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TROPOSPHERIC OZONE CONCENTRATIONS AND METEOROLOGICAL PARAMETERS

Strictly as per the compliance and regulations of :

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Nnenesi A Kgabi [α] & Ramotsamai M Sehloho [σ]

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Keywords : ground level ozone, meteorological parameters, weekend effect, ozone bell behavior.

I. Introduction

Air pollution has impacts on both the ecological equilibrium and the population health (Menut et al., 2000). Stratospheric ozone shields us from ultraviolet radiation, while tropospheric ozone can aggravate existing health conditions such as bronchitis, heart disease, emphysema and asthma (Lippman, 1989) and can result in damage to vegetation (Embersion et al., 2001). Although it is colorless and odorless, the ozone gas is very irritating to the lungs and can cause permanent lung damage. Ozone is very corrosive; it damages the human air sacs that are important for gas exchange. Repeated exposure to high levels of ozone can thus inflame lung tissues and cause respiratory infections.

Ozone damage to plants can occur without any visible signs. The gas interferes with the ability of green plants to convert sunlight into useful energy. This interferes with the normal photosynthesis processes; and causes damage to agricultural crops, commercial timber and natural forest ecosystems, ornamental plants (grass, flowers, shrubs, and trees) and other natural flora (Menut et al., 2000). The economy of the North West Province depends mostly on agriculture; therefore, interference with normal photosynthesis processes is cause for concern. Botsalano is situated in the agricultural area and high levels of ozone can have negative effects on the crops in the area, and Marikana is near the mining industry, where the ozone precursors, oxides of nitrogen and VOC's are mostly produced.

Ground-level ozone is not emitted directly into the air, but rather is formed by gases like oxides of nitrogen (NOx) and volatile organic compounds (VOC), which in the presence of heat and sunlight, react to form ozone. Emissions of NOx are produced primarily when fossil fuels are burned in motor vehicle engines, power plants, and industrial boilers.

The major anthropogenic source regions of atmospheric pollutants in southern Africa are the mining and smelting activities on the Copper belt in northern Zambia and emissions from coal combustion by industry in South Africa (Fleming and van der Merwe, 2002), where emission occurs on a continuous basis. Greenberg et al. (2003) showed that biogenic emissions of hydrocarbons from Southern African vegetation are significant sources of these important ozone precursors. Most biogenic emissions are dependent on the solar cycle and the availability of moisture. As a result, they vary with season and time of the day, being higher in summer than winter and higher during the day than at night.

Biomass of the African savannas is known to produce large amounts of photochemically active aerosols and trace gases that are necessary precursors of tropospheric ozone (Crutzen and Andreae, 1990)

Meteorology plays an important role in the formation, dispersion, transport, and dilution of air pollutants. The variations in local meteorological conditions such as wind direction, wind speed, temperature and relative humidity have a great influence on surface ozone concentrations and its precursors (Elminir, 2005). Weather conditions are also critical to ozone formation, which is greatest during summer, when long hours of sunlight and high temperatures speed up the ozone-forming photochemical reactions.

Relative humidity has an effect on the concentrations of air pollutants. A study by Li et al. (2007) reported that an increase in relative humidity leads to a decrease in average concentrations of ozone.

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High ozone concentrations are also associated with high temperatures and prolonged sunshine.

The main objectives of this study were to determine the concentrations of ozone in the lower atmosphere, and to relate the concentrations to changing meteorological conditions. The study was conducted at the Botsalano Game Reserve, which is considered a 'clean' environment since it is far from mines, industrial areas and human settlements; and at Marikana (Rustenburg), which is considered as relatively "polluted" environment because it is situated close to mines and industrial areas.

The Botsalano game reserve is situated 18 km east of Ramatlabama (Botswana – South Africa) border post, and 65 km north of Mafikeng. The Game Reserve is situated between longitude 25° 32' 30.4" south and latitude 25° 45' 17.8" east and is far from town and mining industries. Ozone concentrations and meteorological parameters were also measured at Marikana municipal offices, with a community health clinic, community hall and library buildings in the same location. Marikana is a township situated between longitude 27°21'53.61" south and latitude 27°28'36.58" east, located to the east of Rustenburg, a pollution hotspot in the North West Province.

II. Materials and Methods

Environment SA 41 m UV photometric ozone analyzer was used to measure ozone concentrations. The ozone analyzer operates on a full scale of 0 – 500 ppb, at a temperature range of 10°C to 35°C, with response time setting of 11 (Automatic response time), and with or without any of the internal ozone generator, and span external control (zero/span solenoid valve) (www.epa.gov/ttn/amtic/criteria.html). The UV photometric method is not subject to interference from any of the common gaseous air pollutants.

The ozone analyzer has three major systems: the optical system, the pneumatic system, and the processing electronic system. Pneumatic system consists of sample probe, sample inlet line, particulate filter which eliminates the dust particles contained in the sample to be analyzed, solenoid valves, and scrubber, internal tubing, flow meter which maintains the necessary flow in the measurement system, and pump, all used to bring ambient air samples to the analyzer inlet (McElroy and Nees, 1997).

The air sample was taken continuously (24 hours a day) by a pump, it passed first through exchangeable Teflon filter. The filter was changed after every two weeks, and the forceps were used to hold the filter during each changing period. The detector measured the light intensity in the absence of ozone. The data logger was connected to the instruments to log the data to the computer. The data for temperature, relative humidity, rain, and wind speed and wind direction were also recorded and stored daily. The Beer-Lambert equation is used to calculate the concentration of ozone from the ratio of light intensity (US EPA, 1996).

