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SOURCE APPORTIONMENT: CASE STUDIES OF SELECTED AFRICAN COUNTRIES

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ABSTRACT

Air pollution has been a major concern throughout the world, Africa inclusive. Particulate Matter (PM) is an area of concern because of the health implications. Source appointment is the technique used in identifying and quantifying the sources of ambient air contaminants. Apportionment studies are on the increase, in the light of this, the paper reviewed the some source apportionment studies in Africa. The review started with the aim and objectives of the emission inventory, sampling, chemical analysis and results and recommendations were discussed.

KEYWORDS: Environment pollution, Particulate Matter, Source apportionment, African countries.

INTRODUCTION

Environment pollution has been a major concern throughout the world. It has affected lives (Plants, men and animals) and materials. Efforts are been geared up to reduce it and its attendant problems. The health impacts of air pollution depend on the pollutant type, its concentration in air, length of exposure, other pollutants in the air, and individual susceptibility (Pope and Dockery, 2006).

Particulate Matter (PM) is part of environment problem. This is classified by aerodynamic diameter size and chemical composition. This is measured in terms of mass

ISSN 2278-7763

concentration (PM_{10}, $PM_{2.5}$, $PM_{0.1}$). It is categorize into two namely primary and secondary particles, primary are directly emitted into the environment through natural sources such as fuel combustion, biomass burning, industrial activities, road dust, sea spray, volcanic activity and windblown soil, while secondary are formed through chemical transformation of gaseous primary pollutants such as sulphur dioxide, nitrous oxides, certain volatile organic compounds and ammonia (Johnson *et al*., 2011).

Source appointment is the technique used in air quality management system. This technique has two basic approaches in determining the sources of air pollution. They are top-down and bottom-up approaches. Several authors (Matawle *et al*., (2014); Kulashrestha *et al*., (2014); Aleksandropoutou and Lazaridis, (2013); Amodio *et al.* (2013); Ny and Lee (2011); Kothai *et al.* (2011) have researched into source apportionment of emissions they were able to obtain information on the types of sources where pollutants come from, quantify the amount in percentage of the source from the locations at a certain period, and a basis for evaluating realistic and cost effective strategies to reduce PM pollution.

This paper reviews the source apportionment technique in selected African countries. The review started with the aim and objectives of the emission inventory, sampling, chemical analysis and results and recommendations were discussed. The results and air quality modeling indicated that the sources of emission from the countries were: dust, industries, biomass burning, transportation, field burning, steel and metal works and sea salt. The importance of the case studies was highlighted.

EGYPT (CAIRO)

The study was based on soil and road dust, also emissions from various sources like cast iron, foundry, lead smelting refuse burning, brick manufacturing etc. Motor emissions were sampled and determined (Abu –Allaban *et al*., 2002).

Sampling

The sampling areas comprised of traffic, industrial, residential and background parts. The site locations were Keha, Shobra El-Khaina, El-Massara, El Qualaly square, Helwan and El-Zamalek.

ISSN 2278-7763

The time frames for the sampling were February/March and October/November 1999 and June 2002.

Minivol ^{TM} Samplers with Teflon-membrane and quartz-fiber filters were used.

