Pollution emission evolution from composite and metal formation in Foundry Industry

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Abstract. The consumption of steel is a major indicator of the rate at which a country is developing. Emerging economies such as China and India markets have developed on the back of products such as steel, aluminum, and alloys. This development have not received much fanfare because of the environmental pollution incurred by the production of this products and at that rapid scale. This paper aims at studying the environmental impact of steel production by identifying the various forms in which pollution occurs in the metal production industry. This study limits itself to understanding the impact of gases evolved from the metal foundry be it from the foundry furnace or the metal mold cast. The study indicates that there is a correlation between the quality of mold cast and the rate of gas emission.

1. Introduction
Developing countries while trying to maintain a good development index have to ask the question, development at what cost? This cost could be with reference to the financial implication but over the turn of the century the sustainable development goals (SDGs) have been at the forefront. Countries have to weigh the long term implication of their development and its implication to the coming generations. Organizations such as the World Health Organization (WHO) and the Global alliance for Health and Pollution have indicated that about 8.4 million death in 2012 was as a result from infected air, water and soil.

The consumption of materials such as steel, aluminum and cement serve as indicator of the rate at which a country is developing [1]. The emergence of China as a world power and the second largest economy was greatly influenced by this products. In 1958 the annual steel production in china was a 158,000 tons [2] and 831 million tons in 2018 according to World Steel Association. Authors such as Gao et al. [3] and Zheng et al. [4] have argued the correlation between steel consumption and economic development. This means increase in economic activity has a direct correlation to increase in energy consumption, energy which is used to power up foundry for the production of metal implements from cast.

The metal foundry industry is an important factor in economic development. This is because the metal foundry help in producing important parts required by other industries be it the automobile industry (in
terms of spare parts), aviation industry, construction industry to as little as the spoons we have on our tables the metal foundries play an important role in ensuring all this basic items are present for use. The activities of the metal foundry come with an environmental cost.

In operating a metal foundry large amount of energy is required [5]. This could come as primary source of energy like the burning of coal, wood, liquefied natural gas, crude or through secondary source of energy like electricity. This forms of energy are indispensable to the production of metals parts because of the high melting point of metals in general. Weber [6] described the various types of pollution in the metal foundry as either emergence of dust from different operations, Odor and gaseous compound and effluence from gas producing operations. The research stated above is important to understanding the nature in which pollution in foundries occur. The effect of foundry pollution should not just be limited to the external environment but also should include the metal foundry workers, who are the first recipients of this toxic products produced from their metal foundry. Studies from authors such as [7-11] have attempted to find relevance to materials discarded as foundry waste. The conflict between the production of metal and it correlating environmental impact prompted this study. The study aims at reviewing the various forms of pollution that occurs in the metal foundry, effects and pollution control techniques.

2. Pollution in Foundry
The introduction of harmful substances into the environment is regarded as pollution [12]. This means for a substance to be regarded as a possible pollutant to the environment at large, it must be regarded as an armful substance to the environment. The main elements that make up the atmosphere are Oxygen, Nitrogen, Water vapor, Carbon in varying quantity [13]. The high temperatures at which metal foundry operates allowed the evolution of gas into the atmosphere. To analyze the different forms in which pollution may occur in the metal foundry, it is important to know the different operations that occur in the metal foundry. The operation performed by a metal foundry can be easily highlighted as melting, casting and finishing.

The melting of metals are achieved by the use of a furnaces. Furnaces are designed based on the melting point of the metal, these design parameters influence the type of fuel used and the lining of the furnace. Metals such has zinc and tin which have melting points hovering around 723K use fuel types such as natural gas, propane or electricity to power up the furnace. Whereas Ferrous metals and nickel which have melting temperature hovering around 1823K uses fuel such as coke or electricity. After the successful melt of metal they are poured into a mold which is designed to have the desired shape required to make what we would know as the metal cast. The molting metal is poured into this cavity and then allowed to cool which in turn would take the shape of the cavity once it is a solid. The characteristic of different gasses evolved as a result of the mold casting have been discussed by different authors [14].

