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TEMPORAL ANALYSIS OF NO2, SO2, PM10 AND O3 CONCENTRATIONS OF URBAN AND RURAL SITES IN TRNC

Department of Geography, Federal University of Kashere, Gombe State

Department of Environmental Engineering, Cyprus International University, Cyprus

Department of Geography, Federal University of Kashere, Gombe State

Department of Geography, Federal University of Kashere, Gombe State

Department of Environmental Science, Cyprus International University, Nicosia, Turkey

Corresponding author: kamaludeenadamu@gmail.com

Adamu, Muhammad. Kamaludeen., [1]Ahmad, Abdelghader., [2]Faruk, I.Gaya[3] Bala Rabiu Hashidu[4] Suleiman Mohammed Gidado[5]

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ABSTRACT

Turkish Republic of Northern Cyprus is gradually turning into a more polluted area as a result of emissions of pollutants like particulate matter, sulfur dioxide, nitrogen dioxide and ozone, from industrial activities with an increase in number of vehicles. O_3 and NO_2 concentrations were measured at two sites i.e. urban and rural sites, Nicosia and Teknecik, respectively. The aim of the study is to determine the temporal analysis of PM_{10}, SO_2, NO_2 and O_2 at daily, monthly and seasonal variation of NO_2 and O_3 were analyzed at both sites and the correlation between the urban and rural sites was indicated. The daily variations mostly for NO_2 and O_3 have the usual features with the afternoon having the maximum due to intense sunlight and vehicular movement while the night is having the minimum which is being more pronounced in the urban area. It was seen from the result that the monthly concentrations for O_3 throughout the year starts to increase from March reaching their maximum in July for the urban sites, in rural site the monthly variations are smaller and reaching their maximum in June. For NO_2, the average monthly concentration starts to increase from April having the minimum while the maximum is attained in January for urban sites while in the rural sites December is said to be the maximum

Introduction

Air pollution is unique among some of the outcomes of this rare change. The World Health Organization (WHO) has categorically stated the unpredicted dead of more than two million yearly was accredited to the impacts of open air and close air contamination as stated by (WHO, 2006). The main air pollutants are

particle matter (PM_{10}), Sulphur dioxide (SO_2), nitrogen dioxide (NO_2) which known together as nitrogen oxides (NOx). O_3 in the troposphere plays an important role in oxidizing the capacity in the atmosphere which is a trace gas.

The essential outflows from engine vehicles come in two overwhelming structures: major vaporous what's more, atmospheric particulate air poisons, which can be found in relatively high amounts in the atmosphere, thus called toxic air, which more often than not are found in low amount in the environment however can have imperative wellbeing suggestions. Exposure to the air pollutants nitrogen dioxide (NO_2) and ozone (O) is detrimental to human health (WHO, 2006; WHO, 2013).

Expanded tropospheric O_3 focuses on the matter of substantial concern. Since the beginning of the century, clearly foundation ozone focuses have dramatically increased as stated by these authors (Selin et al, 2009``). The evaluation in the levels of O_3 is a problem since O_3 is a key component in controlling the compound synthesis in the atmosphere and troposphere.

NO2 remains an imperative barometrical follow gas, in light of its wellbeing impacts as well as additionally on the grounds that (an) it retains obvious sun powered radiation and adds to debilitated air perceive ability; as a precaution of obvious emission it could have a direct potential effect in worldwide environmental change if the situation were to rise up distinctly sufficiently high; it is, alongside with NO, as boss controller of the oxidizing limit in the free troposphere by controlling the level of development and destiny of the radical species, including hydroxyl radicals; also it assumes a basic part in deciding the ozone (O_3) fixations in the troposphere on the ground that the photolysis of nitrogen dioxide (NO_2) which is the main key initiator of the photochemical arrangement of ozone, be mixed or unpolluted airs (EPA, 2014). NO_2 is a Centre of the line between mechanical combinations of nitric corrosive, great amounts of which are delivered and released each year. At higher temperatures it is a reddish chestnut gas which has a brand shape, aggravating scent and is an unmistakable air pollutant (EPA, 2016).

Sulfur dioxides (SO_2) are the combination of sulfur and oxygen compounds molecules. The most predominant form of gas that is found commonly in the lower atmosphere is the SO_2. It is generally a gas that can be detected by taste and smell which is also a colorless gas ranging from 1000-3000 µg/m3. It produces a sharp unpleasant pungent smell or odor in the range of 1000 µg/m3 concentration. The water that is present in the atmosphere usually dissolves SO_2 to form a compound of Sulfuric acid i.e. H_2SO_4. SO_2 in the atmosphere which is about 30% is been converted to aerosol sulphate otherwise known as aerosol acid and its removed in the atmosphere by process known as wet or dry deposition. SO_2 otherwise called the oxide of sulfur is released into the atmosphere either by direct method or from the produced SO_2 which is converted rapidly into sulfuric acid (H_2SO_4) (Dockery et al., 2016).