Chemical Analysis

XRF, IC and TOR were employed for the instrumentation

Model

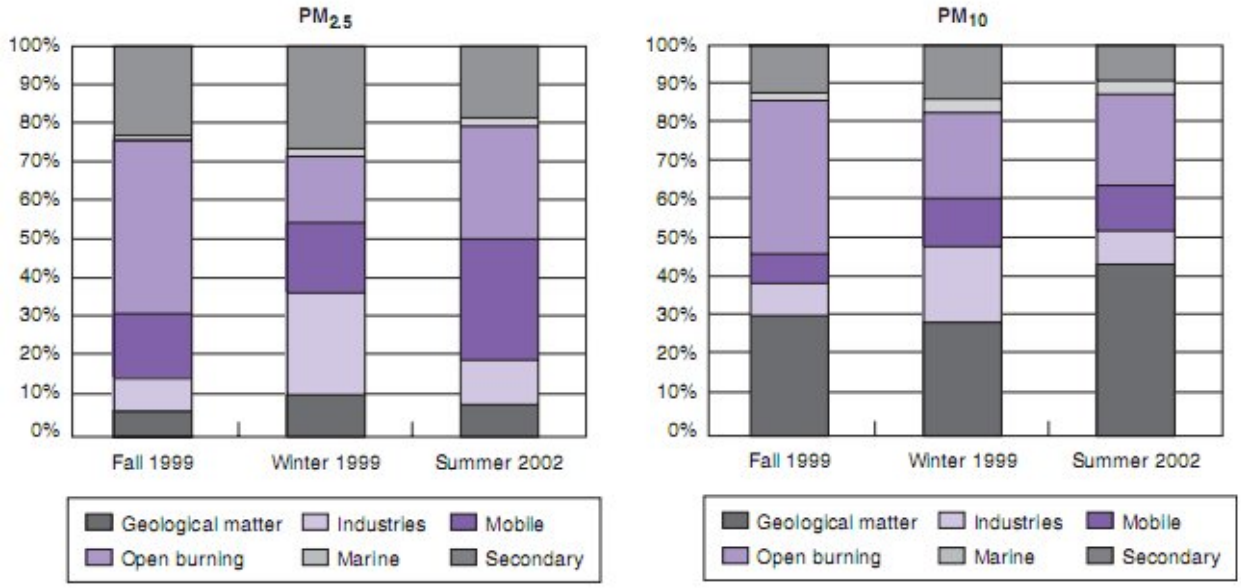
CMB

Results

The average concentrations obtained were 265µg/m^3, 163µg/m^3 and 134µg/m^3 for PM_{10} and 127µg/m^3, 84µg/m^3, and 48µg/m^3 for $PM_{2.5}$ for fall 1999, whiter 1999 and summer 2002 respectively.

From the results (Fig 1), it was depicted that the major contributions to PM_{10} included geological material, mobile source emissions, and open burning while in $PM_{2.5}$ mobile source emissions, open burning and secondary species dominated. Apart from the high level of the mass, most sites had high levels of ammonium chloride during the two 1999 sampling periods. Lead concentrations were high during the winter 1999 sampling period. Most of the lead was in the form of fresh emissions from smelters vicinity (Johnson *et al*., 2011). Based on the findings it was recommended that source of emissions should be reduced, comprehensive program should be put in place to enforce industrial compliance with air quality regulations especially for the lead smelters and to develop policies that will lower emissions.

ISSN 2278-7763



Source: Abu-Allban et al., (2002).

Fig 1: Major contributions to PM_{10}

SOUTH AFRICA (QALABOTJHA)

In this research project, chemical source profiles for low-smoke fuels, soils, vegetable burning were determined. The source profiles for coal fired power, and cement plants and steel industry have earlier been determined (Engelbrecht *et al*., 2002). This study was embarked upon to convince relevant authority in South Africa to subsidize electrification of townships.

Sampling

The sampling areas were three ambient sites in Black Township (residential, coal combustion and other activities like traffic). The area was the background site in Villiers.

Samples were collected on the roof-tops buildings, every day for 24h during midwinter in July, 1997 using Minivol^{TM} samplers. The samplers contained Teflon-membrane and quartz-fiber filters.

Chemical Analysis

XRF, IC and TOR Instruments were used

ISSN 2278-7763

Model

CMB

Results

$PM_{2.5}$ (113 µg/m^3) and PM_{10} (124 µg/m^3). The results obtained in the study showed that residential coal combustion contributed the most source of air pollution (61%, $PM_{2.5}$), while the result showed 43% of PM_{10} at the three sites in Qalabotjha. Next was biomass burning, 14 and 20% respectively (Fig 2).

Dust was only significant in the coarse particle Fraction (11.3 % PM_{10}). Sulphates originated from residential coal combustion. Secondary ammonium sulphate was three-four times greater than from ammonium nitrate accounting for 5 – 6 % of PM mass.

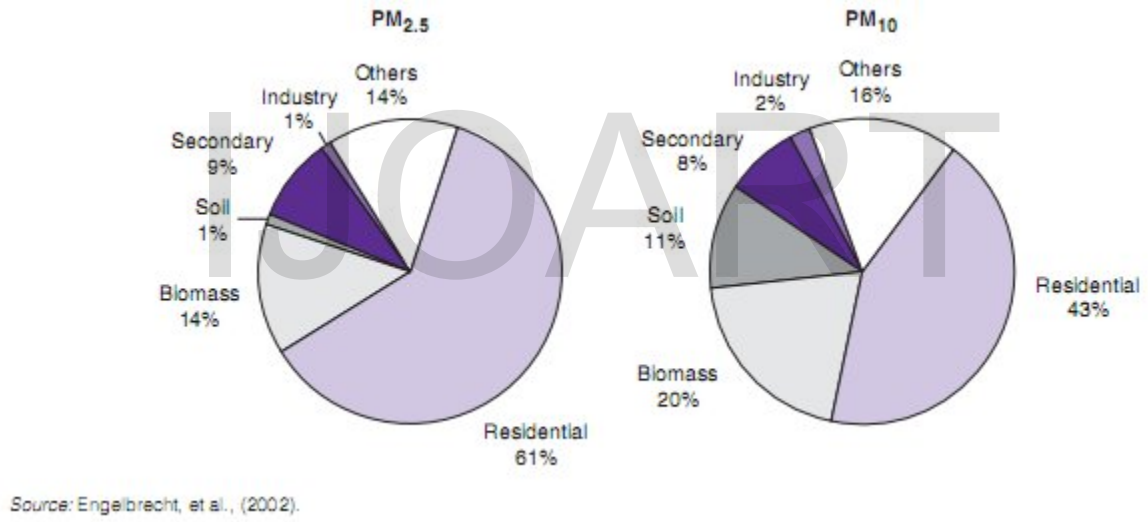


Fig 2: The results obtained in the study

EHIOPIA (ADDIS ABABA)

In the study area, the air pollution sources were light and heavy – duty motor-vehicles, industry, home, paved and unpaved road dust, and 35 – 60% organic matter and elemental carbon (Etyemezian *et al*., 2005). The sources of carbon were limited to gasoline and diesel vehicles, biomass burning and cooking due to low industrialization in the area.