3. Emission evolve from metal pouring operation
A study of the constituents of air pollutant evolved from metal casting was conducted by Wang et al. [15] through the means of analytical pyrolysis to evaluate evolved gases. The casting material commonly used in Chinese foundries according to Wang et al. [15] are furan binder and bituminous coal, these are commonly used for the construction of molds. The authors analyzed the evolved gases in a gas chromatography mass spectrometer/flame ionization detector and identified thirteen (13) air pollutants. Wang et al. [15] was also able to identify Xylenesulfonic acid which is an acidic catalyst in the furan binder as a contributing factor in the emissions of xylene. The authors also identified the temperature range of 623K to 973K, as the range majority of emission is released.

Emission from the degradation of different binders where tested by Tiedje et al. [16]. This included Furfuryl alcohol (FA), phenolic urethane (PU) and resol-CO2 (RC). The authors observed that alloys with higher melting point evolve a high degree of emission initially and then gradually fall to about 0.1
of the max-emission within an hour, exemption this rules are the evolution of hydrocarbons from PU and RC binders. They on the other hand evolve the maximum amount within twenty (20) minutes after this it falls below 0.1 of maximum emission within seventy (70) minutes. Tiedje et al. [17] also identified that the PU binder evolve far more hydrocarbons compared to the other binders and lasts a longer period of time. Tiedje et al. [17] also identified that the original composition of FA binders play a significant role on the properties of gases evolved. Finally the authors also identified shake-out of mold affects the amount of evolved gas composition. A notable limitation to this study was that the authors provided no conclusive evidence that the properties of the other mold affect the types of gas evolved.

The influence of reclaimed mold cast sand on the characteristics of gas evolved was studied by Holtzer et al. [14]. In the study the percentage of reclaimed sand was varied with that of Silica sand, then the molting iron was poured into the metal mold and the evolved gas was studied using the method developed by the faculty of Foundry Engineering, AGH UST. The authors as described in Table 1 discovered that the reclaimed sand evolved almost triple the amount of hazardous gas such as Benzene, Toluene, Ethylbenzene, Xylenes, Polychrinated and Biphenyls compared to the Silica sand.

| Gas Evolved                | How Emission was determined | Type of Binder       | Other            | Reference         |
|---------------------------|-----------------------------|----------------------|------------------|------------------|
| Xylene                    | -                           | Furan binder         | -                | Wang et al. [15]  |
| hydrocarbons              | -                           | Furfuryl alcohol     | -                | Tiedje et al. [16]|
| hydrocarbons              | -                           | Phenolic Urethane    | -                | Tiedje et al. [16]|
| hydrocarbons              | -                           | Resol-CO$_2$         | -                | Tiedje et al. [16]|
| Benzene, Toluene, Ethylbenzene, Xylenes, Polychrinated and Biphenyls | Reclaimed mold Sand | -                   | -                | Holtzer et al. [14]|
| Polychlorinated naphthalenes | -                           | -                   | Fly-Ash          | Liu et al. [17]   |

4. Pollution Control Techniques in Metal Foundry

Pollution control techniques play an important role in environmental protection. Fabric filter [18], Wet scrubber and Cyclone method are air pollution techniques identified by [19], these techniques can be used in metal foundries to reduce the amount of harmful substances that can be released into the atmosphere. Antunes et al. [20] affirmed from the study of 10 plants in Portugal that air pollution control techniques play an important role in reducing the amount of toxic gas emitted into the atmosphere. The air pollution techniques have also found use when try to estimate the amount of emission from this foundries [17].

5. Conclusions
The foundry industry is an indispensable factor to the development of a country. The foundry is responsible for the production of different metallic implement be it ferrous or non-ferrous. This economic importance and the subsequent emission produced by foundry operation have made the foundry operation a global problem. Hence, the need to understand the various foundry processes and the subsequent amount of pollution that occurs as a result of each operation needs to be studied. It was discovered that each foundry operation has a specific form of pollution peculiar from one to the next. The melting operation which involves the melting of metal scraps into molting metal was studied by
various authors and the type of fuel was identified as the major source of pollution. These emissions where found to vary based on the type of fuel used in the operation. The second operation identified for study was the molting metal pouring operation. This operation involves the pouring of molting metal into a mold cavity. Various researchers studied the properties of gas evolved from this process and found that the mold property and the type of binder affect the level of emission produced during the process.

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