Particulate matter (PM) is an unpredictable mixture of little particles and fluid beads made out of number of substances including natural chemicals, acids, metals and tidy and soil particles, dust, liquid droplets, soot. Joined State Environment Protection Agency (USEPA, (2015) recorded that particulate matter has a standout amongst the most well-known toxins and or poisons in the atmospheric air.

The purpose of this study is to collect the data sample of North Cyprus, (Nicosia and Teknecik) for the period of 2012/2013 were used to ascertain the temporal change in the level of the atmospheric concentrations of NO_2, O_3, SO_2 and PM_{10} in the ambient air. Temporal profiles of the NO_2 and O_3 were

constructed together to indicate the interaction and relationship between NO_2 and O_3 concentrations over urban and rural areas of North Cyprus. The following steps were used during this study:

- The hourly, daily, monthly concentrations of NO_2 and O_3 for weekdays and weekends for NO_2 and O3 in both rural and urban areas during the 2012-2013 period were analyzed
- Seasonal concentrations profiles of NO_2,O_3,PM_{10} and SO_2 were obtained
- Relationships between O_3 and NO_2 between urban and rural areas with the EU standards were explored.

The significance of this study is to provide information on the concentrations and levels of NO_2, O_3, PM_{10} and SO_2 on surface level for weekdays and weekends and to check the relationship between the two pollutants (O_3 and NO_2) in rural and urban site for the year 2012-2013 in North Cyprus.

Research has been conducted from several studies around the globe on investigating the levels and source of the four poisons which are connected by complex environmental science. The occupied gathering perceives that air contamination exists as a mind-boggling blend and that impacts credited to O_3, NO_2, SO_2 or PM_{10} which might be affected by the hidden poisonous quality of the full blend of all air toxins. In the rural and urban zones of most European nations including North America, the level of O_3 at the ground is currently been measured. Records shows that long haul of data from the 1980s are accessible at a certain areas when most of the systems started. Likewise, enthusiasm for environmental O_3 in the mid twentieth century gave some European encompassing O_3 estimations as stated by (EPA, 2014). Others intrigued by the early estimations gave a significant data set late in the 1990s ahead of schedule in the twentieth century. By investigating the systems and contrasting it and more cutting-edge strategies by Stroud (2008) could demonstrate that provincial O_3 focuses had multiplied in Europe from around 10–15 ppb between the ends of the nineteenth century to the 1980s of around 20–30 ppb.

Data collection and methodology; the hourly average ambient NO_2 and O_3 data were supplied from the Environmental Protection Department (EPD) of TRNC. In this study, the selected air pollutants include the primary pollutants, PM_{10} and SO_2, and the secondary pollutants, NO_2 and O_3. In most time series, systematic variations in response to seasonal and other factors are quite often encountered. In this study a two-year series of hourly average values were used to examine the statistical characteristics. Although, the two years data is consist of 17520 hrs. Due to instrument calibration and maintenance, only about 16800 readings for each pollutant were collected. However, the missing observations seemed to be evenly distributed throughout the year.

Method

General Statistics was carried out to see the mean, minimum and maximum concentrations for the different pollutants. The monthly, weekly and daily mean concentrations all pollutants were measured to determine the level of significant emissions between the pollutants at different seasons of the year. Hourly, daily, temporal and seasonal analysis for NO_2, and O_3 was carried out by the use of Microsoft excel to analyze the data‘s. Monthly variation to check the level of NO_2, O_3, PM10 and SO_2 in the atmosphere for both weekdays and weekends for the period of two years between 2012-2013 were analyzed. Diurnal concentration profiles of NO_2 and O_3 for weekdays and weekends were also analyzed for the urban and rural areas to compare them.

Results

General statistical analysis, Table 1 shows data for NO_2 in 2012/2013 seasons. The range shows that it has a minimum value of 1.7 µg/m^3, in 2012 and decreases to 1.1 µg/m^3 in 2013 due to sunlight intensity it is usually low in the summer. The maximum having 47.6 µg/m^3 in 2012 and 52.3 µg/m^3 in 2013, which indicates longer period during winter.