ISSN 2278-7763

Sampling

The sampling points were identified to be industries, homes and roads (Paved and unpaved) in Addis Ababa. The timeframe for sample collections were during dry season (January – February, 2004). The PM_{10} was obtained at 12 different sites using MiniVol^{TM} samplers equipped with Teflon –membrane and quartz – fiber filters.

Chemical Analysis

XRF, IC and TOR Instruments were used

Model

CMB

Results

The PM_{10} concentrations obtained ranged between 35µg/m^3 and 87µg/m^3 (Average mass). The results inferred that between 35 – 65% of the PM_{10} was of geologic origin and may also be due to paved and unpaved road. Based on the outcome of the study, followings were recommended:

1. Establishment of monitoring station which will cater for the assessment of multi-year study or a long –term temporal trends.
2. Immediate attention should be focused on the air pollution, the use of biomass indoors should be discouraged or reduced to the barest minimum.

It was observed that the analysis results could be useful for economic placement of air pollution controls.

NIGERIA (CALABAR)

Air quarterly assessment was determined in Calabar Air Basin in view to measure the concentration of Total Suspended Particles (TSP). The results of the study was presented as a baseline data for TSP for the study area (Ikamaise *et al*., 2013).

ISSN 2278-7763

Sampling

TSP was collected gravimetrically using high volume air sampler with Whatman cellulose filter for a timeframe of 24months.

The sampling sites varied emission types like transportation, industrial, residential (low and high density) and rural. The experimental areas were within Calabar and immediate environs (about 30km from the town).

A potable Nigretti (Environmental System) Air Sampler 1000 was used.

Chemical Analysis

The TSP result was computed using the formula:

$$TSP = \frac{Wp}{V_{air}}$$

where Wp = Weight of particulate, V_{air} = Volume of air sampled

Results

The mean results of the particulate ranged from 55.72 – 289.54µg/m (April/June), 106.42 to 284.54µg/m^3 (August/November) and 55.72 – 284.54µg/m^3 (Annual) (Table 1). In comparism of the results with other parts of the world, the study recorded lower concentration. The particulate here exceeded the WHO air quality standard. (40 µg/m^3), but within that values recommended by Nigerian Ministry of Environment Standard. From the study, it was discovered that the major emission sources were industrial, traffic (diesel trucks), commercial activities and biomass combustion.

It was recommended that the Nigerian Government should be conscious of the side effects. Constant monitoring should be paramount to the government.

ISSN 2278-7763

Table 1: Particulate levels from source types

Source type	Mean Concentration ($\mu g/m^3$)	Rural Area Concentration
LDRA	138.09 ± 11.80	108.98± 26.68
HDRA	176.14± 24.76	108.98± 26.68
EPZ	118.14 ±24.76	108.98± 26.68
VS	269.93±10.33	108.98± 26.68

Source: Ikamaise *et al*., 2013.

LDRA - Low Density Residential Area VS – Vehicular emission source

HDRA – High " " " EPZ – Export Processing Zone

GHANA (VOLTA REGION)

The study evaluated trace heavy metals concentrations in road dust in the Ketu South District in Volta Region. The study was meant to form a baseline data in the district and bases for planning environmental air quality strategies (Addo *et al*., 2012).

Sampling

Fifty sampling sites were located in the Ketu South District of the Volta Region for road dust sample collection. At every sampling location, dust composite sample was collected by sweeping using polyethylene brush and tray from 4 to 6 points of road edges during the dry season in March, 2011.

Chemical Analysis

The samples were subjected to X-ray fluorescence (XRF) Analysis

Model

Environment Factor (EF), Pollution Load Index (PLI), Contamination Factor (CF), Index Geoaccumulation (Igeo)

ISSN 2278-7763

Results

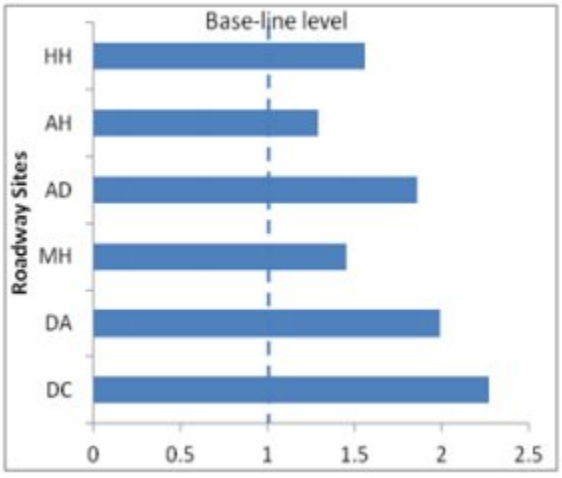
The contamination levels of heavy metals in the street dust samples were determined by using enrichment factor, goeaccumulation index, contamination factor and pollution load index (Fig 3).