Temperature and relative humidity were measured using Rotronic MP 101A (Vaisala HMP50), rain intensity was measured using Thies 5.4103.20.041 Adolf Thies GmbH Co.KG, and wind direction and wind speed were measured using Vector A101ML (Vector W200P).

III. Results and Discussion

The hourly ozone levels are vital in determining the contribution of domestic and industrial activities in the vicinity of the study area.

a) Hourly ozone concentrations for mid week and weekend days at Botsalano Game Reserve

Figure 3.1 shows high hourly ozone concentrations during the weekend, i.e. a maximum of 49.81 and 54.18 ppb on Saturday and Sunday respectively; and low levels during mid week days with a maximum of 36.42 and 41.23 ppb on Tuesday and Wednesday respectively. The ozone starts to increase in the early hours a day from 06h00 in the morning. The afternoon maximum is due to photochemical formation of ozone and the evening minimum can be due to surface deposition, the titration of ozone by nitrogen oxides and the absence of photolysis of ozone precursors that cause ozone production at night. The maximum is also in agreement with the results obtained by Lenkopane and Matale (2000), who measured surface ozone at Gaborone and other parts of Botswana and showed that ozone reached maximum peak in the afternoon.

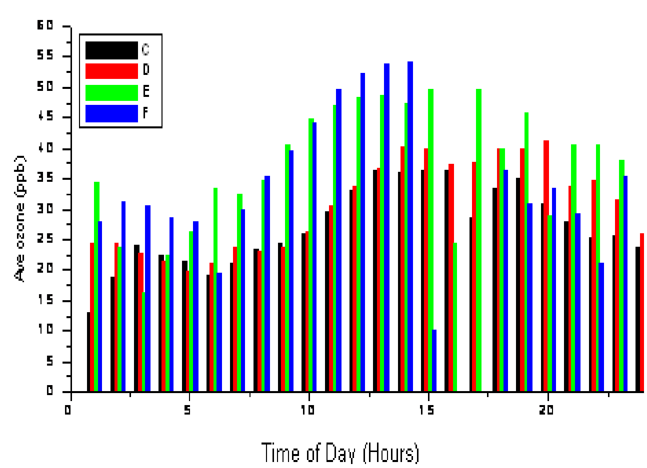

Figure 3.1 : Hourly ozone levels on 09 Jan 07 (C), 10 Jan 07 (D), 13 Jan 07 (E), 14 Jan 07 (F)

The increase of ozone concentration in the late afternoon just before sunset could be due to motor vehicle emissions because of the afternoon traffic density and domestic fuel burning activities.

The results in Figure 3.2 show higher midweek ozone levels with a maximum of 47.21 and 47.06 ppb as compared to 38.34 and 31.51 ppb maxima for the weekend.

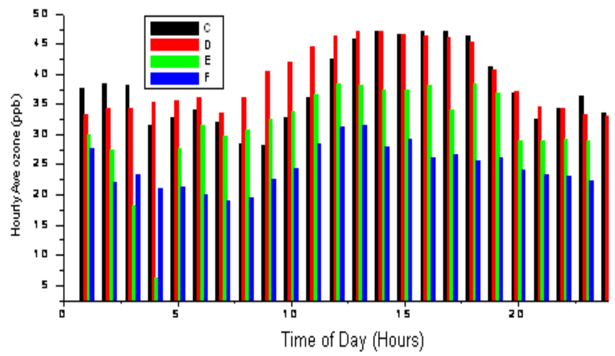

Figure 3.2 : Hourly ozone levels on 13 Mar 07 (C), 14 Mar 07 (D), 17 Mar 07 (E), 18 Mar 07 (F)

The high concentrations during the week occur because of photochemical reactions among ozone anthropogenic precursors from vehicle emissions, and the lower ozone concentration during weekend were because of lower emissions of ozone precursors on weekends. A decrease in concentrations from evening to early morning hours is in agreement with Tyson et al. (1988) who suggested that in the evening, ozone concentration decreases steadily because of the night inversion layer.

The results in Figure 3.3 show that the ozone concentrations for mid week and weekend days start to increase at 07h00 and reach a maximum of 51.37 ppb at 14h00 during the weekend, and 39.28 ppb during mid week at 16h00. It reached a minimum of 30.26 ppb during the weekend at 19h00, and 13.75 ppb during mid week at 20h00. A similar bell plot was observed for Figure 3.4, showing a concentration decrease from 01h00 to 06h00 during the weekend, and increased from 07h00 reaching a maximum of 61.76 ppb at 17h00. The mid weekdays showed an increase from 06h00, reaching a maximum of 45.91 ppb at 17h00, followed by a decrease to a minimum of 18.27 ppb at 24h00.

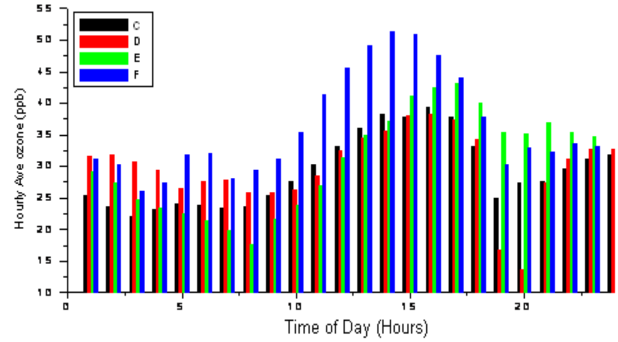

Figure 3.3 : Hourly average ozone on 10 Jul 07 (C), 11 Jul 07 (D), 14 Jul 07 (E), 15 Jul 07 (F)