Table 1 General statistics for NO_2 concentration µg/m^3

Years	MIN µg/m^3	MAX µg/m^3	MEAN µg/m^3	STDEV µg/m^3	NUMBER OF DATA
2012	1.7	115.8	47.6	23.1	8466
2013	1.1	127.1	52.3	23.3	8383

Table2 shows the general statistics for O_3 of which the range minimum is 0 µg/m^3 which is low during winter and the maximum been 114.4 µg/m^3 for the months between 2012 and 2013 which shows that ozone is usually high at summer time of the year. However, O_3 can be high or low sometimes because it usually comes from the wind directions so it doesn't necessary mean that ozone must be present in that location.

Table 2 General statistics for O_3 concentration µg/m^3

Years	MIN µg/m^3	MAX µg/m^3	MEAN µg/m^3	STDEV µg/m^3	NUMBER OF DATA
2012	0	114.4	16.5	15.3	7986
2013	0	137.4	21.1	16.5	8168

Table.3 shows values for PM_{10} for the year 2012/2013. The result shows that it has a minimum value of 15.8 µg/m^{3,} which indicates the tendency to be higher in vehicular emissions in 2013 due to increase number of cars in North Cyprus. It is low summer because of intense sunlight and less wind. The maximum been 354.6 µg/m^3 and it's usually during the autumn because of less sunlight and windy leading to accumulation of PM_{10}.

Table 3 General statistics for PM_{10} concentration µg/m^3

Years	MIN µg/m^3	MAX µg/m^3	MEAN µg/m^3	STDEV µg/m^3	NUMBER OF DATA
2012	15.8	354.6	58.8	32.4	348
2013	17.8	276.8	55.9	31.3	365

Table 4 shows analysis for SO_2 for 2012/2013 seasons. It has a range of minimum value of 0.2 µg/m^3 in 2012, it is generally not found much in the atmosphere because it is recorded only in monthly levels and summer and autumn are low. The maximum in winter and spring due to climatic variations and mixture with other air sources having 11.2 µg/m^3 in 2013.

Table Error! No text of specified style in document.**4** General statistics for SO_2 concentration µg/m^3

Years	MIN µg/m^3	MAX µg/m^3	MEAN µg/m^3	STDEV µg/m^3	NUMBER OF DATA
2012	0.2	7.9	2.14	1.60	345
2013	0.3	11.2	3.05	1.97	349

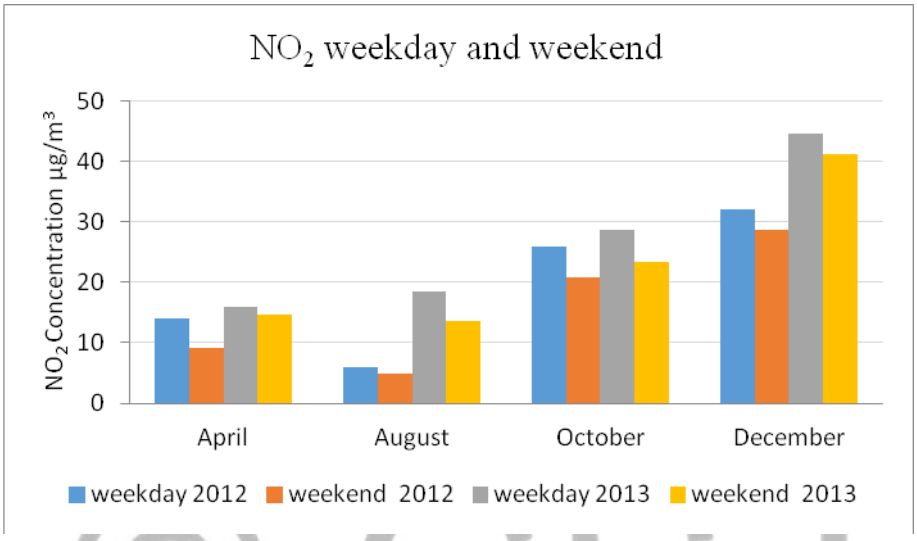


Figure 1 Monthly mean concentration profile of NO_2 on weekdays and weekends of 2012 vs 2013 in Nicosia.

Figure 1 represents concentrations of NO_2 for all seasons between 2012 and 2013 for weekdays and weekends. The least is in the August for both years having 5 µg/m^3 because of intensive sunlight and heavy traffic but less release of gases. There is a decrease in the level of NO_2 during weekends as compared to weekdays. The highest levels of NO_2 were found in winter because of less solar radiation and much cooler air. Winter is having the highest during weekdays because of less sunlight and much emission from traffic and industrial activities as compared to weekends.

