

Emission of Combustible Gases at Traffic and Practising Waste Dumpsite in Freetown, Sierra Leone: A Pilot Study

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Abstract

An assessment of the emission of combustible gases in developing countries requires reliable analytical realtime monitors that can rapidly screen them with minimal handling. Considering the expensive nature of monitoring environmental pollutants, chemical sensors are expected to play a pivotal role in measuring and recording environmental data. The Drager X am 5000 was used to report emission levels of combustible gases in this study, namely; nitrogen dioxide (NO₂), sulphur dioxide (SO₂) and carbon monoxide (CO) at traffic and practising waste dumpsite in Freetown, the main city of Sierra Leone. Hourly average values for the three pollutants were recorded in the morning, afternoon and evening periods, respectively. The range of values were 18 - 76 ppb for NO₂, 211 - 506 ppb for SO₂ and 11 - 14 ppm for CO at traffic site; and 6 - 16 ppb for NO₂, 118 - 276 ppb for SO₂ and 8 - 15 ppm for CO at the dumpsite, respectively. There were significantly high hourly variations for NO₂ and SO₂ at the traffic site and for CO and SO₂ at the dumpsite. Evidence of peak values showed emission levels that were considered dangerous for human exposure. This pilot study revealed that combustible gases released in certain areas of the capital city are a concern for both public health officials and environmental advocates.

Keywords

Pollution, Nitrogen Dioxide, Sulphur Dioxide, Carbon Monoxide, Air Quality

1. Introduction

Urban air pollution is increasingly getting global attention as reported by World Health

Organization (WHO). It is reported that millions of people around the world are exposed to dangerous levels of air pollution. Several key stakeholders such as environmental health research community, environmental regulatory bodies, industries, transport etc. have drawn keen interest on air pollution and public health. The quality of the outdoor or ambient air is tied closely to morbidity and mortality from respiratory and cardiovascular diseases [1] [2] [3] [4]. Common urban air pollutants that have been on the spotlight include nitrogen dioxide (NO₂), sulphur dioxide (SO₂) and carbon monoxide (CO). They are usually released from either stationary or mobile sources in urban areas.

Sulphur in the lower troposphere originates either from natural processes or anthropogenic activity. SO₂ is a renowned anthropogenic pollutant and contributes to the formation of sulphuric acid and formation of sulphate aerosols, and the deposition of sulphate and SO₂ on the surface of the ground. Direct emission of SO₂ is generally by burning fuels containing sulphur which is largely responsible for its presence. It can undergo several processes such as transformation due to atmospheric reactions such as gas to particle conversion and eventually wet and dry deposition. These processes perturb the environment negatively that consequently results in acid rain [5]. Nitrogen dioxide is a constituent mixture of nitrogen oxides [NO_x = NO + NO₂] and it is mostly formed during combustion processes. Mobile and stationary combustion sources have been reported to be the major anthropogenic source of NO₂ in the atmosphere [6] [7]. NO₂ is alongside NO, a major regulator of the oxidizing ability of the troposphere through regulating the buildup and fate of radical species including hydroxyl radicals. It is a precursor of ozone (O₃) during photochemical formation and therefore influences its concentration in the lower troposphere and also plays a significant role in photochemical smog.

CO is a byproduct of incomplete combustion of diesel or gasoline engines in traffic, industrial operations, dumpsites of municipal solid waste where open burning is practiced, cooking with biomass in less ventilated stoves, *etc.* The rapid growth of the capital city Freetown, is considered to have a profound effect on the air quality situation, for instance, emission due to the rapid increase of two stroke engines, increased use of second hand vehicles and poor quality fuels [8] [9] [10]. Freetown has an array of environmental and public health problems including respiratory illnesses due to high levels of pollution [11]. Hence, this study focuses on a weeklong air quality screening at two potential sites of emission of NO₂, SO₂ and CO in Freetown, so as to assess emission levels of these combustible gases in the lower atmosphere.

