health), this buttresses the point that all three pillars must be considered [27]. While this paper acknowledges that economic activity and growth is necessary to development nationwide, it is paramount to ensure proper monitoring and control of these industrial activities to ensure sustainable development and curtail increase in environmental pollution.

2. Industrialization and pollution: The trend
[15], published in their work that economic growth in urban areas cannot continue indiscriminately at the expense the ecological environment, that events such as climate change and deteriorating natural habitats are a function of rapid industrialization and economic growth changes, and that modern cities that support industrialization are overly dependent on fossil fuels energy sources, and estimated that 75% of global energy demand is from industrialized settlements.

[16], published findings on a research work carried out in the Henan province in China, between 1994-2009, that observed for causality between economic growth (industrialization) and environmental growth, he observed that there was an inverse relationship between economic growth and environmental growth in the region, characterized by the degradation of environmental resources as a result of three major forms of industrial pollutants: industrial solid waste, industrial waste water and industrial waste gas, an environmental Kuznets curve (EKC), was then used which to prove this inter-connection. An EKC utilizes a data plot of economic development (measured in GDP per capita) against environmental quality (measured in terms of pollution index “emissions), to predict the relationship between them [8], [9], stated that the EKC predicts at the initial phase of economic development, ecological growth will be sacrificed for economic benefits, because of an increase in emissions due to industrial operations, and continues until a certain GDP is reached, beyond which the trend reverses and economic growth leads to environmental growth, this was also confirmed by [8], who also used the EKC tool in reviewing the relationship between industrialization, energy consumption and pollution on a case study in Bangladesh between 1975-2010, an observed results similar to that of [16], in which the variables are co-integrated, and that an increase in economic development (industrialization, energy consumption) directly leads to an increase in pollution.

[12], also proposed a mathematical model that analyses the relationship between industrialization, pollution and resource depletion on an ecosystem, in order to obtain a criteria to ensure stability, and they confirmed that as industrialization density increases, so also pollution density increases and this has an adverse effect on the environment, as it leads to a decrease in resource density (environmental resources), this was also confirmed by [12, 17], who also carried out studies on developing a mathematical model relating economic growth, industrialization, pollution and resource depletion and also observed an inverse relationship between the factors as resources depleted and the environment degraded as pressure from industrialization increased and lead to pollution increase. In providing a comprehensive overview of pollution rise and energy consumption efficiency in the cement industry, both historical and present day data of the industry are examined and analyzed to provide a comprehensive review.
2.1. Report on industrial activities and generations

Development in the cement production industry has occurred with time, as modern techniques and equipment have made the process of manufacture more sustainable and efficient, e.g. burning and cooling techniques have improved such as use of drum dryers, mill dryers, on-site pre-treatment, incorporating alternative fuels have been developed ensuring energy efficient production [18, 23, 31]. In terms of fuel consumption, pyro-processing accounts for 93-99% of fuel usage, while for electricity consumption, raw material processing and clinker crushing and grinding 38% consumes the most, advances in technology has led to gains in these respective areas [36]. According to [25] in a report published by the World Business Council for Sustainable Development, 2009, estimated that the average energy consumption utilized by current and most utilized preheaters and pre-calciner plants globally, has decreased by 6%, however a sheer increase in the global production volume of cement tens to offset any potential gains made in terms of production efficiency and emission reduction. Global cement production is currently estimated at 2.8-3.6Gt, with a CO$_2$ evolution rate of about 2.6Gt, and the cement production rate is projected to increase annually constituting a subsequent increase in CO$_2$ emissions globally [18, 25, 32]

However, it should also be noted that there have been improvements in terms of the efficiency of the production process, as energy consumption in clinker production has reduced, so also raw material generated CO$_2$ has also been reduced by as much as between 20-40%, through application of measures such as use of alternative fuels, decrease in clinker content of cement, secondary abatement techniques and exhaust gas cleaning among others, although this also has been offset somewhat by an ever increasing demand for cement clinker for production, and cost of energy in terms of rising electricity prices [26, 27].

