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Seasonal Variation and the Effect of Particulate Air Pollution in Freetown, Sierra Leone

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Abstract : *Seasonal variation of air borne particulate matter (PM) concentration in Sierra Leone is poorly understood. . In view of this, we investigate particulate matter concentration ($PM_{2.5}$ and PM_{10}) in specified locations in the city of Freetown from January to December (raining, drying and harmattan seasons) in order to examine and compare any seasonal pattern on the concentration of particulate matter in the air and its health consequence. PM Concentrations in all locations were less in the raining season than values observed during the drying and harmattan seasons. Levels of PM observed in the harmattan were little bit higher than their respective values in drying season. PM average concentrations were found to be ~4 times higher in drying than in raining season and ~5 times higher in harmattan than in the raining seasons. Results also show significant but weak correlation between PM concentrations and ARI (acute respiratory illnesses) cases for nonsmokers. A correlation coefficient of 0.68 for $PM_{2.5}$ and 0.54 for PM_{10} between number of admissions and level of particulate matter in outdoor air was found. The results show that females are mostly affected compared to the children and their male counterpart.*

1. Introduction

Despite significant awareness by the Environmental Protection Agency Sierra Leone (EPASL) and other partners on the negative impact of ambient air quality over the past year especially in Freetown, Sierra Leone, air pollution continues to pose a challenge to regulatory bodies and health professionals in Sierra Leone. Millions of people breathe outdoor air containing pollutants at concentrations sufficient, judging from laboratory and field investigations, to provoke acute respiratory related illnesses. Extensive epidemiological evidence reported that fine particulate matter (PM) air pollution has adverse health effects (1-5). These studies throughout the world have shown that ambient particulate air pollution is associated with an increase in all-causes of respiratory and cardiovascular disease mortality (2-5). These recent evidences on the adverse effects of particulate air pollution on public health has led to more stringent standards for levels of particulate matter in outdoor air in many countries in the world. For instant, South Africa in 2004 implemented the National Environmental Management Air Quality Act No 39(6, 7). This legislation transferred the focus for air quality management from the source to the receiving environment. As part of its implementation, ambient air quality guidelines were conscripted as indicated in the table below:

Table 1: South African PM Standards

South African PM Standards	Averaging period	Limit values ($\mu g/m^{-3}$)
PM_{10}	24 hours	180
	Annual	60
TSP	24 hours	300
	Annual	100
New South Africa PM Standards up to 2014		
PM_{10}	24 hours	120
	Annual	50
South African PM Standards after 2014		
PM_{10}	24 hour	75
	Annual	40

The effects of particulate matter on human health might believably exhibit seasonal variation. Studies in a number of locations in the world have shown that the characteristics of particulate matter constituents change throughout the year and that the composition of particular components to particulate matter mass may vary at different times of the year (8-15). Human activities also change from season to season, thus a specific air pollutant concentration in one season may lead to a different exposure in another season. Other potential time-varying factors, such as temperature, wind direction; rains etc. can also affect the concentration of air pollution and its effect on humans in different seasons. A study has shown that particulate matter composition varies in the spatial domain (10)(17-19), which suggests that seasonal pattern plays an important role in PM concentration in the environment and it effect on human health . For example, in Freetown, burning of waste and resuspension of dust particles due to unpaved road are a greater source of particulate matter in the dry and harmattan seasons than in the raining months (20-22). Thus, sources and mechanisms of PM mixture are known to vary throughout the year. In addition to the diverse forms of exposure of the population in different season, it is reasonable to say short-term associations between particulate air pollution and health risk may change from season to season. Consequently, a seasonal change is an important factor when studying the concentration and health effects of air pollution. Scholars have recognized highest effects of PM in different seasons such as: winter, summer or transition seasons (spring/fall) in different part of the globe, among which most were conducted in developed countries (24-28). There remains a need for research in cities of developing countries such as Freetown, where characteristics and concentration of outdoor air pollution may be different from one season to the other owing to activities being carried out in the different seasons. Moreover, as one of the poorest country in the world, there is little or no data regarding seasonality and the health effect of air pollution. Therefore, there is a need for this type of study to be carried out.

The aims of this paper are to observe the effect of seasonal pattern on the concentration of PM in the air and to evaluate its health consequence, with the listed objectives:

- To determine the concentration of PM
- To identify which season may have the highest concentration of PM
- To investigate the potential for respiratory related health effects from air pollution
- To investigate which class of the population is mostly affected by air pollution (i.e. Male, Female and Children).