2. Methodology

2.1. Study Area

Sierra Leone lies within the West African tropical rainforest belt, although the drier northern areas are transitional between this zone and the savannah belt to the north. The Tropical Front in Sierra Leone lies mainly to the south from December until March and there is very little rain during this dry season. About April, the Tropical Front moves northwards and the country falls under the southwest monsoonal rains from May to October. In November, the Front moves southwards again bringing the return

of the dry winds. Thunderstorms are common during the change-over periods between the seasons. The duration of the “Harmattan” period decreases southwards; conversely, the rainfall increases considerably and is heaviest on the coast while Musaia (in Koinadugu District) in the far north of the country is the driest.

In Freetown, the highest temperatures (average = 31 °C) are experienced at the peak of the dry season in March, whilst the lowest temperatures (average = 23 °C) are recorded during the wet season from July to October. Also, the highest rainfall period is between June and October, with the precipitation reaching its peak during the month of August. Freetown was selected for the study because it is the capital city of Sierra Leone where more than two-thirds of the country’s automobile exists. It is located on the Western Area of the country on a mountainous peninsula stretching into the Atlantic Ocean.

2.2. Site Description

Traffic site: The EASTEND POLICE intersection was selected. It is located in the East end of the city linking the peripheral or sub-urban areas to the central business district. It is the main entry point into the city center via Kissy Road intersecting Fourah Bay Road; a route mostly used by office workers, school-going children, business people, etc. This same route is used by heavy vehicles, with over 4 tons capacity, into the city center conveying imported goods from the Sea Port or Provinces. Traffic jams are quite obvious due to these heavy vehicles that often broke down along the main road giving rise to endless queues of traffic. Parked vehicles along the roadside also contribute to the poor traffic situation. Commercial activities are quite visible along the narrow strip of pedestrian pathway, with petty traders often blocking the narrow footpath. Fairly high rising buildings that are less than 2 - 3 m away from the roadside are noticeable, depending on the area.

Waste Disposal Site: This site is located in a valley of the Granville Brook stream which runs across Bai Bureh road and opens up into the Atlantic Ocean; the surrounding communities are fully urbanized within a residential area. The site is bounded to the east by the valley wall and to the south by the main highway exiting the city center. The west of the site is limited by the Granville Brook stream channel and is open ended to the north where the Granville Brook joins the Sierra Leone River. The dumpsite receives all categories of solid waste as well as liquid waste from various sources such as domestic, hospital, industries etc. Even though “Masada” Company which is charged to manage wastes in the capital has been making huge strides to create a conducive environment for waste management in the past three years, yet, waste is dumped indiscriminately and left untreated and uncovered.

2.3. Sampling Program

2.3.1. Instrumentation

The concentration of combustible gases NO₂, SO₂ and CO were measured during this study using the Drager X-am 5000 obtained from *Ribble Enviro Ltd., UK*; (www.drager.com). It is a small, light and easy to use equipment, which makes it very ideal for field monitoring in areas where conventional monitoring requirements are

somehow restricted. It is very robust, water-tight and is designed for single-handed operation in tough industrial environments. According to IP 67, it is water and dustproof and contains an integrated rubber boot which provides the device optimal functionality even under harsh conditions. The monitor can measure up to six gases simultaneously but for the purpose of this study, three (3) electrochemical infrared sensors for NO₂, SO₂ and CO were utilized. The device has a high resolution of 0.1 ppm for both NO₂ and SO₂ and 2 ppm for CO with very short response times of 15 seconds for NO₂ and SO₂ and 25 seconds for CO. Measurements were recorded at regular intervals of one (1) hour duration at each site in the morning period, between the hours of 07h00 - 09h00, afternoon from 12h00 - 14h00 and evening from 17h00 - 19h00 from both sites over a five-day period. Measurements were recorded at five (5) minutes intervals.

2.3.2. Positioning of Samplers

The sampling was carried out in mid-December 2015 at the two sites. The sampling sites were selected to reflect ambient concentrations of the pollutants released from these two sources in Freetown. A monitoring height of 1.2 m above ground was used during the monitoring. Care was taken to ensure that the sampler was not exposed to the risk of spontaneous fire outbreaks at the dumpsite by keeping a safe distance away from continuously burning garbage. This was especially necessary for situations in which the emitted plume of gases from the dumpsite was blown directly towards the monitoring personnel by the wind. The monitoring duration for each cycle of measurement was one hour.

