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Emission Inventory of Air Pollutants in a Metal Recycling Facility

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Abstract Emission inventory plays important roles in the assessment, monitoring, modelling and management of emissions of air pollutants which have devastating impacts on human health, vegetation and climate. The study estimates the quantities of selected air pollutants generated from a metal recycling process involving charging, melting and tapping using standard emission factor approach. The pollutants considered include Nitrogen oxides (NO_x), Sulphur oxides (SO_2), Carbon monoxide (CO) and Total Suspended Particulate (TSP) matter. The total quantity of material consumption daily represents the activity level. The total quantity of material consumed was combined with appropriate published emission factors by United States Environmental Protection Agency (USEPA). The result showed that the quantities of NO_x, SO_2, CO, and total suspended particulate (TSP) matter emitted are 0.013, 0.012, 0.110 and 2.323 tonne/day, respectively. The percentage proportion of TSP emitted is 94.5 % followed by CO (4.5 %) while the quantities of NOx (0.5 %) and SO_2 (0.5 %) are similar. The inventory information in this study is expected to serve as a guide to researchers and policy makers to know the fate and effects of air pollutants in the study area for adequate air quality management.

Keywords: *emission inventory, metal recycling, emission factors, air pollutants*

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1. Introduction

The complex and local air pollution issues of concern such as acid rain, photochemical smog, material damage, ecosystem disturbances and haze caused by emission sources, especially anthropogenic sources, have become the most crucial areas of research in environmental engineering in most part of the world, particularly in Nigeria. Studies have been conducted to assess the level of criteria air pollutants in highly polluted areas [1,2,3,4]. The increased growth of cottage industries in Nigeria, for example, iron and steel smelting factory has become a major environmental driving force for the deterioration of urban air quality [5]. Therefore, the quantification of air pollutants emission from such industry will be fundamental to the understanding of emission levels, forecasting air quality status, and guiding formidable air pollutant control strategies.

Iron and steel scrap recycling, by nature of its process, is often characterized with emission of toxic air pollutants [6]. Air pollutants such as NO_x, SO_2, CO, and TSP are pollutants generated and subsequently emitted into the atmosphere at each stage of charging, melting and tapping of molten scrap which takes place in electric arc furnaces and the ladle. The emission inventory of the iron and steel smelting industry considered in this work was necessitated due to the heavy dark smoke that escapes from the smelting shop during production. Emission from metal recycling has been reported to be a complex mixture with many toxic metal components which are hazardous to human health [7]. Although, the factory location was initially in the outskirt of the host town, the housing development of the town has in the mean time extended to areas that are in close proximity to the factory. For an effective and efficient air quality execution and planning, there is a need for emission inventory for identification and quantification of its emission.

Emission inventories play important roles in the assessment, monitoring, modelling and management of emissions of air pollutants which have adverse impacts on human health, vegetation and climate [8,9,10,11]. It is a crucial scientific tool used to account for all air pollutants emitted into the atmosphere from sources within a specific geographical area. Due to their importance in forming the basis of modelling studies, and eventually mitigation policies, it is important that emission inventories produce emission estimates that are accurate [12]. It also provides information for judging the efficiency of existing air pollution management programs and for developing future air pollution control strategies.

Considerable number of studies on emission inventory of anthropogenic sources has been done in many parts of the world [13,14,15,16] including emission sources in Nigeria [17]. These studies indicated significant emission increase in the past years, attributed to the rapid industrialization of major cities and energy requirements. Also, the results of these studies have used with different dispersion models to simulate and predict air pollution effects on regional and local air pollution. The results, however, have often yielded modelled concentrations that are consistent with ground level-based observations raising no questions as to the quality of the inventories. Industrial emission inventory on air pollutants can be established by employing emission calculations with standard formulae or by monitoring air pollutants emitted through stacks [18]. However, emission estimations using emission factors have mostly been utilised mainly because of lower costs or lack of stack monitoring data. The quantitative emission estimates provided in this study will promote a better understanding of the actual emission and also raise the awareness of the general public.