2. Materials and Methods

2.1. Site Description

Freetown is the capital and the biggest city in Sierra Leone. It is situated in the western area of the country. Freetown is divided into East End, West End and Central. The East End is the biggest and most populated of the three zones. Central Freetown hosts the central business district and most key national government structures. The West end is the most luxurious area among the three i.e. most people living around this area can be classified as wealthy or are average income earner. The West End is where most of the luxurious city's hotels and recreational centers are located.

Like the rest of Sierra Leone, Freetown has a hot climate with two main seasons (rain and dry season), each lasting for six months. However, the wind blowing from the Sahara desert around December through to February (Harmattan) provides the country its coolest period of the year. Temperature in Freetown range from about 17 °C (63 °F) to 41 °C (106 °F) all year with the average annual temperature around 27 °C (81 °F) (16).

Ten locations were selected to quantify PM_{10} and $PM_{2.5}$ concentration. Three locations where selected from the east end of the city (Upgun, Granville Brook dump site and Allen Town dump site), two from the central part of the city (Circular Road and Kingtom) and the remaining five locations are from the west end of the city (Guma gate, Leicester, Kortright ,Spur Road and Ascension Town). A map of the areas investigated is shown in Figure 1.

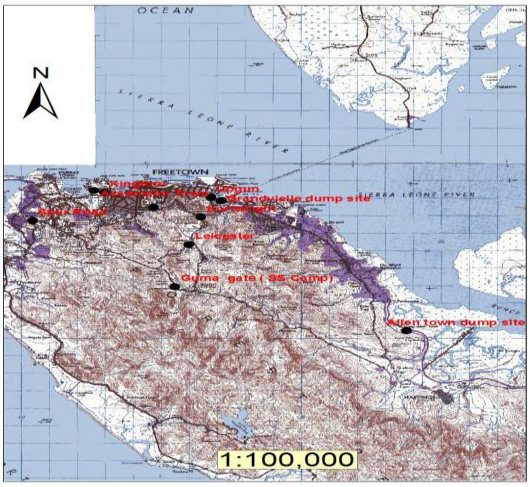

Figure1: Map showing the different sampling points

2.2. **Data collection**

The concentration of PM_{10} and $PM_{2.5}$ were measured using a hinaway CW-HAT200S Handheld Air Tester (figure2).The instrument measure two other parameters (temperature and relative humidity of the location) together with the $PM_{2.5}$ and PM_{10} concentration within 60 Seconds for each reading. Two sets of readings were carried out: outdoor air analysis and indoor air analysis (inside houses in the various locations). Outdoor air analysis in each location was done within 24 hours with a time interval of 30min between each measurement. Each location was properly mapped by a 62s Garmin GPS. Three sampling points at each location were specified and the average was recorded as the PM concentration of a particular location. For the indoor air analysis, six houses in each of the specified location were targeted, with two houses close to each outdoor air sampling point. The average PM concentration of the six houses in each location was recorded as the PM concentration of that site. Analysis in each house lasted for approximately an hour; readings were taken in duplicate in each house with a time interval of 30min. this analysis was conducted in three different seasons i.e. Drying, Raining and Harmattan seasons.

We designed and initiated an investigation to document cases of respiratory related illness of nonsmokers and children in hospitals located in each study area for the period of January to December 2016. Its goals are to determine whether significant health effects related to PM concentration is predominant, and if so, to determine which class of the population is more venerable (male, female and children). Data for children were collected mainly because they spend more time outdoors and exercise more than adults, both of which increase their ambient air pollution exposures. In addition, the risk factors of smoking and occupational respiratory exposures are negligible for most young children.

A questionnaire was also administered in each study area to assess the prevalence of respiratory related illness, outdoor activities, and other possible risk factors such as passive smoking. For children less than five years, information was obtained by parent completing the questionnaires. The questionnaire requested information regarding wheezing, sneezing, symptoms of cough, running and/or stuffed nose without a cold, bronchitis, bronchial asthma, and respiratory infections. We summarized and evaluated the data collected and finally relate the PM concentration to respiratory related disease prevalence in the communities under study.

Figure 2: Hinaway CW-HAT200S Handheld Air Tester

3. Results and Discussion

Figure 3 shows outdoor PM_{10} concentrations for the three seasons (Raining, Drying and Harmattan) .