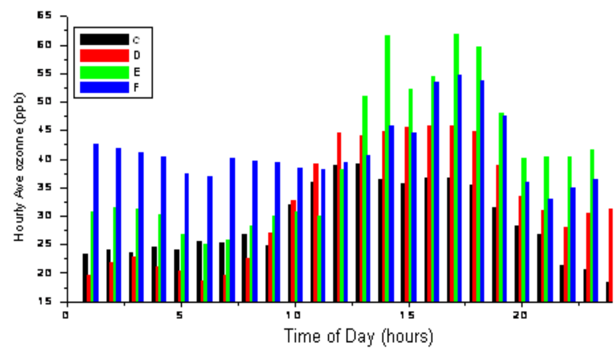

Figure 3.4 : Hourly ozone on 9 Oct 07 (C), 10 Oct 07 (D), 13 Oct 07 (E), 14 Oct 07 (F)

The ozone concentrations measured were generally higher during the weekend than in the mid week days despite the lower emissions of ozone precursors expected on weekend days. These might be because of the left over precursors from the previous day because during the weekend most companies are not operating and that decreases the emissions, most people are not working, so we expected transport emissions to be less.

The observation from the Figure 3.1, 3.3 and 3.4 may also suggest a "weekend effect". According to Qin et al. (2004) and Pudasainee et al. (2006) the phenomenon where ozone levels are higher during weekends than on weekdays is known as the "weekend effects". The mechanisms for the weekend effects on ozone formation are still not well understood. California Air Resources Board (CARB) outlined the following six potential causes of the weekend effect for ozone as described by Huess et al. (2003) and Jimenez et al. (2005): a reduction in NO_x emissions on weekends that reduces the titration of ozone; a weekend change in the timing of NO_x emissions that allows for more efficient production of ozone; increased sunlight caused by the reduction in the amount of soot in the air; carryover of vehicle emissions near the ground; carryover of vehicle emissions aloft, and increase in weekend emissions, particularly from off-road sources.

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b) Hourly ozone concentrations for mid week and weekend days at Marikana

The hourly ozone levels for Marikana are presented in figures 3.5 to 3.8. Figure 3.5 show an increase in ozone from morning hours and a maximum of 56.58 ppb during the week at around 13h00, and 74.24 ppb during the weekend at around 14h00. A decrease is also observed from 20h00 to the early morning hours. Figure 3.6 shows a similar trend with a maximum of 61.80 ppb at 16h00 on the 12 March during the week, and a maximum of 30.66 ppb during the weekend. The increase from morning to late afternoon in the two figures may be associated with photochemical reactions from precursors that include industrial and vehicular emissions of nitrogen oxides and volatile organic compounds in the presence of sunlight.

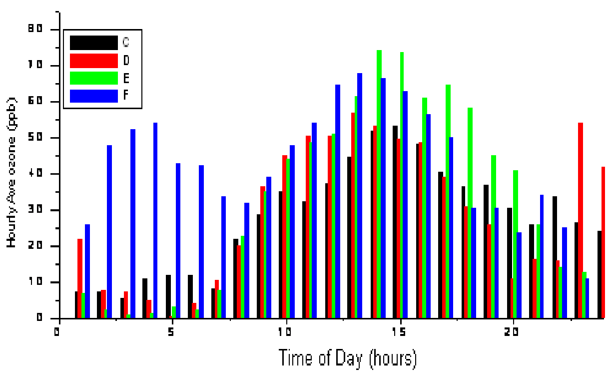

Figure 3.5 : Hourly ozone on 13 Jan 08 (C), 14 Jan 08 (D), 17 Jan 08 (E), 18 Jan 08 (F)

The increase of ozone concentrations during daylight hours is attributed to the photolysis reactions of NO_2 and photo oxidation of VOC's, carbon monoxides, hydrocarbons and other ozone precursors. It is also attributed to the downward transport of ozone by the vertical mixing, due to conventile heating, which happens during daytime hours (Lal et al, 2000).

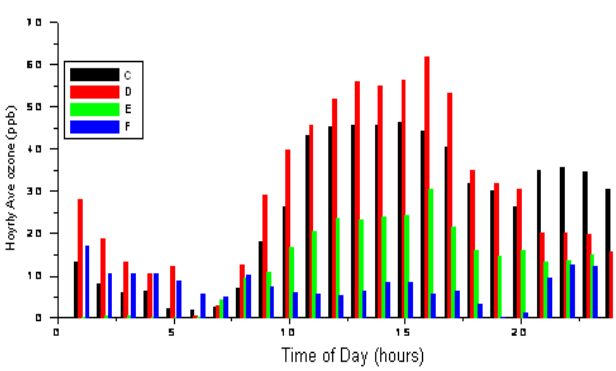

Figure 3.6 : Hourly ozone on 11 Mar 08 (C), 12 Mar 08 (D), 15 Mar 08 (E), 16 Mar 08 (F)

The high ozone concentrations during the week as observed in Figure 3.6 were the result of photochemical reactions among its anthropogenic precursors that include industrial and vehicles emissions and lower ozone concentration during the weekend were because of lower emissions of ozone precursors on weekends.

Figure 3.7 and 3.8 show higher ozone levels during weekend days than midweek days. The 'bell' features are still prominent with maxima of 80.65 ppb and 65.79 for weekend and weekday respectively in July; and 96.908 ppb and 82.982 ppb for weekend and weekday respectively in October.