This was confirmed by [25, 33], that the rate of CO$_2$ emission in the present day will still be on the increase due to an ever increasing demand for cement clinker due to industrialization, economic growth, infrastructural development and population increase, in countries globally with a three to four fold increase projected by 2050, based on data obtained from the World Business Council for Sustainable Development, 2009.

3. Measures to Curbing High Rate of Environmental Pollution (CO$_2$)

Several techniques have been developed in dealing with the issue of high CO$_2$ emissions from the industry, with some measures still in the test phase and yet to find full application, these measures include:

3.1. Use of Supplementary Aggregates

[28, 29], alluded that supplementary aggregates can be added to pure Portland cement to produce blended cements that can significantly reduce CO$_2$ emissions between 20%-40%, as also confirmed by [34, 35]. This also assists in alleviating the amount of limestone (CaCO$_3$), which would have otherwise been simply utilized in producing the clinker. The supplementary aggregates used are obtained from industrial by-products such as (blast furnace slags), from iron making process, up to 50% in ratio, or (coal fly ashes) by-product from coal combustion and they can be used with the Portland cement [34]. [19], also argued that the use of natural (e.g. volcanic ash) and artificial pozzolans up to 40% in ratio, also offers an alternative to ordinary Portland cements to produce ternary cements. The descriptions of the aggregate materials that can be used are included in the table 1.
Table 1. Constituents for cement production [19]

| Group | Material—examples |
|-------|------------------|
| Ca    | Limestone/marl/chalk |
|       | Others, such as: |
|       | – Lime sludge from drinking water and sewage treatment |
|       | – Hydrated lime |
|       | – Foam concrete granulates |
|       | – Calcium fluoride |
| Si    | Sand |
| Si–Al | Used foundry sand |
| Si–Al–Ca | Clay |
|       | Bentonite/kaolinite |
| Fe    | Iron ore |
|       | Other input materials from the iron and steel industries, such as: |
|       | – Roasted pyrite |
|       | – Contaminated ore |
|       | – Iron oxide/fly ash blends |
|       | – Ducts from steel plants |
|       | – Mill scale |
| Si–Al–Ca | Granulated blast furnace slag |
|       | Fly ash |
|       | Oil shale |
|       | Trass |
|       | Others, such as: |
|       | – Paper residuals |
|       | – Ashes from incineration processes |
|       | – Mineral residuals, e.g. soil contaminated by oil |
| Al    | Al Input materials from the metal industry, such as: |
|       | – Residues from reprocessing salt slag |
|       | – Aluminum hydroxide |
| S     | Natural gypsum |
|       | Natural anhydrite |
|       | Gypsum from flue gas desulfurization |

[20], also argued that the use of supplementary additives not only improves CO$_2$ emission gains, but also compliments cement performance. As the materials vary by composition, substitution with clinker can only be achieved to some degree. Slag can be used in proportions of up to 50% with cement, pozzolans like fly ash can be used up to 40% with cement composition. It should however be noted that some variations of this solution offers a trade-off between CO$_2$ emission reduction and the characteristic strength development of the cement with time, as well as cement properties. The demonstration of this data analyzed is provided in Figure 1.
3.2. Carbon Capture and Storage (CCS)
This involves the removal; recycling and storage of CO$_2$ for other purposes, there are three basic techniques for capturing CO$_2$, which are: pre-combustion capture, oxy-fuel combustion, and post-combustion capture [19, 34]. It should be noted that these technologies are still in the design phase and are not scheduled for introduction till around 2020. The technique essentially involves the capturing and compressing CO$_2$ into a liquid form that can be stored underground [24, 31].

3.3. Use of Alternative Fuels
The common fuel sources utilized in the cement industry include: coal, fuel oil, petroleum coke, diesel [23], however this fuel sources are fossil fuel based and their combustion evolves CO$_2$ emissions, alternative sources of fuel can be used to substitute in varying degrees to substitute fossil fuel sources, they are obtained from industrial, municipal and hazardous wastes [35]. According to [36], the various types and classification of alternative fuels include: gaseous fuels (natural gas, refinery effluents), liquefied fuels (low chlorine spent solvents, hydraulic oils), solid fuels (shredded tyres, waste plastic, sawdust and wood waste, hardened sewage and sludge).