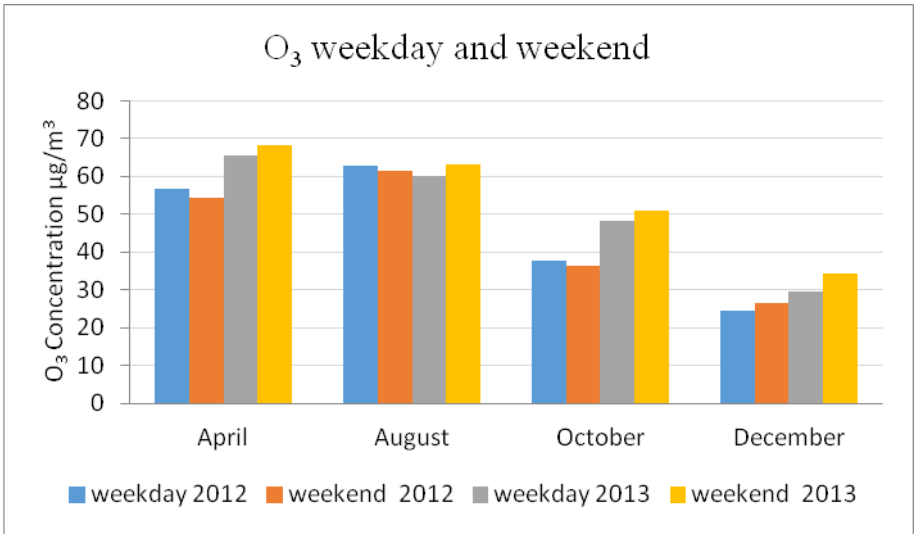


Figure 2 Monthly mean concentration profile of O_3 on weekdays and weekends of 2012 vs 2013 in Nicosia.

Figure 2 represents Ozone concentrations for weekdays and weekends for all seasons for 2012/2013. It shows that ozone is usually high in spring and summer because O_3 formation depends on solar radiation with spring been the highest for 2013 and winter having lowest for weekdays. The four seasonal cycles of O_3 concentrations in the mid-year shows a uni-modal peak, with summer having high level of O_3 as a result of phytochemical local production. The results indicate that the weekend effect was due to decrease of emissions with much availability of sunlight that favors formation of O_3.

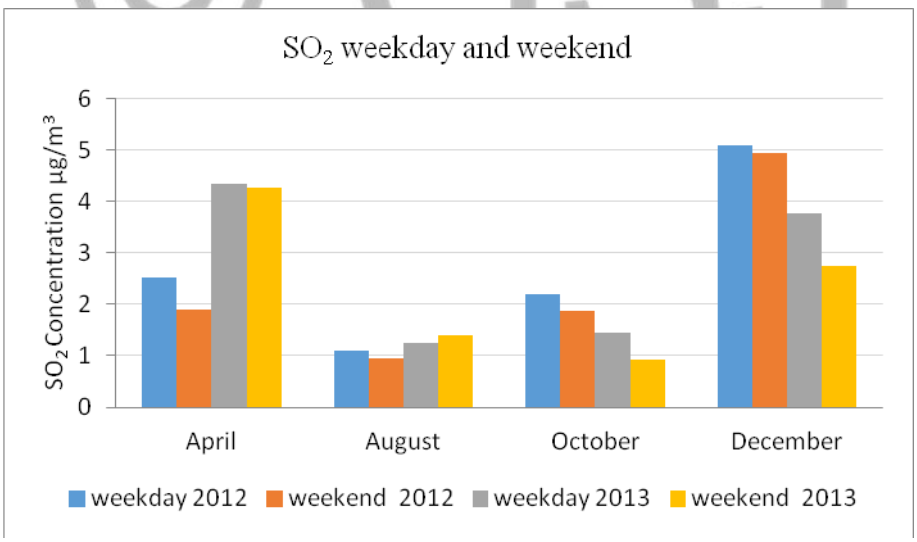


Figure 3 Monthly mean concentration profile of SO_2 on weekdays and weekends of 2012 vs 2013 in Nicosia.