2. Materials and Methods

The inventory calculations in this study are for NO_x, SO_2, CO and TSP. The description of the study area is discussed below. The standard emission factor approach for estimating criteria air pollutants are clearly discussed.

2.1. Study Area

The iron and steel smelting factory considered is located on the outskirt of Ile-Ife, Osun State in Southwestern Nigeria (Figure 1). The visible dark plume often seen during production makes the area of special interest in emission inventory study. The factory operates few meters away from a busy expressway.

The study area lies between latitude 7° 29' 0' - 7° 29' 30' N of the equator and longitude 4° 28' 0' E - 4° 28' 30' E. The area is not really an industrial area but it has a potential to become one in the nearest future. It has some specific physical features like cafeteria for scrap transporters, food vendor kiosks, airtime sellers' stand, farm settlement and a university campus and some residential houses in close proximity. Scrap and unused materials are often transported from all parts of the country to the factory which indirectly creates a source of income to the inhabitants of the host town. It is pertinent to note that the released gases and particulate matter from the factory apparently escape released indiscriminately into the atmosphere without any identifiable source of emission.

2.2. Study Materials

The documented records containing the daily material consumption for six months were obtained from statistics section of the factory. Six days were randomly selected to be representative of the total monthly consumption and thereafter compiled as shown in Table 1. United States Environmental Protection Agency (USEPA) compilation of criteria air pollutants emission factors (AP-42) was used in the study [19]. The selection of emission factors took into account the total quantity of feed materials for the selected records. The google map of the study area and its geographic location are shown in Figure 1.