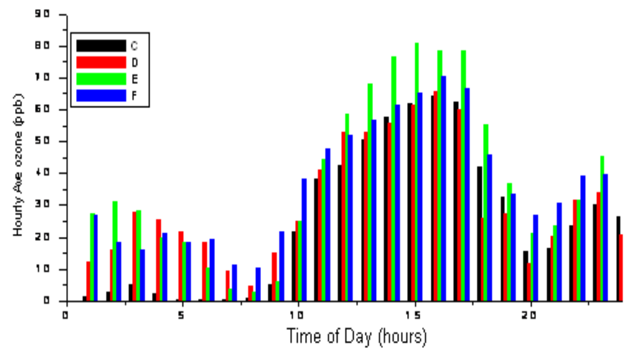

Figure 3.7 : Hourly ozone on 15 Jul 08 (C), 16 Jul 08 (D), 19 Jul 08 (E), 20 Jul 08 (F)

The rate of ozone level increase in the morning is faster than the evening one. This may imply that, in situations with significant ozone formation (including most urban and polluted rural areas weather conditions favorable formation), the removal of ozone is small compared to the rate of ozone production. The process of NO_x titration can only remove one ozone per emitted NO, whereas that of ozone formation typically produces four or more ozone per NO emitted (Sillman 1999). The slow ozone formation in the evening is attributed to the reduction of hydroxyl radical concentrations.

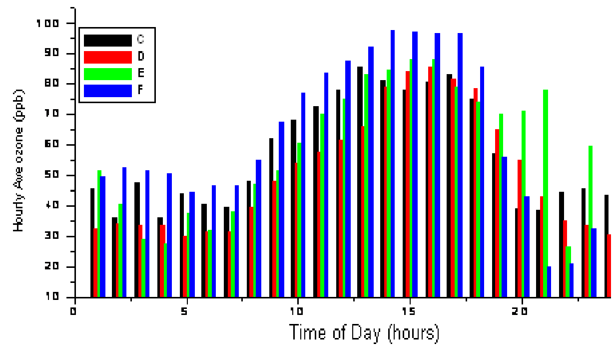

Figure 3.8 : Hourly ozone on 14 Oct 08 (C), 15 Oct 08 (D), 18 Oct 08 (E), 19 Oct 08 (F)

The hourly ozone concentrations at both sites increase from the early hours of the day and reach a maximum in the afternoon, then decreases slowly from the early hours of the evening until it reached minimum in the early hours of the morning; thus suggesting a 'bell plot' behavior, supported by several researchers including Zunckel et al. (2004), who measured surface ozone in the Southern African regions, and showed that surface ozone concentrations exhibit seasonal and diurnal variations and it increases just before sunrise and reach maximum in the afternoon then minimum in the evening. Formation of ozone is lowest in the morning and highest in the late afternoon when sunlight intensity and temperature peak. The ozone peak diminishes quickly when the sun sets; therefore an accumulation of the concentrations from one day to another is not expected. The concentrations however, are higher during the weekend than in the mid weekdays despite lower emissions of ozone precursors expected on weekends; thus suggesting a 'weekend effect'.

The hourly ozone levels at Marikana are higher than the levels observed in Botsalano Game Reserve. This is in agreement with a study by Byun et al. (2007), which concluded that ozone production in the industrial regions can be very efficient, ranging between 50 and 150 ppb h-1 due to high concentrations of reactive hydrocarbons in the presence of NO_x.

c) Daily Ozone Concentrations And Meteorology

According to Zunckel et al. (2004), mean surface ozone concentrations exhibit strong seasonal and diurnal variations. Ground level ozone concentrations increase in the spring and summer when there is more sunlight and temperatures are higher.

The daily ozone concentrations on Figure 3.9 were high during week-days with a maximum on the 4th and 15th. The maximum may be as a result of busy roads and industries, trans-border air pollution, and the biogenic emissions of hydrocarbons from vegetation. The highest daily average was found to be 44.41 ppb on the 15th of the month, which is lower than the 90 ppb daily average set by the South African Department of Environmental Affairs and Tourism; and higher than the ambient air quality standard (AAQS) for monthly average ozone of 30.00 ppb.

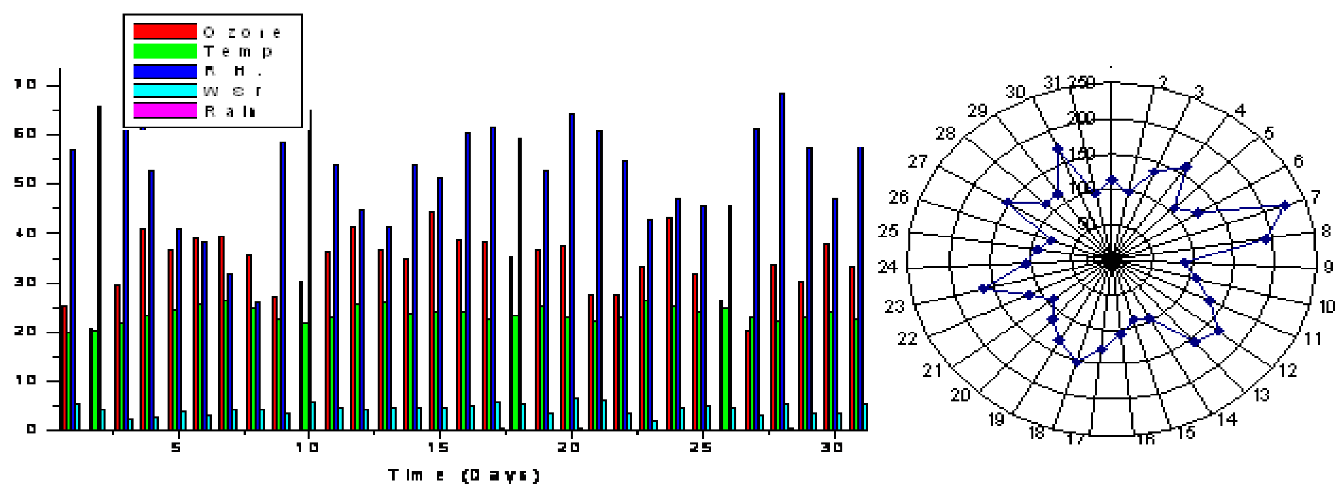

Figure 3.9 : Daily ozone levels and meteorology for January 2007

The January 2007 maximum of 44.41ppb was reached at a temperature of 24.1^{0}C and relative humidity of 51.3%; and a minimum of 20.23ppb at 22.9^{0}C, relative humidity of 61.1%, and 0.18mm rain. The measured concentrations were positively correlated with temperature (r = 0.61). A negative correlation between ozone and relative humidity, and positive correlation between ozone and the following parameters; wind speed, wind direction, and rain was also observed. The wind rose above show the direction of prevailing winds from south east (SE) and east of south east (ESE) for most of the days during this month. The wind was very light to moderate (from 2.07 to 6.77 m/s).