Figure 3 presents temperature and concentrations of pollutants in the four seasons. Summer recorded highest SO_2 concentrations on the contrary winter has the lowest value. The SO_2 concentration in the summer decrease with an increase in temperature level but increase in December. It also relates to much

emission of gases from traffic and heavy industries and less sunlight resulting in much accumulation of SO_2 in the winter and it is less in the summer because of less emission of gases and intense sunlight. The intense SO_2 level during the summer is the resultant effect of low humidity with an increase level of temperature that causes gradual removal of SO_2 in the atmosphere. Sea surface vaporization can be the other cause since the monitoring station is situated near the seashore by the registered thermal springs containing SO_2.

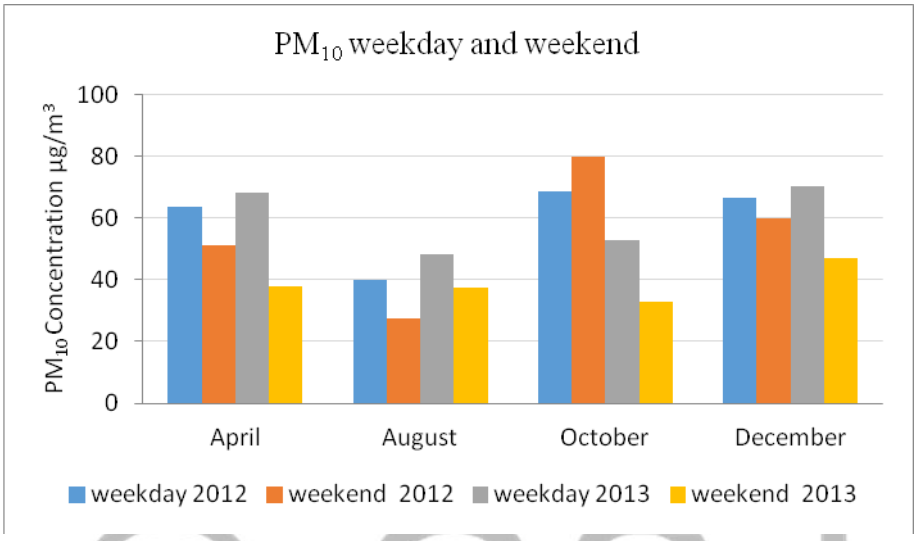
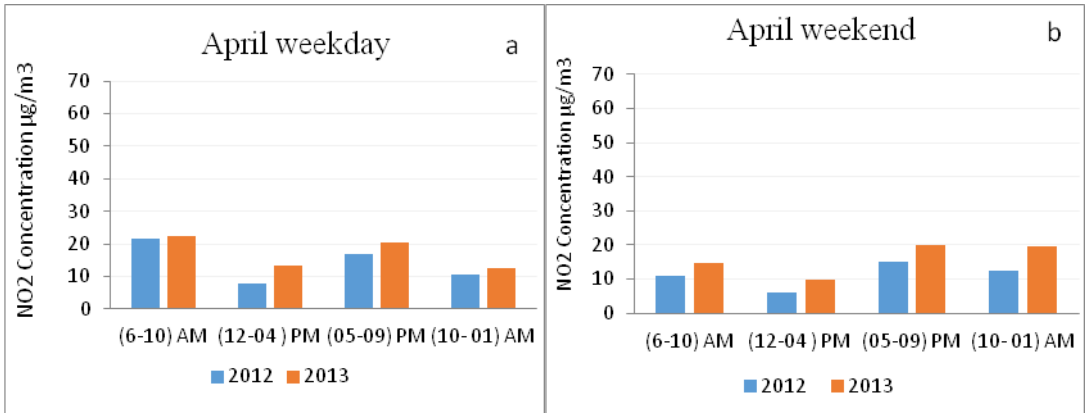


Figure 4 Monthly mean concentration profile of PM_{10} on weekdays and weekends of 2012 vs 2013 in Nicosia.

Figure 4 show that PM_{10} has highest concentration in the autumn for weekend because PM_{10} works the same way as NO_2. There's less sunlight during autumn and much wind resulting in accumulation of PM_{10} as well as other particulate matters like NO and NO_x and less during weekdays summer because of intense sunlight and less emission of gasses from traffic and heavy industries.