3.4. Waste heat recovery
Waste heat can be recovered from the hot combustion gases has been discovered to increase process efficiency, the waste heat loss due to convection and radiation through the kiln wall surfaces have been estimated to be about 15% of the energy input to the system [27]. This is be mitigated through the use of insulation on the exterior surfaces of the pre-calciners and kilns. Other approaches to waste heat recovery include: the use of single flash steam cycle, or dual flash steam cycle on the exhaust gases from the clinker cooler or pre-heater exhaust, to recover heat in form of steam, which could then be used in turn to generate electricity by driving a steam turbine, with an estimated 4.4MW of energy possible [36]

From study, other measures that can be employed include:
- Utilization of a lower clinker to cement ratio (increasing additives ratio)
- Industries and corporations involved taking responsibility and adopting best practices for continued operations.
• Industries adopting more fuel efficient and energy efficient practices
• Investing in mineral polymers, i.e. alternate cements
• Regulation of emission standards and introduction of stringent policy on emissions for industries to comply with observed in European Union

4. Conclusions
From the comprehensive review carried out, it was observed that industrialization and increased capital intensity leads to increase in pollution and environmental degradation as affirmed by scholars, and in particular in the cement industry.
• As observed from the overview cement production generate steady increase between 1994 and 2010, and this has also characterized an increase in the emission of CO₂.
• However, despite the efforts of the industry and government to increase efficiency of production and regulate the emission of CO₂ associated with cement production, a rise in CO₂ continues particularly as a consequence of increased demand for infrastructural development.
• It was affirmed that while improved techniques and modern technologies have brought about an increase in efficiency of production, such as also influence reduction in CO₂ emissions

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References
[1] Wang X Dong X Fan W Xu Z and Wang Y 2019 Air pollution terrain nexus : A review considering energy generation and consumption 105(December 2018) 71–85
[2] Franchini M and Mannucci P M 2018 European Journal of Internal Medicine Mitigation of air pollution by greenness : A narrative review 55(June) 1–5
[3] Antoci A Galeotti M and Sordi S 2018 Commun Nonlinear Sci Numer Simulat Environmental pollution as engine of industrialization Communications in Nonlinear Science and Numerical Simulation 58 262–273
[4] Benhelal E Zahedi G Shamsaei E and Bahadori A 2013 Global strategies and potentials to curb CO₂ emissions in cement industry Journal of Cleaner Production 51 142–161
[5] Perera F 2017 Pollution from Fossil-Fuel Combustion is the Leading Environmental Threat to Global Pediatric Health and Equity: Solutions Exist. International journal of environmental research and public health, 15(1), 16. https://doi:10.3390/ijerph15010016
[6] Constant K Nourry C and Seegmuller T 2014 Population growth in polluting industrialization Resource and Energy Economics 36(1) 229–247
[7] Asici A A 2015 Economic growth and its impact on environment : A panel data analysis 24(2013) 324–333
[8] Shahbaz M Salah G Ur I and Imran K 2014 Industrialization, electricity consumption and CO₂ emissions in Bangladesh Renewable and Sustainable Energy Reviews 31 575–586
[9] Cherniwchan J 2012 Economic growth, industrialization, and the environment Resource and Energy Economics 34(4) 442–467
[10] Spangenberg J H 2010 Biodiversity pressure and the driving forces behind 1. https://doi.org/10.1016/j.ecolecon.2006.02.021
[11] Almeida T Cruz L Barata E and Garcia-sánchez I 2017 Economic growth and environmental impacts : An analysis based on a composite index of environmental damage Ecological Indicators 76(x) 119–130
[12] Dubey B and Narayanan A S 2010 Nonlinear Analysis : Real World Applications Modelling effects of industrialization, population and pollution on a renewable resource Nonlinear Analysis: Real World Applications 11(4) 2833–2848

[13] Maslesa E Jensen P A and Birkved M 2018 Indicators for quantifying environmental building performance : A systematic literature review Journal of Building Engineering 19(June) 552–560

[14] Moldan B Tomas H and Janousková S 2012 How to understand and measure environmental sustainability : Indicators and targets 17 4–13