From the calculation, it was found that AS (EF = 2.31) and Cr (EF = 3.84 were moderately enriched (Table 2).

The elemental marker by Zhang and Liu (2002) for EF suggested that the metals are entirely from crusted material or natural and anthropogenic processes.

Table 2: Enrichment Factor of metals

Roadway	As	Cr	Cu	Mn	Ni	Pb	Zn
DC	2.4	6.63	0.59	0.34	0.42	0.89	0.91
DA	3.01	3.32	0.64	0.31	0.72	1.25	1.25
MH	2.48	3.56	0.58	0.35	0.86	1.09	1.18
AD	2.96	3.63	0.78	0.35	0.55	1.13	1.29
AH	1.52	2.71	0.41	0.27	0.31	0.62	0.45
HH	1.51	3.16	0.5	0.29	0.37	0.86	1.23
Mean	2.31	2.84	0.58	0.32	0.54	0.97	1.05



Source: Addo *et al*., 2012

Fig 3: Pollution index for the roadways

ISSN 2278-7763

KENYA (NAIROBI)

The study was undertaken in 2008 /2009 Session at two sites in the Nairobi metropolitan area. The aim was to identify sources of $PM_{2.5}$ and evaluate their seasonal variations based on measured concentrations of $PM_{2.5}$, black carbon and 13 trace elements (Gaita *et al.*, 2014).

Sampling

Samples of $PM_{2.5}$ were collected at two sites, the first at the University from 22 May 2008 to 2 April, 2010. Cyclone sampler was mounted on a rooftop at about 17m above ground, the second, at UNEP site (16 April 2009 to 30 March 2010). The sampler was placed on rooftop at about 10m above ground.

The cyclone samplers (Casella, Bedford UK) contained pre-weighed polycarbonate filters with 0.4 pore size (Whatman International Ltd, Maidstone, UK). Samples were obtained for 24h period (Flow rate of 3L min^{-1}) and 48h during weekends.

Altogether, 780 samples were collected.

Chemical Analysis

EDXRF

Model

PMF

Results

The study presented five-factor solution data (Fig: 4).

The factors were attributed as follows:

1st Exhaust and non-exhaust traffic emissions (39% of mass concentration)

2nd Mineral dust (35% of mass concentration).

3rd Biomass burning, secondary aerosol particles and aged sea salt (13% of mass concentration)

4th Combustion processes (6% of mass concentration)

5th Industrial emissions (7% of mass concentration)

ISSN 2278-7763

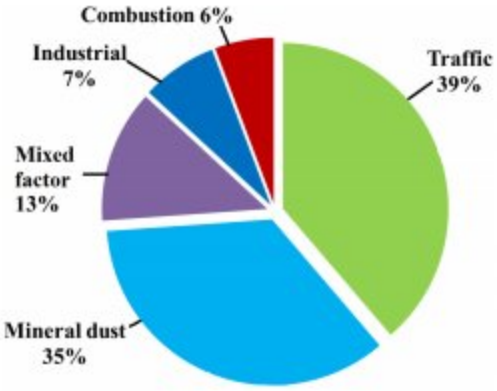


Fig 4: Source appointment for Nairobi, Kenya

Weekly Trend of PMF

The findings showed that the contribution of dust particles to airborne $PM_{2.5}$ was influenced by both anthropogenic activities and natural phenomena (Fig: 5).