2.4. Quality Control Procedures

The zero point accuracy of the sensors was reached by carrying out the fresh air calibration each time measurement was made in order to correct instrument drift. Significant drift may interfere with data quality and this was achieved by the one-button calibration procedure in an area away from the monitoring zone or area where trace levels of the measured gases or interfering gases are found. Field assistants had to move to the middle of nearby secondary school campuses where there is little evidence of ambient air pollution to carryout fresh air calibration. The display containing the current gas concentration changes with the display showing "OK" when calibration was done indicating a successful calibration process.

2.5. Data Analysis

Quantitative and numeric data were obtained during the study which was then subjected to descriptive statistics. Five minutes averages were computed within an hour to obtain hourly averages for the morning, afternoon and evening periods; t-test was used to compare mean concentrations for NO₂, SO₂ and CO between the traffic site and the dumpsite. Since the data did not follow a normal distribution pattern, a Wilcoxon non-parametric test was used to test whether group means are similar across each pollutant (NO₂, SO₂ and CO). A threshold value of significance (*p value*) was taken at 5% or 0.05 from which all statistical inferences were made. These analyses were conducted using JMP 8 statistical package. Results are presented in the form of charts.

3. Results and Discussion

Results of three air pollutants of interest namely, NO_2 , SO_2 and CO were recorded for the two sites monitored in Freetown. **Figure 1**, revealed the spatial and temporal variation of air quality indicators between the two sites. It can be observed that there were significant elevations of NO_2 in the morning and afternoon periods at the traffic site relative to the dumpsite. A similar observation was again manifested for SO_2 between the sites but only a significant difference was noted for CO in the afternoon period.

Generally, levels of pollutants were higher in the traffic site relative to the dumpsite and a probable reason for such observation could be due to low general circulation of air and thus more stagnant air masses resulting in more accumulation of pollutants. Given the open area of the dumpsite facing the Atlantic Ocean, the high wind speed and sudden changes in general wind direction might have affected and aided the dispersion of gases emitted at the dumpsite, hence low level of pollution observed. The dispersion of gases has further being enhanced over the past few years considering the responsibilities of MASADA, a company charged to manage municipal wastes in the city. The company has been engaged in clearing areas down towards the Atlantic Ocean so as to restrict the neighborhood from illegal disposal of wastes. Dispersion of air pollutants by wind