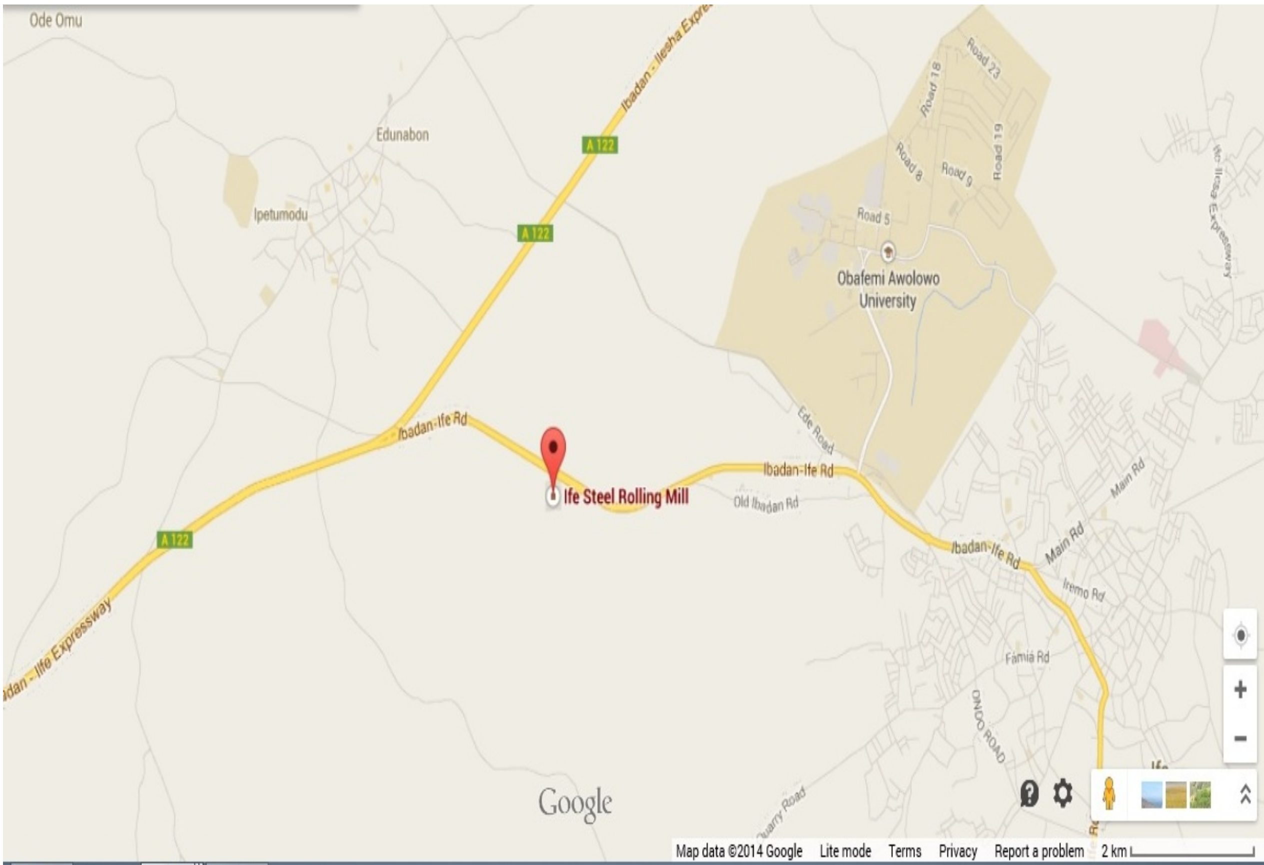

Figure 1. The plant location on google map of Ile-Ife

Table 1. Material consumption rate

Material	Quantities of material consumed on selected days (tonne/day)					
	Days					
	1	2	3	4	5	6
Steel scrap	60.000	60.00	60.00	60.00	60.00	60.00
Si-Mn	0.820	0.821	0.770	0.780	0.725	0.700
Fe-Si	0.000	0.009	0.009	0.009	0.009	0.009
Aluminium	0.000	0.003	0.003	0.003	0.003	0.003
Redex	0.030	0.030	0.030	0.030	0.030	0.030
Sand mix	2.100	1.200	1.900	1.200	1.200	1.200
Total	62.962	62.050	62.682	63.022	63.165	61.942

2.3. Sample Emission Calculations

A standard approach often used to estimate air pollutants emission from the source was utilized (USEPA, 1997) as indicated in equation 1. The equation combined relevant emission factors with the activity level of the recycling process. The emission rate was estimated for each selected day. The average value of which was thereafter estimated. For an uncontrolled particulate matter emission, ER is set equal to zero. The sample emission calculations for two of the pollutants are as follows:

$$\mathbf{E} = \mathbf{AR} \times \mathbf{EF} \times (\mathbf{1} - \frac{\mathbf{ER}}{\mathbf{100}}) \qquad 1$$

Where,
E = the emission of specified pollutant
AR = the relevant activity rate for the process
EF = the emission factor for the pollutant
ER = overall emission reduction efficiency %

2.4. Sample Calculations

Calculation for NO_x emission
Emission factor = 0.22 lb/tonne
Material consumption = 62.962 tonne/day
NO_x Emission = 62.962 tonne/day x 0.22 lb/tonne x 0.0005 tonne/lb = 0.007 tonne/day
Calculation for SO_2 emission
Emission factor = 0.2 lb/tonne
Activity = 62.962 tonne/day
Emission = 62.962tonne/day x 0.2 lb/tonne x 0.0005 tonne/lb = 0.006 tonne/day.

3. Results and Discussion

The results of this study provide information on the quantity of emission of common air pollutants NO_x, SO_2, CO and TSP from the entire process of metal recycling. It is imperative to note here that the emission factor method adopted became necessary because direct measurement was impossible due to restrictions by the operators. Additionally, the estimated quantities of the pollutants represent the time period of six consecutive months of production. During the study of the production process, emission was observed to occur majorly in electric arc furnace (EAF) and the ladle processing facilities. These are open chambers in which the melting process takes place at an average temperature of 1450°C. Presented in Table 2 and Table 3 are the estimated daily emission rates of the air pollutants in the study. The results revealed that particulate matter is predominantly generated and subsequently emitted from the metal recycling process which (Figure 2). As expected from a high temperature process, the process is characterized with high emission of particulate matter. This scenario could be attributed to the open burning method being employed by the operator of the furnace.

