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# Analysis of Total Particulate Matter from a Secondary Steel Smelting Industry

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**Abstract** Particulate matter (PM) in ambient air is a potential carrier of toxic metals. This study determined the concentration of total suspended particulate matter in the ambient air of a secondary steel smelting plant and further determined the level of selected metals in the collected samples. Deposition gauges were installed at four distinct sampling locations in the vicinity of the plant for collection of ambient particles. The particulate samples were collected simultaneously and removed at two weeks interval from October, 2015 to April, 2016. Particulate matter from solution was recovered through Whatmann filter paper by filtration. All samples were digested and analyzed by Flame Atomic Absorption Spectrophotometry (FAAS) instrument. The elements analyzed included Copper (Cu), Iron (Fe), Nickel (Ni), Zinc (Zn), Manganese (Mn) and Chromium (Cr). The ambient concentration of ambient particulate matter was in the range of 390-1450 µg/m$^3$ with an overall average of 918.0±325.5. This average concentration significantly exceeded the allowable limits of 150 µg/m$^3$ set by the World Health Organisation and 250 µg/m$^3$ by Federal Ministry of Environment of Nigeria. Analysis of the total suspended particulate matter shows the concentration (µg/m$^3$) range of 0.1-24 for Cu, 2.3-500 for Fe, 0-3 for Ni, 11-540 for Zn, 11-120 Mn and 0-6 for Cr. The upper limit for Cu was above the values in literature. The results suggest the need to install particulate matter control device to curb the release of particulate matter into the area for adequate air quality management.

***Keywords:*** *particulate matter, ambient air, heavy metals, metal recycling, FAAS*

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## 1. Introduction

Air pollution is a growing hazard to health and the environment throughout the world. Toxic air pollutants are continuously released from numerous anthropogenic sources into the natural environment. Effort to regulate hazardous air pollutants has yielded little or no results because the laws guiding emissions are not strictly adhered to. In recent years, air pollution has been a serious environmental challenge especially in industrialised and densely populated cities in Nigeria [1] and other parts of world [2]. This is a consequence of the various developmental activities in the industrial, transportation and other related sectors of the economy. Many Nigerian cities on the ladder of industrialization have continued to grapple with air quality degradation. Generally, the grave consequence of air pollution on human health is ill-health or death.

Particulate matter (PM) has been of major concern in environmental engineering. It is a ubiquitous and widespread pollutant in the atmospheric environment [3] while the amount of atmospheric PM is one of the most important indicators of air quality. Elevated levels of PM from secondary steel smelting process have been recorded in Lagos [4]. The study revealed high concentration of metal components such as Lead (Pb) and Zinc (Zn) which exceeded the standards provided by Occupational Safety and Health Administration (OSHA) and US Environmental Protection Agency. Similarly, a study [5] reported high concentration of PM in the production section of a metal recycling plant. The reported concentration was ascribed to highly turbid air due to low speed of the surface wind. Particulate matter in the air in appreciable level is known to cause serious breathing difficulty because it is absorbed into the lung tissues. Epidemiological studies have linked exposure to high level of PM to cardiovascular diseases, pulmonary diseases, abnormal lung function, skin and eyes irritation [6,7,8]. Depending on the source, PM may include chemical species ranging from elemental to inorganic compounds. The most significant of the inorganic compounds are heavy metals. Heavy Metals are mostly emitted anthropogenic sources which could be from construction activities, combustions processes, recycling activities and other industrial emissions [9]. Particulate matter in its broad sense is an important carrier of toxic metals. Moreover, when PM carrying heavy metals are inhaled or ingested, they result in serious damaging health effects [10]. It also results in alteration in climate stability, ecosystem imbalance and visibility reduction. Facts are emerging that some PM in the air may be more dangerous than others. For instance, PM emitted from scrap metal-based source may be richer in toxic metals than that from fuel-based source.