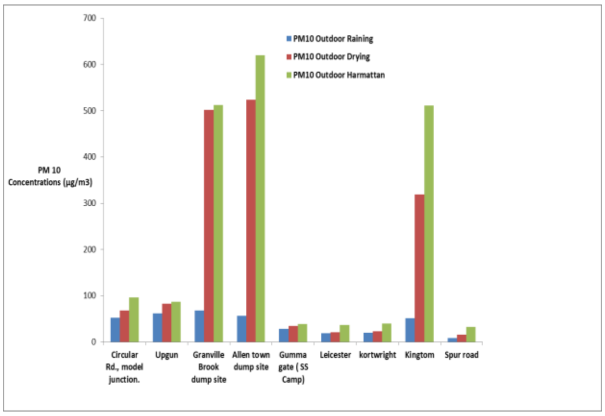

Figure 3: Outdoor PM_{10} concentrations for the three seasons (Raining, Drying and Harmattan).

PM_{10} Concentrations in all locations were less in the raining season than values observed during the drying and harmattan season as shown in figure 3. Levels of PM observed in the harmattan were little bit higher than their respective values in drying season. PM average concentrations were found to be 4.34 times higher in drying than in raining season and 5.39 times higher in harmattan than in the raining seasons. Burning activities are normally high during the drying season and the end of the raining season. . This is so because during the raining season, piles of waste will be stored at dump sites waiting for the rains to end. Moreover, natural sources such as dust re-suspension may be primary contributors to these higher values in drying season because of ground heating and thermal convention of particles in the dry conditions of the monitoring locations. Also the harmattan season is accompanied by heavy wind from the Sahara desert which could have contributed significantly towards higher levels of PM as there is a general assumption that strong winds cause more dispersion of particulate matter. Harrmattan is also responsible for increasing concentrations, thus having a significant influence upon atmospheric conditions affecting concentration, transportation and/or dilution of particulate matter.

The different concentrations at different locations may be attributed to the different activities that take place at the different times. The trend of PM_{10} observed over the study depicts an uneven spread of particulate matter. The lowest observed throughout the seasons was recorded in the western area, (Figure 3). The highest, on the other hand was recorded in the east end area followed by the central locations. High temperatures contribute to an increase in PM2.5 (29) and our data also showed higher values of PM during the warm season (drying season). However, PM concentrations were much higher during the harmattan than the drying season. A study of the temporary pattern/variation of particulate matter concentration conducted in Ghana and Tanzania. (30,31) and similar results were concluded with highest PM concentrations in the drying and Harmattan season compared to the raining season. Harmattan annual $PM_{2.5}$ and PM_{10} increases by 21-23µg/m^3 and 33-36µg/m^3 respectively in Ghana ((30);) and concentrations of PM constituents varied considerable between seasons (dry and wet season), with highest concentration of PM in urban areas recorded in the drying season in Tanzania's largest city(31) . Our results are also comparable to study conducted in Japan. Particulate matter showed great seasonal impact due to different dispersion levels in summer and winter seasons. All fractions of particulate matter were observed to be greater in summer than in winter. Highest monthly mean volume concentration (2.7 $\mu m^3/cm^3$) of accumulated particles (0.3 µm < D < 1.0 µm) was observed in June, while the mean value in winter (October to February) was 0.7 $\mu m^3/cm^3$ (32). The possible reason behind this trend may be formation of warm thermal layer on floor during summer (33).

The values recorded for the Harmattan and drying season in this study were found to be higher than guideline values established by WHO . The 24-hour values of PM2.5 established by WHO is 25µg/m³ while that of PM_{10} is 50 µg/m³ respectively (43).

Since increased hospital admissions for respiratory related diseases have been associated with particulate matter air pollution in numerous studies in most cities in the world (1-3,5,14,33-34), it triggers the need to correlate acute respiratory illness (ARI) of non-smoker to the current air quality in the city. Previous and current studies show that the air quality in Freetown is very poor (21-22). As a result, it may be insinuated that most respiratory related illness can be associated to the poor quality of air in the city.

Figure 4 and 5 relates average PM concentrations with the prevalence of respiratory related disease based on data obtained in various hospital in the study locations and feedback from the questionnaires been administered.