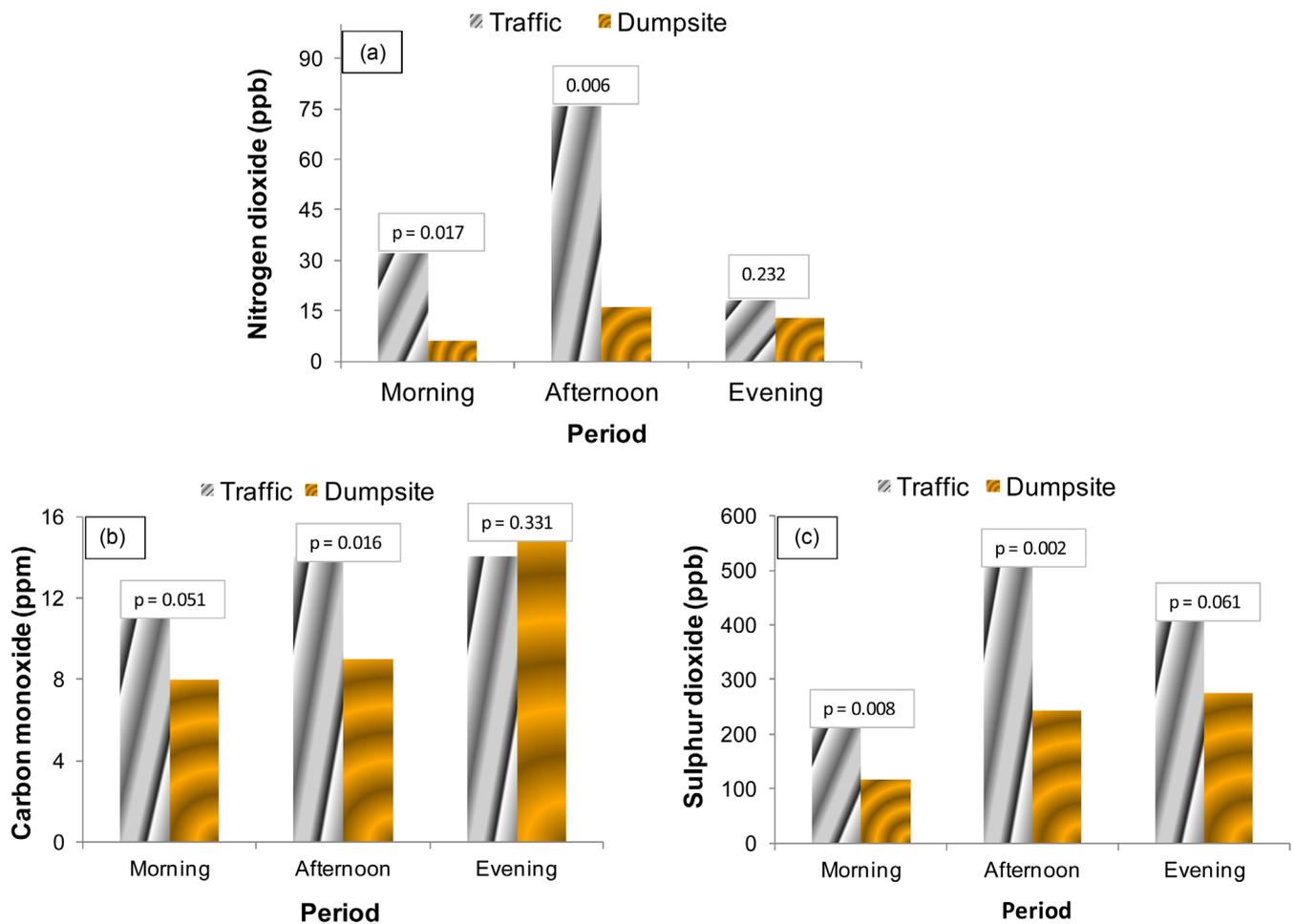


Figure 1. Spatial and temporal distributions of air pollutants across traffic and practising dumpsite for (a) NO_2 levels (b) SO_2 levels and (c) CO levels.

enhances further dilution of the gas concentrations and there is a greater tendency to transport them further inland where they are not generated posing health risks to residents.

The highest levels of NO₂ and SO₂ were recorded in the afternoon period at the traffic site. This observation is in agreement with a previous study in Tanzania along a busy road site (*Askari*) showing relatively higher levels of NO₂ and SO₂ in the afternoon period relative to the morning period [12] but similar observable levels have been reported in Lagos, Nigeria [13] even though the sampling or monitoring regime is different. Average values of NO₂ and SO₂ in this study are lower than what the study in Tanzania reported [12], but the SO₂ levels in the current study is higher than a previous study in India for all the months being monitored [6] although variation in the study design exists. However, in countries where stricter emission controls are enforced such as in Japan and India, our reported levels are by far higher than what has been reported [3] [14].

Empirical evidence has shown that NO₂ is low during periods of sunshine usually in tropical or sub-tropical regions [6]. It should be observed that the formation of NO₂ depends on the atmospheric condition and primary emission source of NO [15]. Due to its reactivity with other species in the atmosphere, NO₂ can undergo complex photochemical reactions. Previous evidences have shown a reduction in NO₂ levels during the summer or periods of intense sunshine [16] [17] and we are of the view that the source and sink pathway of this species is rather complicated.

According to **Figure 2**, the 1-hr average levels showed significant variation for NO₂ with the highest variance being observed in the afternoon at the traffic site. No such difference in variation was noted for CO for the various monitoring periods but there was a considerable variation for SO₂. **Figure 3** also showed significant variation in values for SO₂ and CO at the practising dumpsite relative to NO₂.