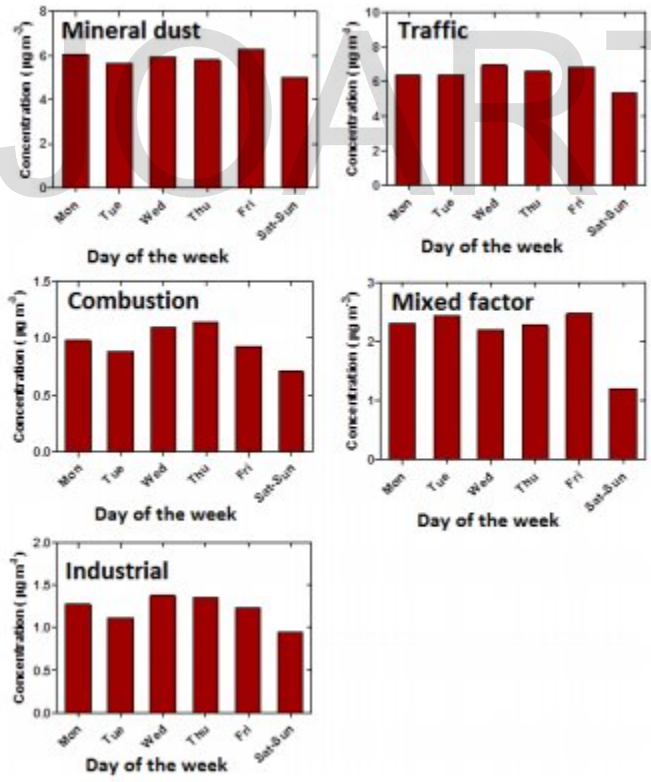


Fig 5: PMF analysis of samples

ISSN 2278-7763

The study confirmed that the contributors to $PM_{2.5}$ were traffic related emissions and mineral dust. It was concluded that contribution to the $PM_{2.5}$ by the traffic factor can be controlled by inclusion of emission checks as part of a normal vehicle inspection, this would reduce air pollution in the city. The concentration of mineral dust would give guidance when formulating any policy aimed at air pollution mitigation.

TUNISIA (TUNIS)

The study investigated the origin and variability of PM_{10} and $PM_{2.5}$ in the urban area of Tunis. The measurements of the mass concentrations and the different chemical compositions were undertaken. The PM characteristics of the sites were compared and the source apportionments of the PM in the locations were determined.

Sampling

Three sites were used for the research work - site 1 (Bab saadoun; traffic density), site 2 (Ben Arous; Industrial areas) and site 3 (El –mourouj; residential)

Sampling of PM_{10} and $PM_{2.5}$ were performed in 2008 (June 6 to 27, 24h a day, 7 days a week) totaling 82 samples.

The sampler (HYDRA Dual Sampler – FAI Instruments) operating at a flow rate of $2.3m^3/h$ were equipped with a PTFE membrane and a quartz fiber membrane.

Chemical Analysis

ED-XRF was used for metals, Ion Chromatography for anions and cations, EC/OC was determined with a themo-optical analyzer integrating a flame ionization detector.

Model

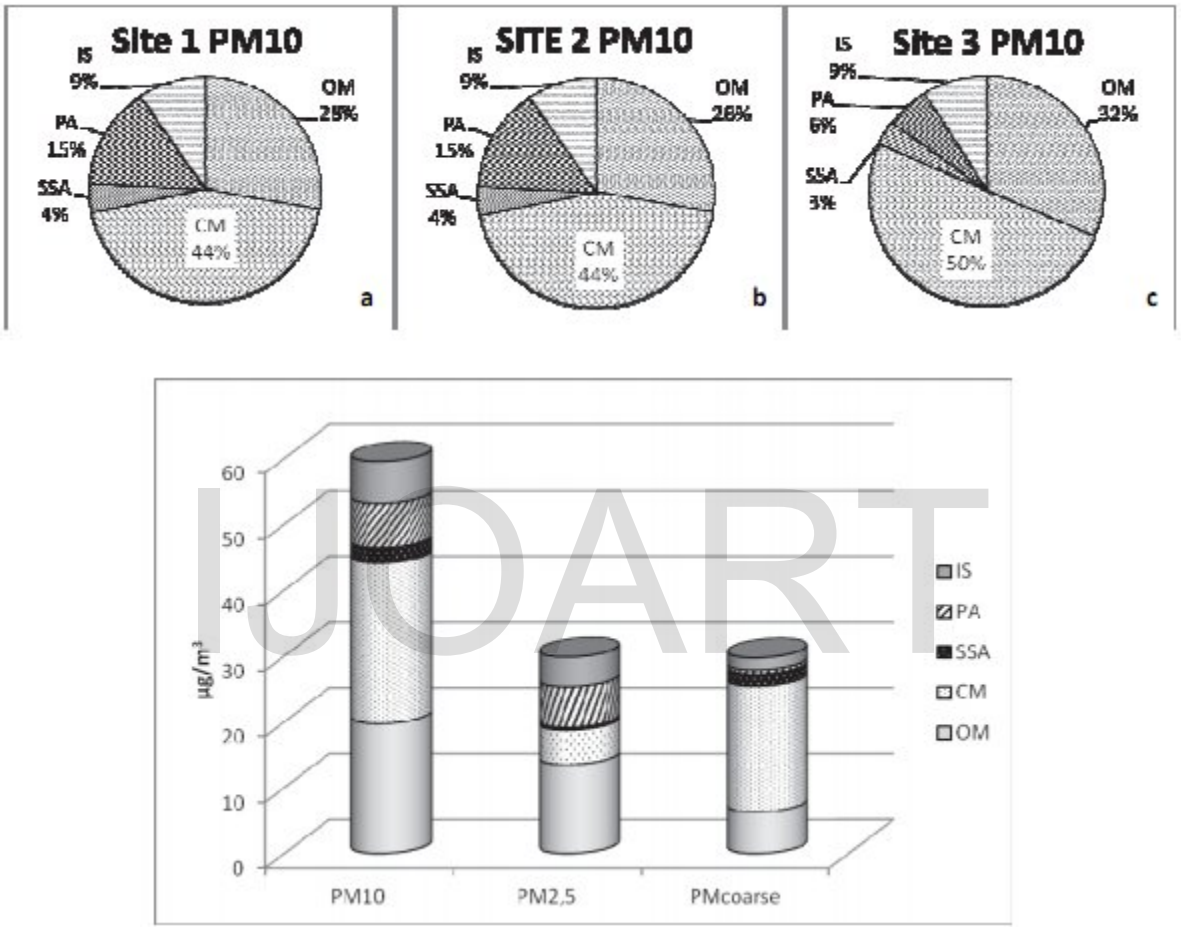
The contribution of each source were considered and calculated:

1. Crustal Matter (CM) Eldred *et al*., 1987; Chan *et al*., 1997)
2. Sea-salt aerosol (SSA) Perrino *et al*., 2008a,b)
3. Primary anthropogenic pollutants (PA) (Viidanoja *et al*., 2002)
4. Secondary Organic matter (OM) (Turpin and Lim, 2001)

ISSN 2278-7763

Results

For the three sites, the mass concentration was mainly composed of CM (41-50%), P.A (6-14%), OM (30% of the total PM_{10} mass at the three sites), 15 (annual 10% at all sites), SSA (3-4% of all the sites). However, the primary anthropogenic compounds were (68%) and inorganic secondary species (71%). Crusted material (80%) and Sea salt (81%) (Fig 6).



Source: Kchil *et al*., 2015

Fig 6: Mass concentration and contribution of each source of PM_{10} at the three sampling sites

It was hoped that the results obtained would assist the stakeholders and decision makers in their actions against tropospheric pollution, useful in education of the effects of environmental aerosols on health, assist in the study of global climate change and also contribute to atmospheric knowledge.

ISSN 2278-7763

NIGERIA (ILE-IFE)

The study was undertaken to estimate the chemical compositions and source identification of $PM_{2.5}$ and $PM_{2.5-10}$ fractions. It was aimed at the nature of emissions from a production factory that converts scrap materials into steel products (Owoade *et al*., 2015).

Sampling

The sampling was performed at the iron-smelting plant along Ife-Ibadan highway. A total of 100 samples of $PM_{2.5}$ and $PM_{2.5\ -\ 10}$ air borne particulate matter were collected on nuclepose polycarbonate filters using the low-volume GENT stacked unit sampler with the average flow rate of 15 – 16L/min at the height above 1.6m above the ground covering dry and wet sessions.

Time frame: May, 2011 to April, 2012.

Chemical Analysis

Elemental concentrations (ED-XRF), black carbon (Optical Transmissometer)

Model

PMF, CPF

Results

From the PMF results obtained, four factors were assigned to each data set. The sources were identified as cooking coal, crustal/soil, metallurgical production and electronic wasters processing for $PM_{2.5}$, while $PM_{2.5\ -\ 10}$ showed metallurgical production, electronic waste, suspended input materials, crustal/soil and galvanized steel (Table 3).

ISSN 2278-7763

Table 3: Mean source contribution derived from the PMF modeling for $PM_{2.5}$ and $PM_{2.5-10}$

Source	$PM_{2.5}$		$PM_{2.5-10}$	
	%	mass($\mu m/m^3$)	%	mass ($\mu g/m^3$)
- Soil	10.0	9.94	18.0	24.63
- Suspended input material			28.0	40.01
- Galvanized scraps			1.0	1.45
- Metallurgical Product and electronic waste			53.0	73.97
- Cooking coal	83.0	87.12		
- Electronic Waste	1.0	0.98		
- Metallurgy	6.0	6.40		

It was concluded that coking was the major source of fine particles, while contributions were related to the prevailing wind directions. Calm winds produced the highest mess concentrations due to the distance of the sampler to the source. The study could be useful for source apportionment of other industries and the potential health risks associated. The authors concluded that the study will be of assistance when formulating policies and strategies for air quality management.

GHANA (ACCRA)

The study was conducted to evaluate the level contamination of surface dust from paved roads in City of Accra, Ghana. Varimax with Kaizer normalized rotation was applied, which can maximize the variance of the factor loadings across variables for each factor (Atiemo *et al*., 2011).

Sampling

Road dust samples were collected by sweeping using soft touch brush and plastic dust pan at four sites in Accra. A minimum of ten samplers were collected from each point at 6 days interval from October 2008 to March 2009.