[15] Song Q Li J Duan H Yu D and Wang Z 2017 Towards to sustainable energy-efficient city: A case study of Macau 75(November 2016) 504–514

[16] Gao B 2011 The Impacts of Economic Growth on Resources and Environment in Henan Province. Procedia Environmental Sciences 11 810–816

[17] Misra A K and Verma M 2013 Applied Mathematics and Computation, A mathematical model to study the dynamics of carbon dioxide gas in the atmosphere. Applied Mathematics and Computation 219(16) 8595–8609

[18] Gursel A P Masanet E Horvath A and Stadel A 2014 Cement & Concrete Composites Life-cycle inventory analysis of concrete production : A critical review Cement and Concrete Composites 51 38–48

[19] Schneider M Romer M Tschudin M and Bolio H 2011 Cement and Concrete Research Sustainable cement production — present and future. Cement and Concrete Research 41(7) 642–650

[20] Schneider M 2015 Cement and Concrete Research Process technology for efficient and sustainable cement production Cement and Concrete Research 78 14–23

[21] Fayomi G U Wusu O Mini S E Fayomi O S I Kilanko O 2018 Data analysis on the level of exposure to pollutions in industrial zone: A case study of Ewekoro and Ota Township Data in Brief 19 859-864

[22] Fayomi O S I Olukanni D O Fayomi G U and Joseph O O 2017 In situ assessment of degradable carbon effusion for industrial waste water treatment Cogent Engineering 2017 4 1291151

[23] Ke J Mcneil M Price L Khanna N Z and Zhou N 2013 Estimation of CO₂ emissions from China’s cement production : Methodologies and uncertainties 57 172–181

[24] Ke J Zheng N Fridley D Price L and Zhou N 2020 Potential energy savings and CO₂ emissions reduction of China’s cement industry Energy Policy 45 2012 739–751

[25] Imbabi M S Carrigan C and McKenna S 2013 Trends and developments in green cement and concrete technology International Journal of Sustainable Built Environment 1(2) 194–216

[26] Ali M B Saidur R and Hossain M S 2011 A review on emission analysis in cement industries. Renewable and Sustainable Energy Reviews 15(5) 2252–2261

[27] Habert G Billard C Rossi P Chen C and Roussel N 2010 Cement and Concrete Research Cement production technology improvement compared to factor 4 objectives Cement and Concrete Research 40(5) 820–826

[28] Gartner E 2004 Industrially interesting approaches to ‘‘low-CO₂’’ cements $ 34(January 2004) 1489–1498

[29] Liu J Zhang S and Wagner F 2018 Exploring the driving forces of energy consumption and environmental pollution in China’s cement industry at the provincial level Journal of Cleaner Production 184 274–285

[30] Hendriks C A Worrell E Jager D De Blok K and Riemer P 2004 Emission Reduction of Greenhouse Gases from the Cement Industry 1–11

[31] Hasanbeigi A Lobscheid A Lu H Price L and Dai Y 2013 Science of the Total Environment Quantifying the co-benefits of energy-efficiency policies : A case study of the cement industry in Shandong Province, China Science of the Total Environment 458–460 624–636
[32] Hasanbeigi A Morrow W Masanet E Sathaye J and Xu T 2013 Energy efficiency improvement and CO$_2$ emission reduction opportunities in the cement industry in China Energy Policy 57 287–297

[33] Hasanbeigi A Price L and Lin E 2012 Emerging energy-efficiency and CO$_2$ emission-reduction technologies for cement and concrete production: A technical review Renewable and Sustainable Energy Reviews 16(8) 6220–6238

[34] Hasanbeigi A Price L Lu H and Lan W 2010 Analysis of energy-efficiency opportunities for the cement industry in Shandong Province, China: A case study of 16 cement plants Energy 35(8) 3461–3473

[35] Jokar Z and Mokhtar A 2018 Policy making in the cement industry for CO$_2$ mitigation on the pathway of sustainable development- A system dynamics approach Journal of Cleaner Production 201 142–155

[36] Madlool N A Saidur R Hossain M S and Rahim N A 2011 A critical review on energy use and savings in the cement industries Renewable and Sustainable Energy Reviews 15(4) 2042–2060