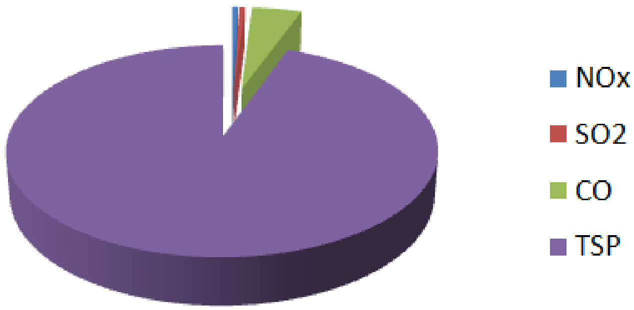

Figure 2. Proportions of air pollutants inventoried

Table 2. Estimated Air Pollutants Emission Rates from the EAF

Pollutant	Days						Average emission	Average emission
	1	2	3	4	5	6		
	tonne/day	tonne/day	tonne/day	tonne/day	tonne/day	tonne/day	tonne/day	g/s
NO_x	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.201
SO_2	0.006	0.006	0.006	0.006	0.007	0.006	0.006	0.194
CO	0.057	0.056	0.056	0.056	0.057	0.056	0.056	1.735
TSP	1.196	1.179	1.179	1.178	1.202	1.177	1.185	36.571

Table 3. Estimated Air Pollutants Emission Rates from the Ladle

Pollutant	Days						Average tonne/day	Average emission g/s
	1 tonne/day	2 tonne/day	3 tonne/day	4 tonne/day	5 tonne/day	6 tonne/day		
NO_x	0.007	0.006	0.007	0.007	0.007	0.007	0.007	0.201
SO_2	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.185
CO	0.054	0.054	0.054	0.055	0.054	0.053	0.054	1.667
VOCs	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.022
TSPM	1.140	1.130	1.136	1.150	1.148	1.125	1.138	35.126

As can be seen from the tables, the estimates of the gases NO_x, SO_2, and CO were relatively low (0.5%, 0.5% and 4.5%). The generation of these gases could occur as a result of chemical reactions taking place during the process. Nitrogen oxides are formed from the reaction of Nitrogen content of the other materials added with oxygen in the burning zone in the furnace. The EAF and ladle utilized in metal recycling are reservoirs of these chemical reactions. For example, NO_x generation occurs due to high temperature condition which is required during scrap melting activity. Also, the generations of SO_2 and CO occur due to the reaction of the sulphur and carbon contents of the raw material with the oxygen in the melting furnace chamber. The quantities of the emitted air pollutants usually depend on the quantity of material feed. Consequently, low quantity of raw material generates low level of air pollutants. However, this result is indicative of the fact that if the operators of the factory expand the production capacity, it could lead to an increase in the levels of air pollutants in the study area. This may eventually worsen the air quality in the airshed around the factory.

Table 4. Combined Estimated Air Pollutants Emission Rates from EAF and Ladle with the Percentage Proportions

Air Pollutant	Emission Rate (tonne/day)	Percentage (%)
NO_x	0.013	0.5
SO_2	0.012	0.5
CO	0.110	4.5
TSP	2.323	94.5

4. Conclusion

This study has estimated the quantities of NO_x, SO_2, CO and TSP generated by a metal recycling process throughout the process of charging, melting and taping in the EAF and ladle. Recent studies have also documented metal recycling activity as a significant source of toxic gases and particulate matter. This toxicity has been ascribed the nature and chemical components of the raw materials utilized. The quantity of air pollutants generated during scrap melting was calculated based on the activity rate and the default emission factor published by US Environmental Protection Agency. The study provided that that particulate matter constituted the highest proportion (94.5%) of the emission. This suggests that the study area is polluted with particles which could certainly be traced to the metal recycling activity since it is the major emitter in the study area. However, the proportions of the gaseous pollutants considered were estimated to be insignificant. It is recommended that the laws restricting emission of harmful pollutants should be enforced on the plant to prevent the release of such quantities of air pollutants from been released into the atmosphere.

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