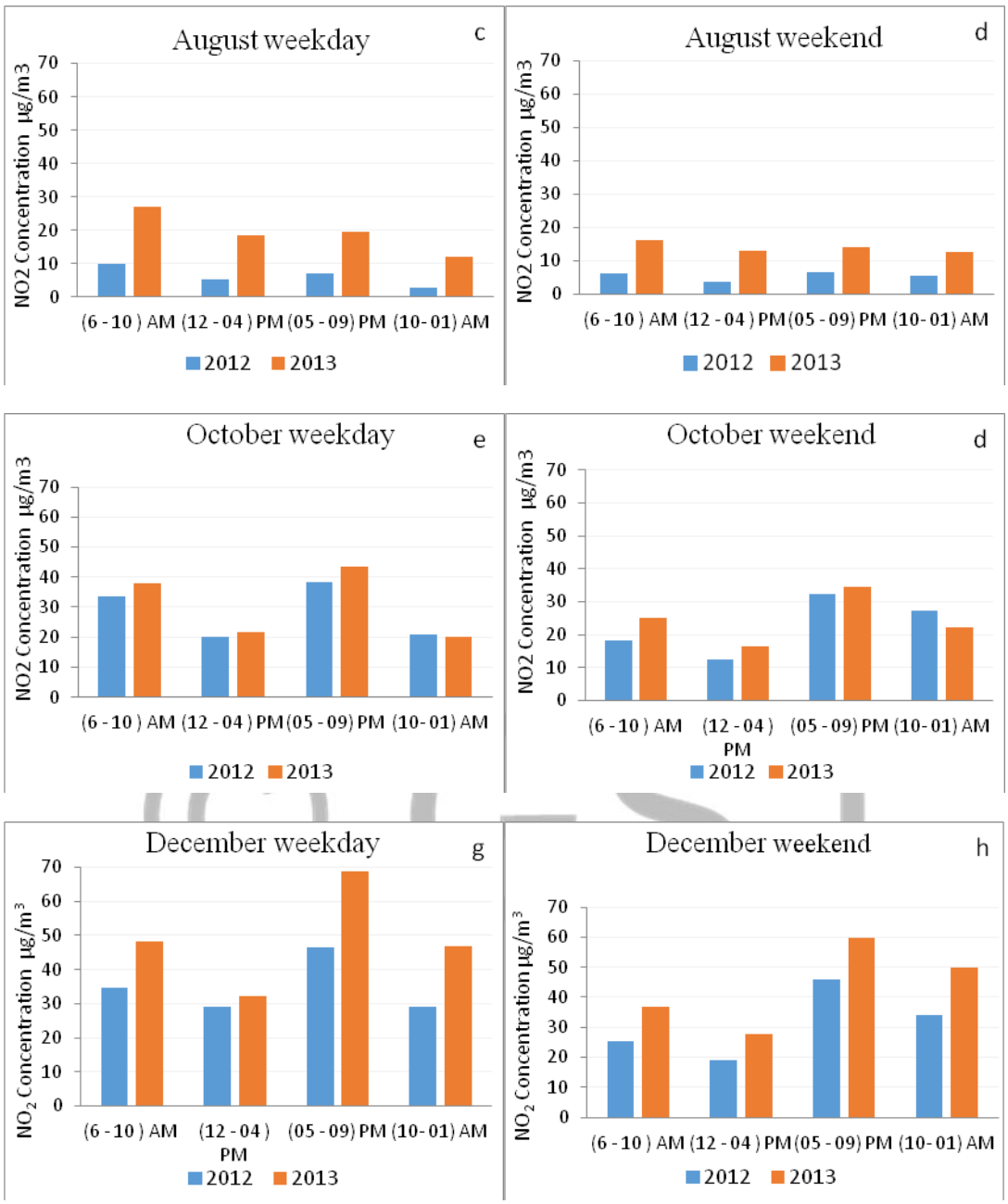
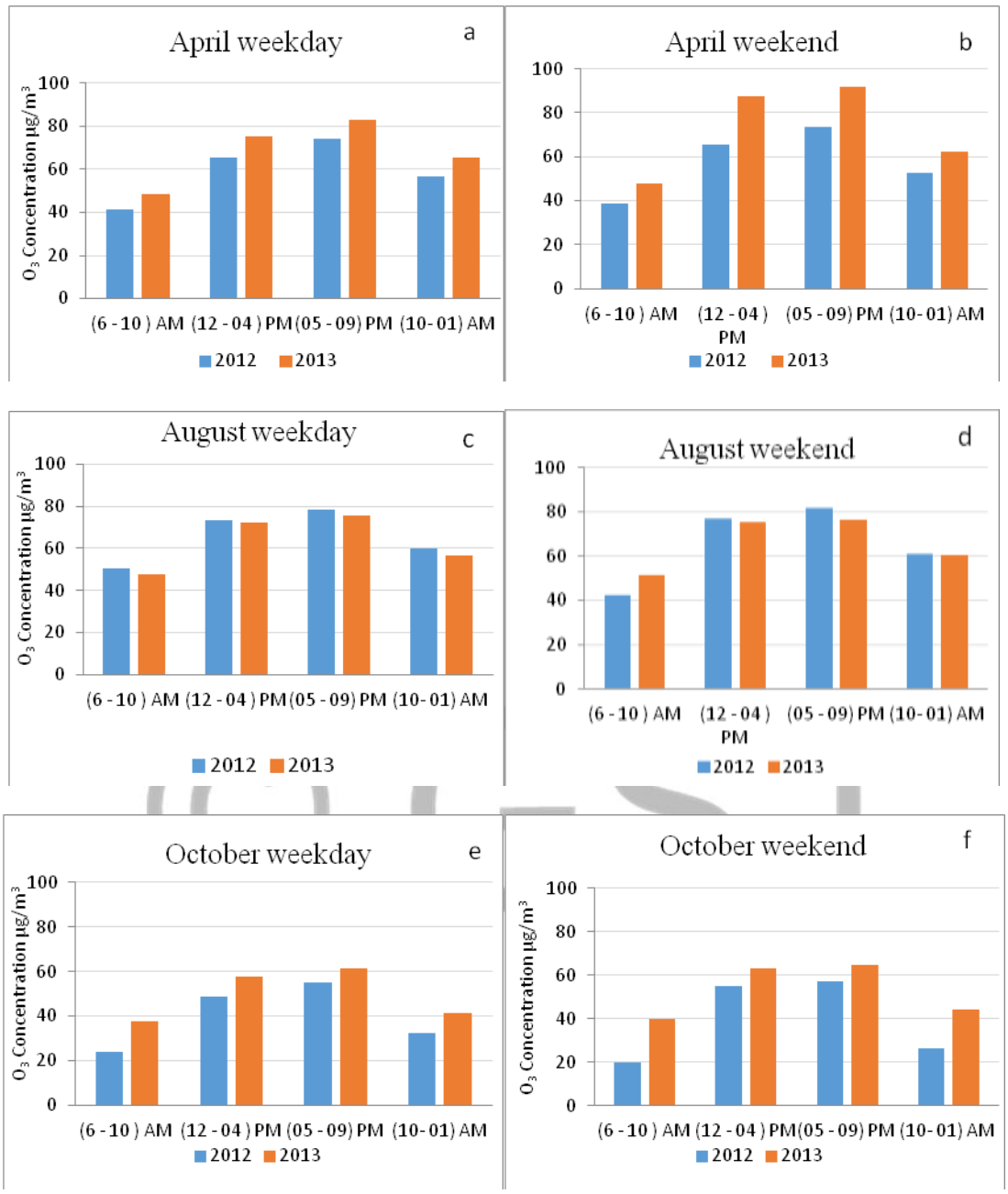