ISSN 2278-7763

Chemical Analysis

EDXRF (for elements)

Model

PCA, EF, Igeo, CF

Results

Components 1 – 3 extracted from PCA model results showed that the metals were likely to be from anthropogenic influence. The sources of emission were traced to natural crust origin, fuel combustion, tyre abrasion, brake wear, both exhaust and non-exhaust emissions (Table 4).

Table 4: PCA Rotated Component Matrix

	Component		
	1	2	3
Ti	0.626	0.725	-0.066
V	0.206	0.920	-0.011
Cr	0.235	0.183	0.910
Mn	0.731	0.487	-0.015
Ni	-0.236	-0.214	0.903
Cu	0.716	0.697	0.060
Zn	0.601	0.794	0.032
Br	0.465	0.650	0.028
Zr	0.893	0.205	-0.049
Pb	0.622	0594	-0.026
Variance (%)	41.33	25.71	16.57
Cumulative (%)	41.33	67.04	83.61

Source: Atiemo *et al*., 2011

ISSN 2278-7763

NIGERIA (WARRI)

The research focused on providing baseline information on air quality in Warri and it also quantified the contribution of the industrial activities to the pollution of the city (James and Ndiokwere, 2006).

Sampling

The samples were collected in four locations. In these areas, there are the presence of refinery, Petroleum Training Institute, airport, traffic and small-scale businesses;

Sampling duration was 18months (dry and wet sessions). Particulate matter samples were obtained with a SKC side kick sampling pump 224 – 50 by filtration through Whatman membrane filters of 25mm with a pore size of 3.0µm for 8h. Flow rate of 0.10.0Lmin^{-1}. This sampler was placed on the roof top of story building.

Chemical Analysis

AAS (for elements)

Model

EF, FA, CMB

Results

The particulate matter ranged from 922 – 2333 m^{-3}. It was noted too that steel/metal works, sea salts, residual oil combustion, motor vehicle and re-entrained soil dust were the major sources of the elements and PM in the atmospheric environment. CMB detected an anthropogenic contribution of (37 – 75%) (Table 5 and 6).

ISSN 2278-7763

Table 5: Elemental Concentration of Total Suspended Particulate Matter (µm/m^3)

Elements	Range	Mean	Enrichment Factor
As	3.01 – 5.21	3.97 ± 1.00	3288.97
Mn	0.02 – 0.05	0.01 ± 0.02	0.66
Ni	1.05 – 2.03	1.17 ± 0.01	44.84
Cd	0.02 – 0.23	0.12 ± 0.01	3395.82
Se	4.03 – 6.01	4.65 ± 0.95	39424.56
V	1.45 – 2.68	2.09 ± 0.05	153.37
Fe	1.13 – 1.38	1.18 ± 0.03	1
Pb	1.01 – 1.04	1.02 ± 0.12	113.42
Cu	0.01 – 0.09	0.04 ± 0.03	8.48
Al	0.01 – 0.68	0.19 ± 0.03	0.16
Cr	0.03 – 0.06	0.02 ± 0.01	1.35
Na	5.06 – 7.77	6.16 ± 1.14	32.96
K	1.38 – 2.66	2.00 ± 0.39	15.88
Ca	1.67 – 3.46	2.23 ± 0.25	0.57

Source: James and Ndiokwere (2006)

ISSN 2278-7763

Table 6: Rotated Factor Loading for TSPM

Variables	Factor 1	Factor 2	Communality
As		0.844	0.949
Mn		0.690	0.923
Ni	0.979	0.255	0.988
Cd	0.925		0.918
Se	0.423	0.328	0.941
V		0.948	0.941
Fe	0.999	0.421	0.998
Pb		0.721	0.977
Cu	0.850		0.832
Al	0.968		0.990
Cr	0.988		0.984
Na	0.843	0.458	0.937
K	0.612		0.982
Ca	0.929		0.902
Variance	8.929	4.293	
% Variance	64.133	30.700	
Possible Sources	Steel metal works/Sea salts	Residual oil combustion Vehicle exhaust/Soil dust	

Source: James and Ndiokwere (2006)

NIGERIA (LAGOS)

This work was carried out to determine the contribution of the sources identified to the TSPM at two different sites within Lagos township (Oluyemi and Asubiojo, 2001).

Sampling

Sampling was carried out at three different sites namely Ikeja (Industrial area), Yaba (Commercial centre) and Ikoyi (Atlantic Ocean/Lagoon). Seiria Anderson high volume air sampler (USA) fitted with a cascade impactor was used for the collection of air particulate. The

ISSN 2278-7763

collection medium was Whatman 41 cellulose acetate filter paper treated with Vaseline in hexane.

Time frame: 1989 and 1991.