The ancient city of Ile-Ife in Nigeria has been a host to an operating scrap metal recycling plant. The factory is situated on an expressway linking the city with other small and medium-sized towns in the southwest region. One major advantage is that it has enormously helped to reduce the solid wastes substances (scrap metals) dumped indiscriminately within and outside the town. This has created employment for a teeming population of youth who scavenge scrape metals and exchange with specialised scrap dealers for money. On the other hand, emissions generated in the plant is indiscriminately released into the ambient environment with potential health effects of the workers thereby reducing their productivity, traders and also the residents of nearby residential buildings. Several of the studies carried out in relation to emissions from metal recycling plants in Nigeria were mostly done in industrialised areas like Lagos. This study therefore, determines concentration and characterizes the ambient particulate matter from the smelting plant.

## 2. Materials and Methods

### 2.1. Description of the Study Area

This study was conducted in the ancient city of Ife, Osun State in Southwest region of Nigeria (Figure 1). The city is a medium-sized town with a university campus and other private institutions of higher learning. It is between latitude 7o 29’ 0’ - 7o 29’ 30’ N of the equator and longitude 4o 28’ 0’ E - 4o 28’ 30’ E. The metal recycling factory produces iron rods and bars of different sizes for consumers. It uses the traditional way of recycling scrap metals by melting in open furnaces powered by electric current. The ambient concentration of total suspended PM was determined as well as the levels of heavy metals (Copper, Iron, Nickel, Zinc, Manganese, Chromium) in the atmosphere around the plant. The study area is characterised with specific physical features such as the palace of the traditional head of the area, scrap yard for stockpiling scrap metal prior to being sold, food vendor kiosks, airtime sellers’ stand, farm settlement and a university campus located few kilometers away. The scrap and unused metallic materials are often transported from different parts of the country to the plant. This serves as a source of income to some individuals. It is pertinent to note that the exhaust gases and particulate matter emissions are released indiscriminately into the atmosphere which has generated so much concern from nearby residents. The sample collection points selected were locations where people spend substantial hours of their day.

### 2.2. Materials

The materials used in the study were a rigid collection bottle, a funnel of diameter 15 m, fresh distilled water ser-ving as the collection solvent, a fabricated tripod stand having a height of 1.6 m above the ground. Also used in the analysis is a Whatmann filter paper, Hydrogen Trioxonitrate V ($HNO_3$), Flame Atomic Absorption Spectrophotometry (FAAS), USEPA air quality document [12], a computer with Microsoft excel package. A total of 105 samples were collected from all sampling points and analysed.