Figure 3.10 shows maximum mean ozone concentrations reached on the 1st and 2nd days of the month in week-days and low on the 3rd and 4th weekend days of January 2008.

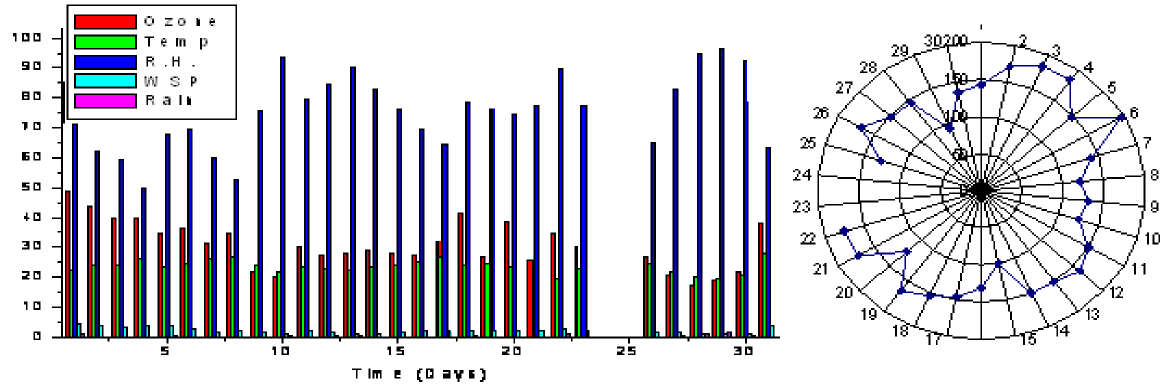

Figure 3.10 : Daily ozone and meteorology for January 2008

The January 2008 daily ozone concentrations reached a maximum of 48.80 ppb at temperature of 22.5^{0}C, relative humidity of 71.4%, and 0.96 mm of rain. The minimum average daily ozone was measured as 17.53 ppb when temperature was 20.1^{0}C, relative humidity was 94.8%, and rainfall of 1mm of rain. The ozone might be influenced by temperature and wind speed and wind direction, because they correlated positively, 0.44, 0.83 and 0.29 respectively. A negative correlation between ozone and relative humidity (r = -0.6381) was measured.

The wind rose in Figure 3.10 shows the direction of prevailing winds as SE and SSE most of the time during the month, with a very light to light wind (from 0.9 to 4.24 m/s).The wind came from locations were most of the sources (traffic, mining and industry) are situated.

The difference in ozone levels for January 2007 and 2008 can be linked to wind speed which measured 2.07 to 6.77 for January 2007 and 0.9 to 4.2 mm/s for January 2008. The low wind speed lead to the build-up of high local pollutant concentrations while high wind speeds promote the dispersion of ozone precursors and thus decrease ozone concentrations locally near sources but they also transport ozone to distant locations, often causing high ozone concentrations in areas without large sources of nitrogen oxides (NO_X) and volatile organic compounds (VOCs) (Sanchez-Ccoyllo et al., 2006).

Figure 3.11 shows the lowest daily ozone concentrations measured on weekend-days (1st and 2nd of March 2007) and this might be the results of low weekend traffic, and closure of industries in the nearby town. The ozone concentrations were high during the week-days (6th and 7th), thus showing the results of biogenic emissions, and biomass burning which are major sources of gases and aerosols in the Southern African atmosphere (Silva et al., 2003). The highest concentration was 40.96 ppb and the lowest was 4.03 ppb.

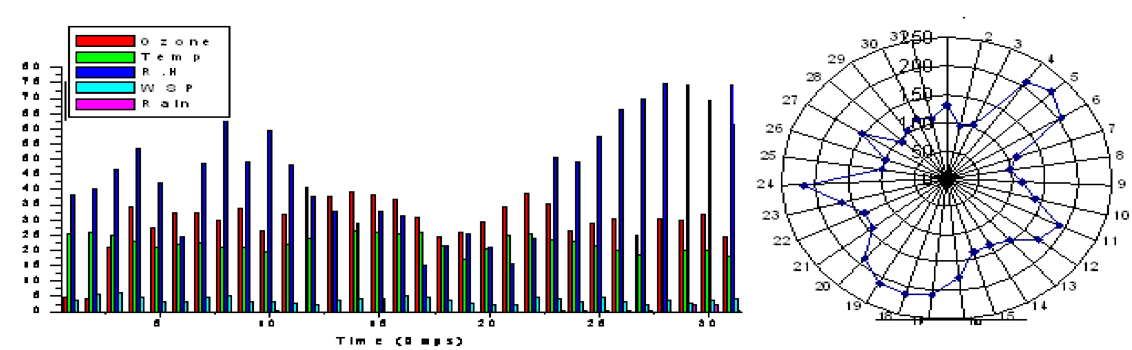

Figure 3.11 : Daily average ozone and meteorology for March 2007

The figure shows maximum concentration of 40.96ppb at temperature and relative humidity of 24^{0}C and 37.7% respectively. A positive correlation between Ozone and temperature, and wind direction, and a negative correlation between ozone and relative humidity, and wind speed was observed. The prevailing wind direction was east (E) and ESE for most part of the month and the other part was from SE and SSE, with very light to moderate wind speed; thus most of the ozone precursors might have come from south to east directions because Mafikeng the nearest town to Botsalano is situated on the south and the cement industry -

High daily ozone concentrations for the week-days 12th and 13th March 2008 that may reflect the effect of continuous emissions from transportation, industries and mining occurring in the surrounding areas are shown in Figure 3.12.