The observed variation in the afternoon along the traffic site according to **Figure 2** is strongly attributed to the change in the flow of vehicle pattern. This period is characterized by entry into and exit from the city center by heavy duty vehicles that carry goods and services. Although this period should be considered off-peak period, yet, the levels are higher due to endless queue of traffic. It was observed from **Figure 2** that the short term exposure can be astonishingly high as evident in the peak or maximum values. All three indicator species showed critical values that exceeded ambient air quality standards for any reference period. For instance, peak exposure can reach 240 ppb for NO₂, 1900 ppb for SO₂ and 70 ppm for CO, an indication that critical values for NO₂ can be 4 - 5 times higher, SO₂ 25 times higher and CO is 2 times higher than ambient thresholds, respectively. There is a growing body of evidence of strong association between combustible gases and health outcomes. For instance, previous studies have revealed association between NO₂ and CO and cardiac problems in patients [18] [19]. Other studies have reported elevated levels of gaseous air pollutants and worsening asthma conditions in patients and daily mortality [20] [21].

In Sierra Leone, most of the vehicles are powered by gasoline and the evidence of sulphur compounds in the atmosphere of Freetown could be an indication that fuels imported into the country contain sulphur. It has been earlier reported that SO₂ is a

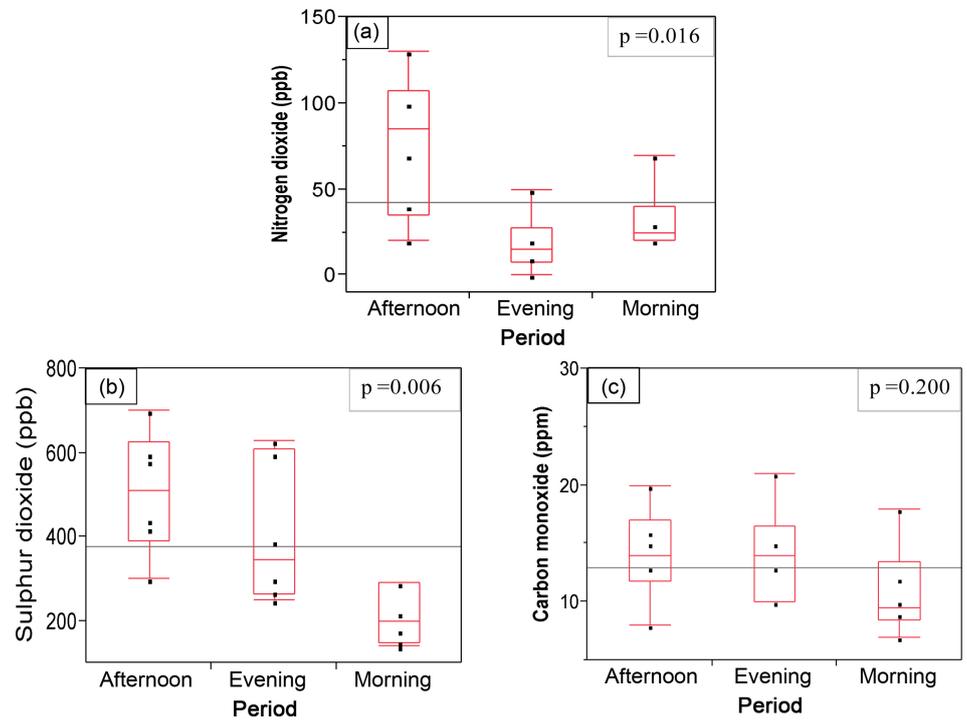


Figure 2. Box plots showing hourly variation at traffic site for (a) NO₂, p = 0.016; (b) SO₂, p = 0.006 and (c) CO, p = 0.200.