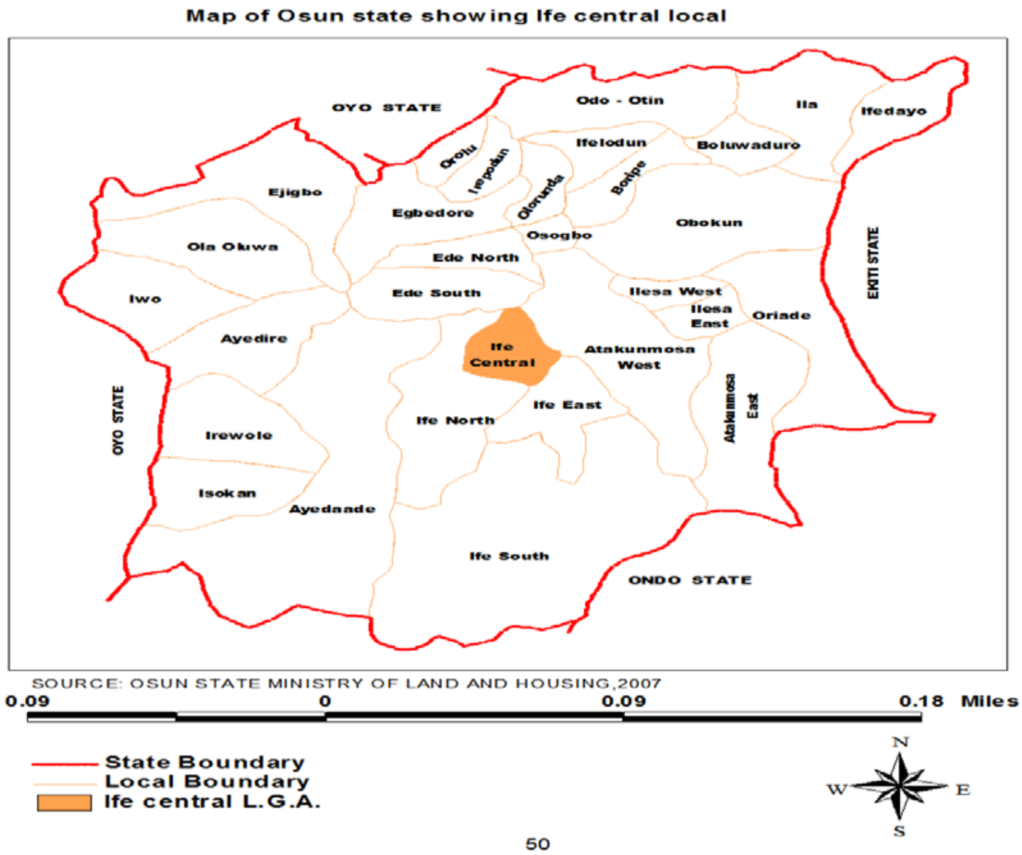


**Figure 1.** Map of Osun State showing Ife central Local Government Area [11]

## 2.3. Methodology

### 2.3.1. Method of Sample Collection

Four sampling points were considered in this study. The sampling points were coded A, B, C and D. Point A at about 25 m from the main gate beside a mosque in the north direction, point B beside the scrap dealers' main office near the plant's staff apartment, point C 25 m in the direction to the south close to traders' containers shops and D in the west directions on a farmland at the rare end of the plant. Three of the sampling points were the areas where majority of the people (workers and non-workers) in the premises of the factory spend larger part of their days carrying out different activities of buying and selling edible and non-edible goods. The last sampling point was on a farmland behind the plant. Deposition gauges were carefully installed at these points to collect total suspended particles from the ambient air. The sampling bottles were replaced at two weeks interval from the beginning of October 2015 to the end of April 2016 (7 months) which corresponds to the dry season period. The deposited PM was recovered in the laboratory by filtration using Whatmann filter paper. To determine the concentration of PM, the filter paper was weighed before and after filtration. The concentration of total suspended particulate matter in the sample was obtained using the following mathematical equation.

$$C_{TSP}\left(\mu g/m^3\right)=\frac{W2-W1}{V} \qquad 1.0$$

Where,
$C_{TSP}$ = Concentration of total suspended particulate matter
W1 = Weight of filter paper before filtration
W2 = Weight of filter paper + particulate after drying
V = Volume of solution.

### 2.3.2. Sample Digestion

The filtered particle was digested using a mixture of hydrofluoric and perchloric acids in Teflon crucible placed on a heated sand bath. Concentrated hydrochloric acid was added to the digested samples to make it volume up to 75ml. This is in line with open acid digestion approaches reported in available literature [13,14]. A 25ml aliquot of the solution was further diluted to a total of 100ml using distilled water. The resulting solution was in digesting flask and placed in the digester. The digester set up was put in a fume and a digesting controller was used for the process set up. The controller temperature reading was set to 70°C for a period of 100s. The digested sample was filtered and the filtrate taken for Flame Atomic Absorption Spectrophotometry (FAAS) analysis. Each sample was introduced into the flame which atomises the elements. In other to check for possible background contamination, blank samples were used and processed simultaneously with filled samples.

## 3. Results and Discussion

### 3.1. Total Suspended Particulate

Presented in Table 1 are the monthly average concentrations with their standard deviations for the entire study period. The lowest and highest average monthly values for the study period were 461.25±73.75 and 1300±147.2 μg/m$^3$, respectively. The month of October, 2015 recorded the lowest value while the highest value was recorded in January, 2016. Such elevated values were expected because of the open furnace method of metal recycling employed by the plant. Particulate matter visible in form of smoke predominate the study area especially during production hours except when there is equipment breakdown or repairs.