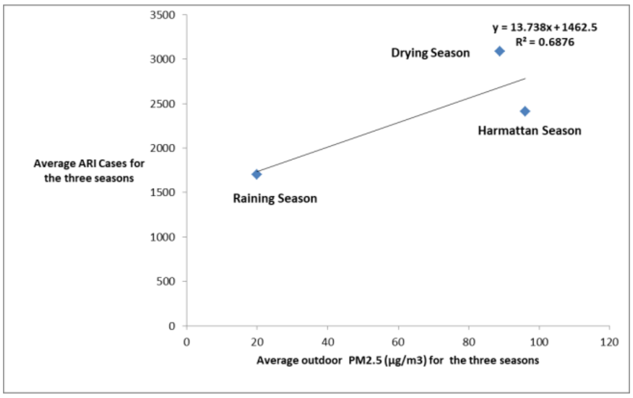

Figure 4: Correlation between $PM_{2.5}$ concentrations and the prevalence of respiratory related disease

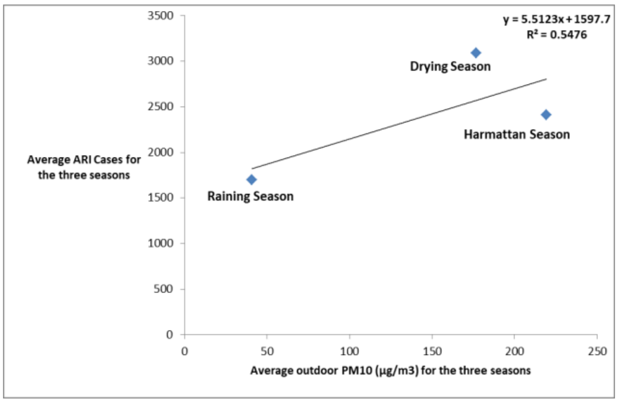

Figure 5: Correlation between PM_{10} concentrations and the prevalence of respiratory related disease

Results show significant but weak correlation between PM concentrations and ARI cases for nonsmokers. A correlation coefficient of 0.6876 for $PM_{2.5}$ and 0.5476 for PM_{10} between number of admissions and level of particulate matter in outdoor air was found. $PM_{2.5}$ correlation is a little bit stronger than PM_{10} correlation. This indicates that it's effect on human health is much more severe than its counterpart PM_{10}. Numerous studies have come up with similar finding in different part of the globe. Brunekreef & Forsberg, 2005 found mixed results of strong and weak associations of coarse particulate matter with cardiovascular and respiratory disease admissions (37). Valley, 2000 found an association between coarse particulate matter and cardiovascular mortality in California (38), as did Burnett, et al; 1997 in a Canadian study (39). Likewise, Kan et al., 2007 found strong associations between coarse particulate matter and cardiovascular mortality in Shanghai, China (40).

Figure 6 shows the class of the population that is mostly affected by air pollution (i.e. Male, Female and Children).

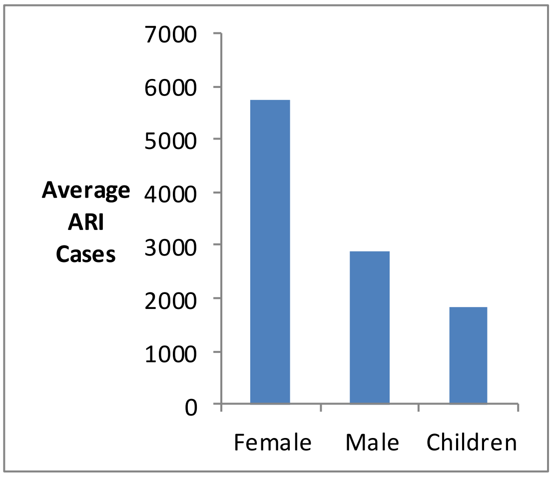

Figure 6: comparing ARI cases of female, male and children

The results show that females are mostly affected compared to the children and their male counterpart. This may be ascribed to the fact that most of the cooking at homes is done by the women in which the commonly used form of energy is first, fuel wood and second charcoal. Both sources of energy used for cooking have been shown to release toxic air pollutants such as polyaomatic hydrocarbons and carbonmonoxide gases (36) (41-42) which affect human health. Moreover, women spent most of their time within the homes visited in the study locations as the men normally leaves in the morning to engage in employment activities outsides these locations. Thus, if the vicinity is highly concentrated with PM, the women are the most vulnerable.

4. Conclusion:

In the present study the following findings were made:

- Significant seasonal variation of particulate matter concentration was observed.PM Concentrations in all locations were less in the raining season than values observed during the drying and harmattan season.
- Respiratory related illnesses were found to be associated with exposure to air pollution. Associations were stronger in female than in male. Due to the very young age of the children, it is too early to draw definitive conclusions from this study. Thus, the association between long-term exposure to air pollution and respiratory related illnesses needs further study when the children are older.

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