Chemical Analysis

Wavelength Dispersive XRF equipment (For elements)

AAS (Sodium)

Model

FA, CMB, EF

Results

The results of CMB model on the coarse particles from Ikeja depicted that the 13 elements obtained were from four major sources namely: soil, marine, vehicle exhaust and regional sulphate. The percent contributions of the sources were 46%, 29.6%, 0.3% and 2.0% respectively. The compositions of the fine particulates were soil/dust (29.6%), marine (27.8%), oil combustion (4.9%), incinerator (2.5%), vehicle exhaust (4.0%) and regional sulphate (14.0%).

The results of Yaba location for coarse particulates revealed as follows: Soil (54.1%), marine (26.2%), vehicle exhaust (0.3%) and regional sulphate (1.9%) while fire particulate had; soil (35.5%), marine (34.2%), oil combustion (4.9%), incinerator (2.9%), vehicle exhaust (3.5%) and regional sulphate (12.1%).

Finally at the third location – Ikoyi, the results obtained were; coarse particulate (Soil 950.4%), marine (27.3%), incinerator (2.5%) and regional sulphate (1.9%). Fine particulate (Soil (56.9%), marine (24.4%), incineration (4.5%), vehicular exhaust (0.7%) and regional sulphate (8.1%).

ISSN 2278-7763

The SPM at the three locations:

Location	Mean Value ($\mu g/m^3$)
Ikeja	176 ± 78
Yaba	188 ± 64
Ikoyi	92 ± 36

OBSERVATIONS FROM THE CASE STUDIES

Interest in air pollution has been on the increase in the developing countries due to the attendant problems encountered by man, animals and materials. Based on the case studies evaluated in this paper, the followings were observed:

1. Low utilization of source apportionment.

From the literatures it was found out that few papers dealt with source apportionment. Most papers on dust dealt with characterizations of metals, aerosol and PM. This may be due to lack of knowledge on the use. There would be the need for proper training and capacity development on the source apportionment. Developed countries should endeavor to assist developing nations on this subject matter.

Another salient point is that the tools and techniques needed to embark on these studies are scarce. Where they are available majority of researchers may not avoid the cost.

There would be a need for collaborative works between developed developing and underdeveloped countries. This will assist in developing local capacities.

2. From the case studies in this paper, the tools and techniques used were narrowed down to few methods and models compared with the source apportionment studies from Asia, Europe and other continents where a wide variety of the tools are used.

According to Johnson *et al*., (2011), critical inputs are needed when conducting effective bottom-up and top-down analyses. Such as quality emission inventories and source profiles, unfortunately, these are lacking in the countries selected in this paper.

3. Some of the common sources identified in this report are:

i. **Dust**

This came from activities like unpaved roads, wind or vehicle travel, construction, demolition and others. The followings could be control measures: keeping road access points

ISSN 2278-7763

free of materials that may be carried to the roadway, paving of unpaved roads, minimizing track – out onto paved roads, rapidly clearing up materials spills on roads.

ii. **Industries**

These are part of the contributors especially in urban settings. They contribute to ambient concentrations in these areas. Necessary regulatory regimes from the emission sources should be enforced.

iii. **Biomass burning**

Most residential areas of the case studies depend on the use of wood, coal, biomass for cooking. The obvious reason is poverty. The healthier solution could be to discard the use of this and employ electricity on gas.

iv. **Transportation**

PM pollution in the case studies was caused by indirect emission from fugitive dust or resuspension. This had resulted into energy consumption, thereby causing harmful effects on the environment. In dense traffic zones, pollutant were emitted near populations that are potentially exposed whereas other pollutants can travel long distances before they were deposited on the ground.

v. **Field burning**

All the countries under this study were involved in field burning activities. This was due to the belief of the local farmers that once the farms are burnt it would increase crop yield, control weeds and pests, ignorantly not knowing that they pollute the environment.

vi. **Steel and metal works**

The experience here was observed in Nigeria (Ile-Ife) where study was undertaken within a scrap iron and steel smelting industry. According to Johnson *et al*. (2011), polluters are difficult for regulator to identify, much less monitor. In this area, it is only innovative environmental management strategies that can be effective.

ISSN 2278-7763

IMPORTANCE OF CASE STUDY

This report has been able to identify and describe the source apportionment studies of selected African countries. This paper is important in formulating an effective air quality management system in Africa. The models used by the researchers were few compared to other researchers in developed countries.

The results obtained in these studies would serve as a baseline to other researchers who would want to extend works or continue where the previous workers stopped. It would be a useful tool (resource) for workers that have not amassed details, accurate information base of pollution sources.

Model results gathered here would serve as guidelines for regulatory purposes where there is the need for issuing emission permits (Nguyen, 2014).

The paper would assist in the scientific research on characterization and source apportionment. It would serve as a means of comparison with other published or ongoing works. The bases for comparison between researches in developed and underdeveloped countries would be made possible.

It would provide information to the populace where the study was undertaken. It would give insight on how safe the environment is and from the sources of emission.

The implementation of an effective air quality management system in these areas and other areas of study is possible. The results of source apportionment used could offer a powerful tool in improving the air quality.

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