However, in comparison with standards, the concentrations considerably exceeded the statutory limits of 250 μg/m$^3$ set by the Federal Ministry of Environment of Nigeria [15] and 150 μg/m$^3$ set by the World Health Organisation [16] (Figure 2). This could occur because meteorology of the region is usually characterised with extreme dryness and stable atmospheric condition, hence the high ambient PM concentrations. The results agree with the findings of [5]. Other studies have also reported elevated levels of ambient particulate matter in industrialised areas [17]. The direct implication is that the effects can even be worse when this quantity of particulate matter is added to existing background concentration levels.

**Table 1. Average Monthly Concentration of Total Suspended Particle Matter in Ambient Air**

| Month | Average Concentration (μg/m³) |
|---|---|
| Oct '15 | 461.25±73.75 |
| Nov '15 | 1050±228.9 |
| Dec '15 | 1100±226.7 |
| Jan '16 | 1300±147.2 |
| Feb '16 | 795±122.9 |
| Mar '16 | 1097.5±221.4 |
| Apr '16 | 622.5±197.5 |

**Table 2. Concentrations of heavy metals in comparison with literature values**

| Author | Heavy Metal Concentrations(μg/m³) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Cu | Fe | Ni | Zn | Mn | Cr | Area of study |
| Present study | 0.1 - 24 | 2.3 - 500 | 0 - 3 | 11 - 540 | 11 - 120 | 0 - 6 | Ife |
| [20] | 0.510 | 40.60 | NA | NA | NA | NA | University of Ilorin |
| [19] | 12.75 – 34.75 | 2701 - 2798 | NA | 160 - 161 | 87.5 – 124.5 | NA | Aba, Nigeria |
| [18] | 0.860 – 3.120 | 1111 - 2436 | NA | NA | 10.03 – 24.99 | NA | Amber Province, Iraq |