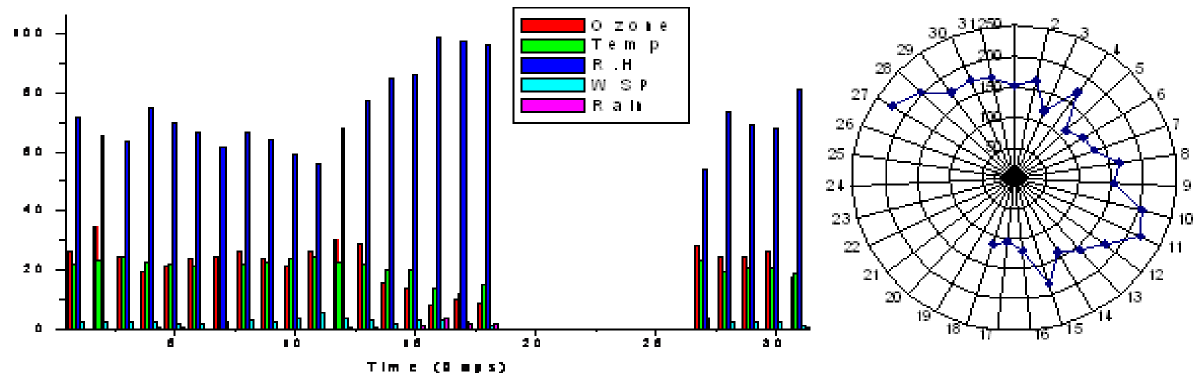

Figure 3.12 : Daily average ozone and meteorology for March 2008

The daily ozone reached a maximum of 34.43 ppb when temperature was 23.3^{0}C, and relative humidity was 65.7%, and there was no rainfall on that day. The minimum ozone was 7.78ppb when temperature was 14^{0}C, while relative humidity was 99% and rainfall was 36 mm of rainfall on that day. This minimum concentration can be as a result of washouts of air pollutants from the atmosphere by rain. Ozone and temperature are highly correlated, at 0.8047, and also ozone and wind speed and wind direction are positively

The wind rose in the figure shows the SE, SE, ESE, and SSE wind directions for most of month, with wind speed of 0.8 to 4.3 m/s. Only on three to four days the wind prevailed from SSW, where the Marikana Township, municipal dumping site and other mining industries are situated.

The March 2007 and 2008 levels are lower than the January 2007 and 2008 levels. This shows the influence of meteorological parameters like temperature, wind speed and relative humidity since the month of January is the end of summer and March is mid autumn. A decrease in temperature and an increase in relative humidity from January to March may account for the measured levels.

Figure 3.13 shows daily ozone concentrations that reached a maximum of 37.37 ppm on the 24th of July 2007, and minimum daily ozone concentration of 20.20 ppb on the 28th on the month. The maximum daily ozone concentration was reached during week-days, and this could result from emissions from buses transporting people to work and learners to different schools around the area; and the burning of wood. The minimum daily ozone concentration was reached on weekend and this might have resulted from the few transports passing by because most people are not working during weekend and even the operation in the nearby farms stops during weekend. The monthly average for the month of 28.171 ppb which is lower than the monthly average of 30.00 ppb set by AAQS.

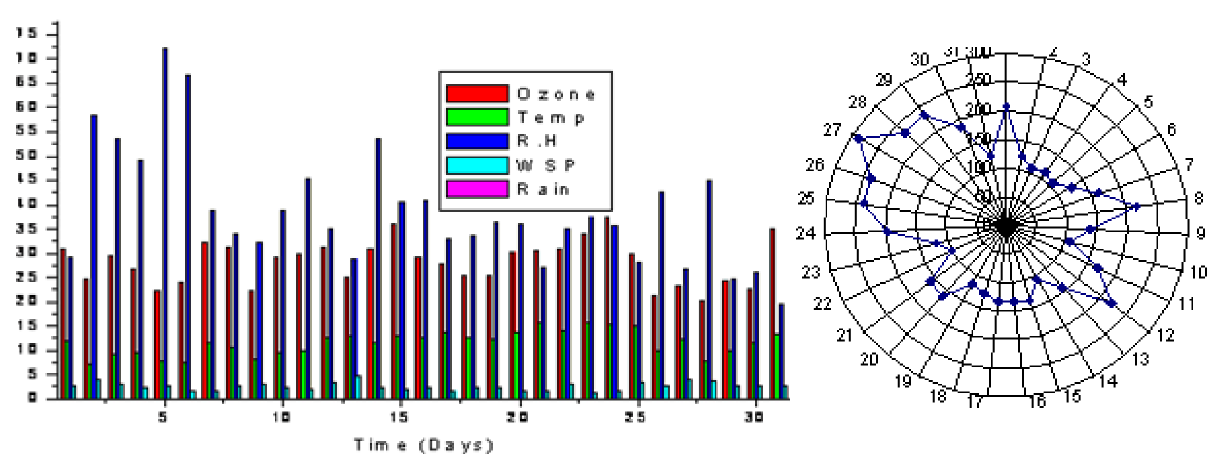

Figure 3.13 : Daily average ozone and meteorology for July 2007

A correlation coefficient of 0.6362 was obtained for ozone and temperature, and ozone and the other meteorological parameters; relative humidity, wind speed and direction showed negative correlation values, of -0.2365, -0.351 and -0.1860 respectively. The low wind speed of 1.4 to 4.8 m/s was expected to yield high ozone concentrations but this was not the case mainly because of the low winter temperatures.