Figure 5 Average NO_2 concentration in different time periods of the day in Nicosia for weekdays (a, c, e, g) and weekends (b, d, f, h) of four different Months.

Figure 5 shows that the NO_2 peak concentrations for both weekdays and weekends were observed for 2012 and 2013. For April 2013 is having the highest with 22 µg/m^3 due to heavy traffic and industrial activities. NO_2 is low during summer because of intense sunlight and less windy clouds. The highest peak as seen from the graphs is in December 2013 having 68 µg/m^3 which happens to be the highest month for NO_2 in the whole year which occurs as a result of less sunlight and windy clouds with smog and which usually occurs in the evening time when traffic is heavy (5-9pm). This shows therefore that in 2013 NO_2 is very high as a result of much traffic and industrial activities in the area.


April weekday
a
O_3 Concentration µg/m³
100
80
60
40
20
0
(6 - 10) AM
(12 - 04) PM
(05 - 09) PM
(10- 01) AM
2012
2013
April weekend
b
(6 - 10) AM
(12 - 04) PM
(05 - 09) PM
(10- 01) AM
2012
2013
August weekday
c
(6 - 10) AM
(12 - 04) PM
(05 - 09) PM
(10- 01) AM
2012
2013
August weekend
d
(6 - 10) AM
(12 - 04) PM
(05 - 09) PM
(10- 01) AM
2012
2013
October weekday
e
(6 - 10) AM
(12 - 04) PM
(05 - 09) PM
(10- 01) AM
2012
2013
October weekend
f
(6 - 10) AM
(12 - 04) PM
(05 - 09) PM
(10- 01) AM
2012
2013