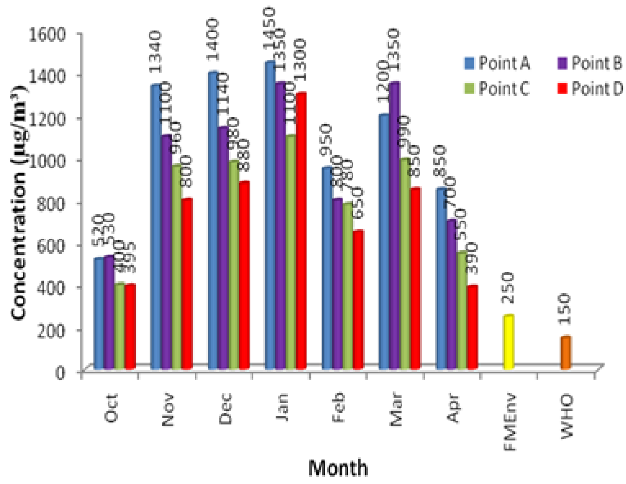


**Figure 2.** Concentration of ambient particulate matter in the study samples

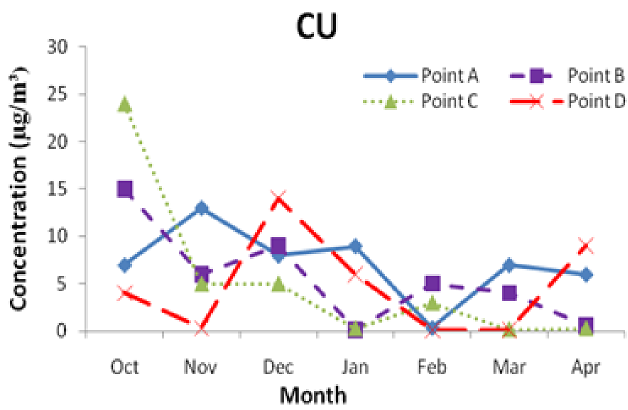


**Figure 3.** Monthly average concentration of Copper in ambient particulate matter

## 3.2. Flame Atomic Absorption Spectrophotometry

The fundamental idea of performing quantitative analysis of heavy metals in the PM collected arose from the fact that the factory is presently the predominant source of emission in the area. Therefore, it is inevitable that the ambient air will carry with it some heavy metals considering the nature of the raw materials. The results of FAAS showed the concentration of Cu, Fe, Ni, Zn, Mn and Cr in the ranged of 0.1-24, 2.3-500, 0-3, 11-540, 11-120 and 0-6 µg/m$^3$, respectively. There were considerable variations in the concentrations of the elements at the sampling points throughout the study period (Figure 3). Although, the concentration of Cu was highest at sampling point C in October, 2016 but drastically dropped in the first month and continued to reduce until April, 2016. On the other hand, the level of Fe in the ambient air at point B was higher than at other sampling points throughout the period except in December, 2015 when it was slightly higher at point A (Figure 4).

Nickel monthly average concentrations were close at for the study period at all points except at point A where it dropped from 3 µg/m$^3$ in October, 2015 to zero in November, 2015 (Figure 5). There were noticeable fluctuations in the monthly concentration of Zn at points A and B as shown in Figure 6.

This could be attributed to the unstable weather condition in the study area. The monthly average concentrations of Mn and Cr also showed significant variations in the ambient air in the vicinity of the plant (Figure 7 & Figure 8). Table 2 shows the comparison between the recorded concentrations in the present study and those available in literature. The levels of concentrations of these heavy metals with the values in literature were fairly comparable.