The daily ozone concentrations shown on Figure 3.14 reached a maximum of 39.53 ppb on the 22nd of July 2008, and minimum of 15.85 ppb on the 7th of the month. The maximum daily average ozone concentrations were reached during week-days, and this could have resulted from the industries, mining activities taking place in the area, transport from the nearby road and railway line, also from the burning of wood and coal from the nearby township because during winter some families use fire to keep their homes warm.

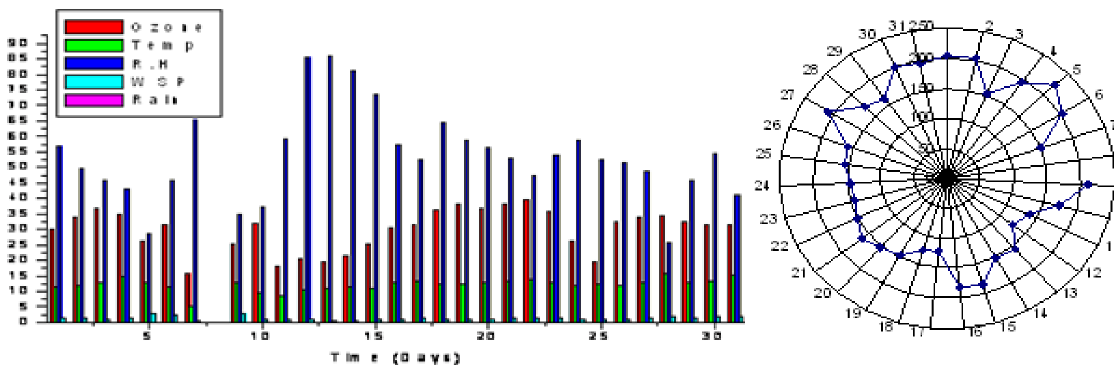

Figure 3.14 : Daily average ozone and meteorology for July 2008

The maximum of 39.53ppb was observed when temperature was 11.8^{0}C, and relative humidity was 58.8%, and the minimum of 15.85 ppb of ozone concentration was observed when temperature was 5.02^{0}C, and relative humidity was 66.6%. These confirm a positive correlation between ozone and temperature. Higher levels were expected for the winter month (July) since most of the biomass burning of the African savannas is observed during the winter and spring seasons (Levine et al, 1996).

Exchange processes between the stratosphere and troposphere influence ground level ozone variations, which can lead to frequent occurrences of high values in spring (Monks, 2000). The second process occurs at multiple spatial and temporal scales. High ozone concentrations might be registered within the city or at a distance downwind because of the high emissions of precursors in urban areas. These precursors may also be transported over long distances, resulting in ozone formation far from the sources under the influence of meteorological conditions (Hastile et al., 1999). The results presented in Figure 3.15 and 3.16 are representative of the Spring season, which normally lasts from August to October in Marikana and Botsalano.

The daily ozone concentrations shown in Figure 3.15 reached maximum of 52.03 ppb on the 16th of October 2007, and the minimum of 14.25 ppb on the 21st of the month. The daily average ozone concentration maximum of 53.03 ppb could have resulted from the long hours of spring day, from the plants which are found in the area and its surrounding, and from fuel burning by transports traveling in the road in that area. These maximum concentrations may cause damage to the growing maize in that area, because October is one of the months when the maize is grown. Maize is most susceptible to damage by ozone during the flowering season.

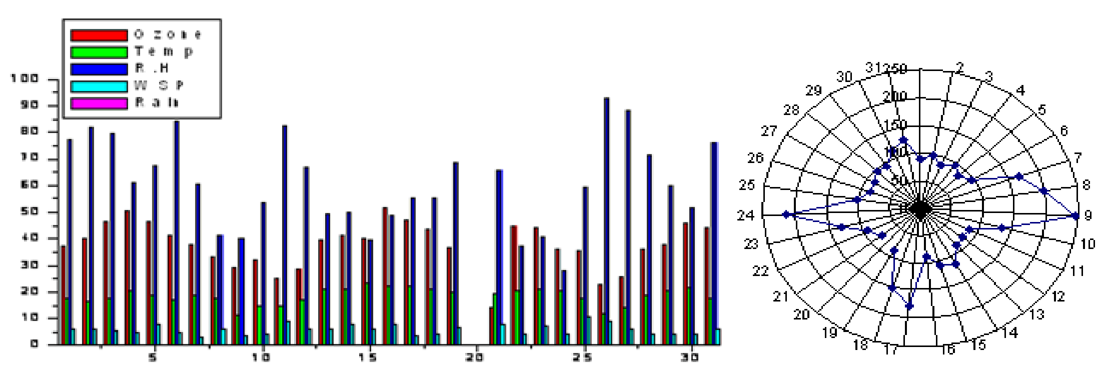

Figure 3.15 : Daily average ozone and meteorology for October 2007

The daily ozone levels shown in the figure reached a maximum of 52.03 ppb when temperature was 22.3^{0}C, relative humidity was 49.2% and there was no rainfall. on that day. The minimum ozone concentration was 22.86 ppb when temperature was 12.1 ppb, and relative humidity was 93%, with 0.2mm rainfall on that day. The high ozone might be associated with the high temperature (r = 0.6323).