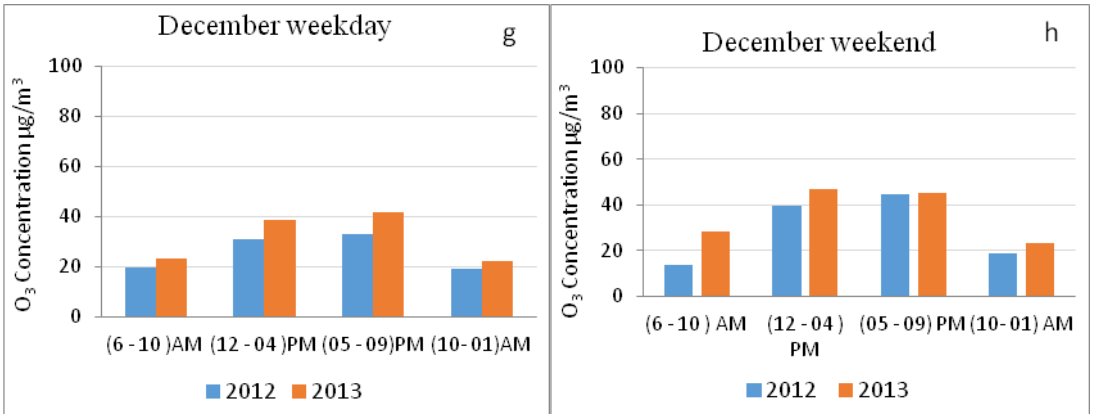


Figure 6 Average O_3 concentration in different time periods of the day in Nicosia for weekdays (a, c, e, g) and weekends (b, d, f, h) of four different Months.

The Figure 6 shows the concentration of O_3 for weekends and weekdays 2012-2013 for all seasons. From the table above it shows that for spring it is usually high during weekends because of increase in traffic and heavy machineries from industries as compared to weekdays because O_3 level tends to go with radiation intensity of the sun which results in high O_3 concentrations. O_3 is usually high during the daytime because of the chemical reaction of the sun and other gases which leads to its formation as well as smog from factories and cars. O_3 levels tend to be higher amid ends of the week than on weekdays in some urban. For August it reveals that the level of O_3 is higher in summer weekends because of the local phyto-chemicals that is been produced. High concentration of O_3 in the summer is due to smog photochemical production. O_3 levels are high in weekends as compared to weekdays in other areas irrespective of O_3 low emission precursors in the weekends. This phenomenon is known as the "weekend effect. It further reveals that decrease in the level of emissions with high sunlight is the resultant factor for weekend effect which favors O_3 formation. For October it shows a slight decrease with the highest during weekend and high for weekdays, ambient O_3 concentrations is much high on weekend in comparison to weekday under comparable meteorological conditions. For winter December it tends to be very low because of changes in weather conditions and less concentration of sunlight resulting in smog.

Conclusion and recommendation

The study of the temporal analysis of NO_2, SO_2, O_3 and PM_{10} were studied in Nicosia and Teknecik area of North Cyprus. For NO_2 the peak concentration time was usually in the morning and evening with the spatial factors since NO_2 is it emitted by the vehicles. NO_2 is also higher during weekdays than weekends which are low in summer because of intense sunlight radiation while winter is usually high because of less solar intensity with much accumulation of NO_2 in the atmosphere. Surface O_3 level in the atmosphere is usually higher in the rural areas than the urban areas. Because NO is less and it destruct O_3. There is a clear seasonal variation for O_3 with the highest peak in summer due to intense solar radiation and prolong sunlight time per day. O_3 diurnal concentration is also high in the rural areas as compared to the urban areas due to the differences in site characteristics that is being influenced by O_3 nocturnal destruction in the ground level. O_3 have the highest value of about 114 µg/m3 in the summer4 for the rural areas while the urban areas are having the highest peak is around 85 µg/m3 in the summer. Comparison between the two years shows 2013 is higher as compared to 2012 because of more vehicular movement as well as more industrial activities going on in the country. PM_{10} works the same way as NO_2 so the concentration

is high during autumn with much windy climate and less sunlight. The concentration of SO_2 in 2012 is higher as compared to 2013 with the winter and spring having the highest concentration while summer has the lowest.

There is however, correlation in some of the months between urban and rural areas but most are negatively correlated. The level of O_3 and NO_2 are not too high which implies it has less toxic effect on the human health.

The level of O_3, NO_2, in the rural and urban sites are gradually increasing each year, a proper analysis and investigation should be carried out after every six months so that it would not exceed the limit. Vehicles imported should also be checked to determine the level of NO_2 they generate to the environments as well as the industrial fumes and home heating appliances.

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