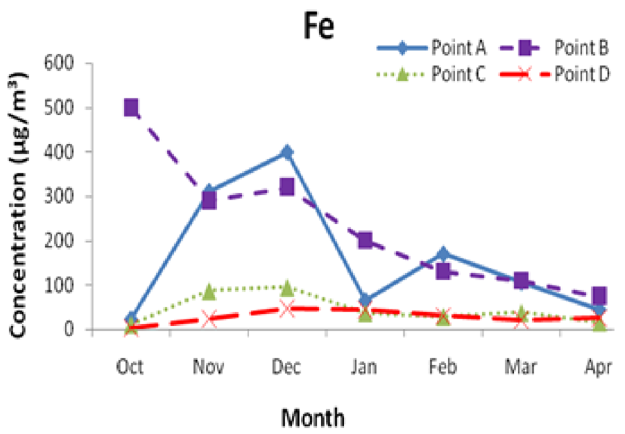


**Figure 4.** Monthly average concentration of Iron in ambient particulate matter

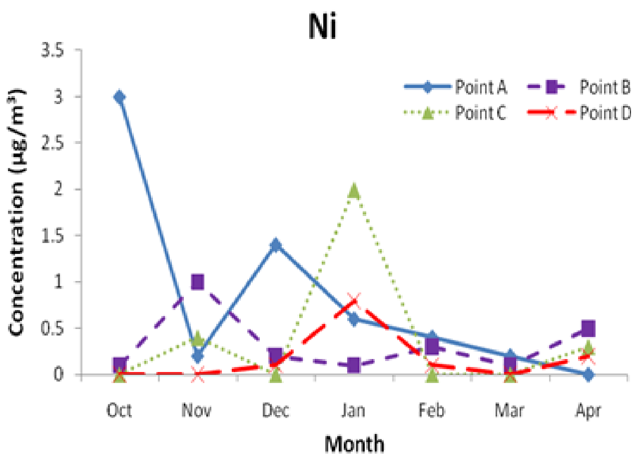


**Figure 5.** Monthly average concentration of Nickel in ambient particulate matter

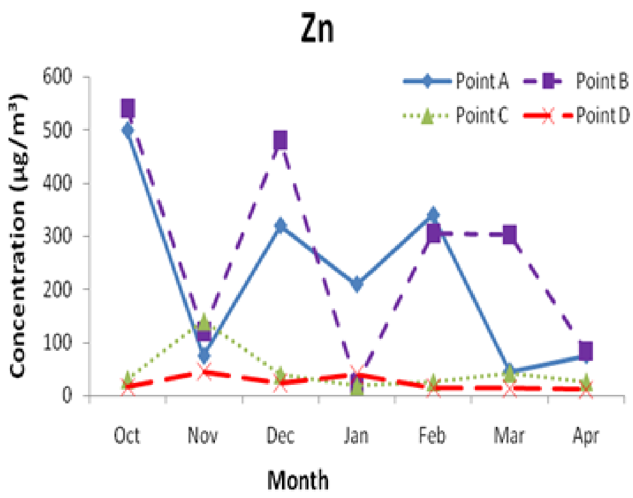


**Figure 6.** Monthly average concentrations of Zinc in ambient particulate matter

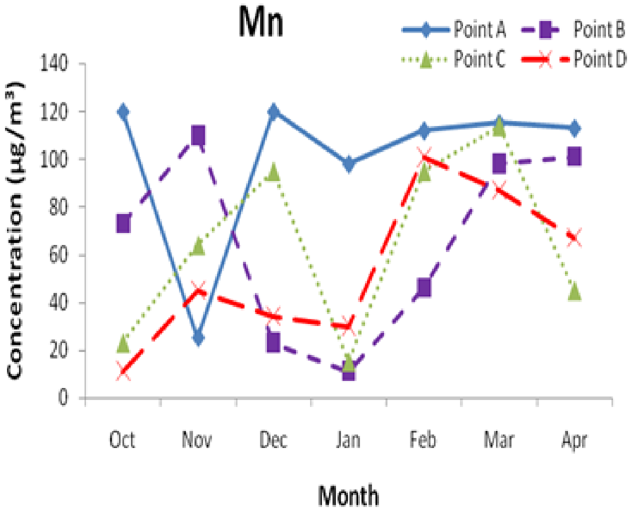


**Figure 7.** Monthly average concentrations of Manganese in ambient particulate matter

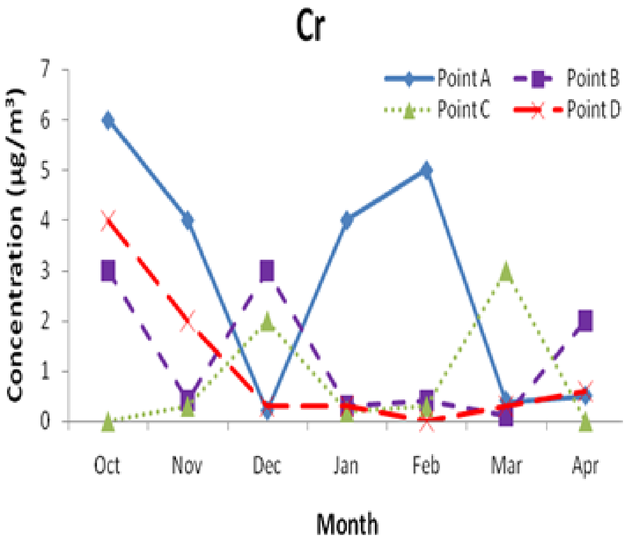


**Figure 8.** Monthly average concentrations of Chromium in ambient particulate matter

The levels of some heavy metals in this study were considerably lower than others reported in literature (Table 2). The values reported in this study for Cu were significantly higher than the literature values. The reason for this could be traced to the nature of the raw materials used in the factory. However, a study [18] reported lower values for Mn in the Amber Province, Iraq. Also, the concentrations of Mn reported by [19] in University of Ilorin, Nigeria were higher than sthe present study.

## 4. Conclusion

Particulate matter (PM) is made up of many different elements, originating from numerous sources including metal recycling. Transition metal components such as copper and iron are thought to be particularly harmful as they have the potential to produce reactive oxygen species, causing inflammation throughout the body. In view of this, the study has provided information on the concentration of ambient PM and the level of the some metals in the vicinity of a metal recycling plant. However, metal recycling plant operator could easily help to reduce high rate of emission of harmful substances into the atmosphere by adhering strictly to the use of modern emission control technologies thereby mitigating air quality deterioration.

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