The daily average ozone concentration shown in Figure 3.16 was 64.33 ppb on the 3rd of October 2008 and it was on busy working day of the week. these concentrations could be the results of long hours of spring day, fuel emission from transport sector, industries, and mining activities occurring in the surrounding area, where emission occurs continuously, and also from the waste dumping side. The minimum daily average ozone concentration was 26.25 ppb on the 26th of the month, and it was on a weekend when most of the industries are closed and the road and railway line are not busy, so the precursors are low. The average monthly ozone concentration was 50.02 ppb.

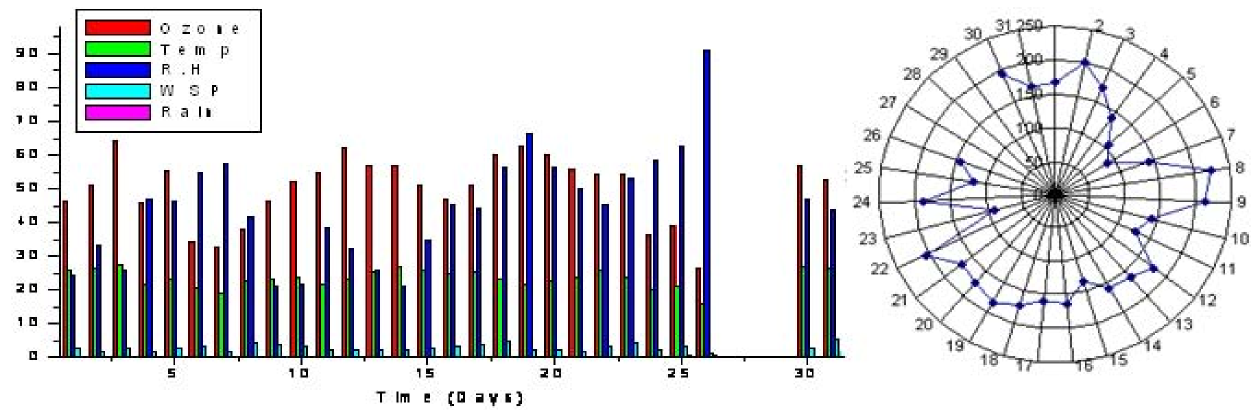

Figure 3.16 : Daily average ozone and meteorology for October 2008

The average ozone concentration reached a maximum of 64.33ppb when temperature was 27.1^{0}C, and relative humidity was 33.7%, with 0.1mm/h rainfall on that day. Ozone and temperature are highly correlated, with a correlation value of 0.6853, also ozone and wind speed and direction have positive correlation, at 0.1174 and 0.1822 respectively. This means the ozone concentration was influenced by these meteorological parameters. There is a negative correlation between ozone and relative humidity, and rain, at -0.4499 and -0.3936 respectively.

The levels observed for Botsalano (October 2007) and Marikana (October 2008) are within the range observed by Zunckel et al. (2004) in Botswana and the Mpumalanga highveld. In both regions the spring time maximum was between 40 and 60 ppb, but reached more than 90 ppb as a mean in October 2000. In these two regions the monthly minimum was between 20 and 30 ppb. The mean daytime ozone concentrations in Botswana and on the highveld reached 40 ppb as early as 10:00 and remain above that level for up to 10 hours. The seasonal maximum in this study generally occurred in the spring months from August to November and the minimum occurred in December and January. With the exception of Cape Point, a strong diurnal variation was observed at all sites. Ozone concentrations increased from a minimum near sunrise to a maximum in the afternoon then decreased again to the early morning minimum.

In general, the daily ozone levels measured during this study can be represented in order of decreasing abundance from October, January, March, July; representative of the seasons: Spring, Summer, Autumn, and Winter.

IV. Conclusion

The daily ozone concentration for Botsalano Game reserve ranged between 4.03 and 52.04 ppb; whereas the hourly concentrations were in the range of 6.306 to 61.762 ppb. The daily and hourly ozone concentration ranged between 21.074 and 50.019 ppb, and 0.0768 and 96.908 respectively for Marikana. The measured hourly ozone concentrations at the two study sites were below the one hour ozone standard for South Africa and also the standard set by the World Health Organization (WHO). In general, daily and hourly ozone concentrations for Marikana were found to be higher than that of Botsalano Game Reserve throughout the study period.

An increase in hourly ozone concentrations from early morning hours, reaching a peak around 15h00 and decreasing into night time was observed. The study therefore presents a 'bell' behavior of ozone with a peak between 12h00 and 16h00 and a low from evening to early morning; thus suggesting anthropogenic (domestic, industrial, and traffic) activities that increase emission of photochemically active aerosols and trace gases that are necessary precursors of tropospheric ozone in Botsalano and Marikana.

The fact that high ozone concentrations were observed during the weekend than in the mid weekdays, suggests a 'weekend effect' despite lower emissions of ozone precursors on weekends. This suggests the need for further studies into possible sources of ozone concentrations during weekend days, including a further investigation into the six potential causes of 'weekend effects' suggested by previous studies.

The meteorological parameters (temperature, relative humidity, wind speed and direction) were also successfully measured and related to the measured ozone concentrations. A negative correlation between ozone and relative humidity was observed at the two study sites; i.e. ozone increased with a decrease in relative humidity; whilst a positive correlation was observed for ozone and temperature, i.e. an ozone concentrations increased with increased temperature. For an increase in wind speed, a corresponding increase in ozone concentration was also observed. It was also evident during this study that wind speed cannot be separated from wind direction. Wind direction gives an indication of whether the ozone concentrations measured reach the community or not. The wind speed also gives an idea of the possible sources of the ozone levels measured.

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