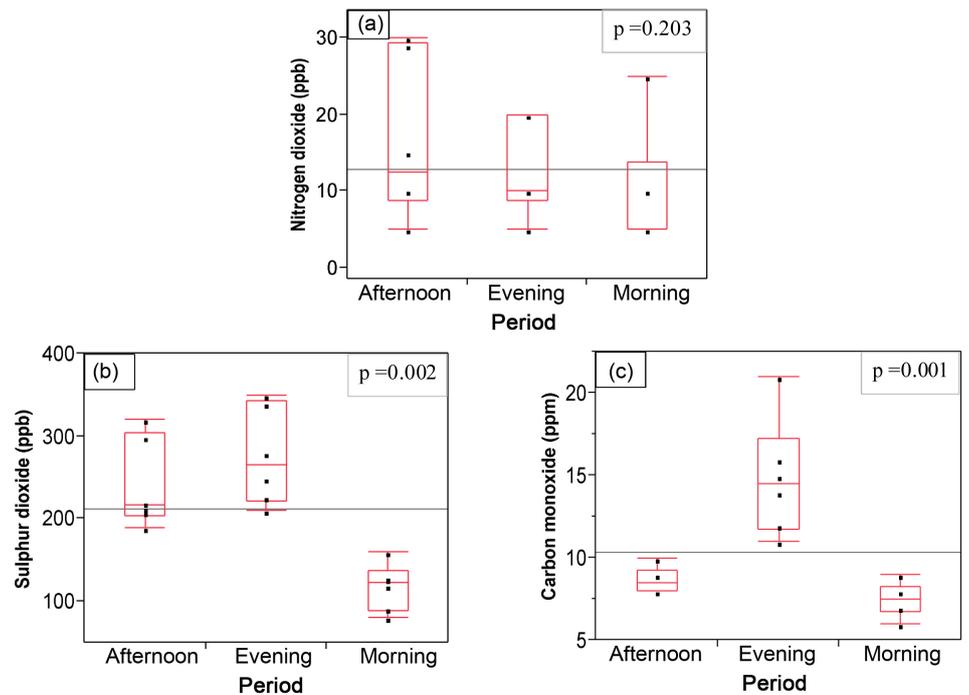


Figure 3. Box plots showing hourly variation at practising dumpsite for (a) NO₂, p = 0.203; (b) SO₂, p = 0.002 and (c) CO, p = 0.001.

conventional air pollutant that is released into the atmosphere mainly from anthropogenic sources like combusting sulphur containing fossil fuel [16]. Whilst SO₂ levels in cities of other countries outside Africa appear to have declined due to stricter emission

controls [21] [22] and increased use of low sulphur fuel, the situation in developing countries such as Sierra Leone is different as evident in this study. One direct environmental impact of high levels of sulphur dioxide in Freetown is the formation of acid rain given the heavy downpour of rain in that part of the country. Considering the fragile state of the water resources in the country, this foreseeable problem needs urgent policy action.

The air quality of Freetown would continue to be challenging if urgent regulations are not passed into law by the government. Key considerations in the regulations should include; levy more or higher taxes on all used imported vehicles rather than on brand new vehicles; discourage the practice of open burning of domestic wastes with tougher penalties for defaulters; rigorous testing for sulphur content in all imported fuels; stop all street trading along traffic routes in the city so as to avail footpath for pedestrians and protect traders (mainly women and children) from exposure to high emission levels; reduce the flow of heavy tonnage vehicles during the day; development of effective waste management system *etc.* In addition, we strongly agree with the integrated approach put forward [23] to addressing the problem of air pollution in developing countries [23]. This should include emission inventories focusing on characterizing pollutants and their sources; followed by atmospheric modeling which provides the basis of spatial and temporal coverage of the area. When the modeling provides adequate representation of the measurements made through the ambient monitoring program, then the process can continue with further modeling, both primary (human health) and secondary (welfare) effects [23]. It is only through this approach that decision makers can reach beyond the boundaries of geography and divergent interests to develop effective policies to achieve improved air quality.

4. Conclusion

In this pilot study, we determined the emission levels of NO₂ and SO₂ and CO at a busy traffic road and a practicing waste dumpsite in Freetown where similar meteorological conditions were present. The results revealed relatively higher emissions at the traffic site than the waste dumpsite although significant differences in emissions were noted for the morning, afternoon and evening periods between the two sites. This piece of work provides valuable background information that can be guided in dispersion modeling as well as evaluating the possible impacts from mobile and stationary sources. It is strongly recommended that a long term monitoring program should be done so as to observe meteorological influences on pollution episodes.

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