WEEKDAYS AND WEEKEND VARIATIONS OF SURFACE OZONE LEVEL IN THE FRASER VALLEY (FV) OF BRITISH COLUMBIA

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ABSTRACT

This paper analyzed ambient ozone and its precursor data from nine monitoring sites of the Fraser Valley (FV) of British Columbia to study the possible influence of primary pollutants emissions on the weekdays and weekends variations. Greater Vancouver Regional District Authority provided the data for the study. Despite the decreasing trend in ambient level of CO, NO_x, SO_2, and PM_{10} in the FV region, average level of surface ozone has been in increasing trend since the last decade. In general, level of traffic vehicles mileage in Canada varies according to the days of the week with maximum mileage during week days particularly on Thursday and Fridays which corresponds with the variations in CO and NO_x levels in the FV region. Both CO and NO_x levels follow the similar patterns in all the selected stations. Distinct variations in O_3, CO and NO_x levels exist between weekdays and weekends for different seasons with higher percentile variations in winter and lower in spring. Despite reduction in CO and NO_x levels during the weekends, ozone level increases during the weekend. Within the weekdays, relatively higher level of CO and NO_x were observed during Tuesday, Thursday, and Friday. Significant correlations between daily average values of CO and NO_x indicate the influence of traffic volume on the productions of surface ozone. Higher Ozone level during the weekends shows the importance of advection phenomena due to meteorological conditions, possible NO_x limiting condition in the low traffic areas, and topography of the site.

Key words: Surface Ozone, Weekdays and Weekends, Traffic Emissions, Fraser Valley

1.0 INTRODUCTION

The Fraser Valley (FV) air shed contains the majority of the population of British Columbia (more than 5 million) and continues to have a high population growth. Unique geographic features and the growing large population, the interaction of urban, suburban, marine, and agricultural emissions of pollutants cause air pollution that are frequented in the FV. As such, surface ozone is on the air quality agendas of the public, planners and policy makers at all levels of government.

Fraser Valley is bounded by the Coast Mountains in the north, the cascades mountains in the Washington state of the USA in the south, and the Pacific Ocean in the west.

Presence of cascades of mountains causes the air masses trapped into the Fraser basin when wind travels towards the mountains. Fraser valley region has a relatively mild climate with low to moderate winds. The prevailing wind directions are dominated by airflow towards the north and north easterly directions. Besides, the wind directions are associated with the see breezes which occur during the middle of the day.

Seasonal variations in air pollutants including surface ozone in the region are well documented where sea breeze and other meteorological factors like solar radiation, wind velocity and directions, vertical temperature structure and temperature inversion effect influences the dispersion of the air pollutants. Besides, Weekdays and weekend variations in surface ozone level has also been reported by many (Viras, 2002; Lal *et al*., 2000; Pont and Fontan, 2001; Marr and Harley, 2002). Marr and Harley (2002) reported about the "weekend" phenomena where weekend ozone level could be related to either NO_x or VOC-sensitivity of the area. Ozone standard exceedance events, diurnal and seasonal pattern of ozone level has also been studied by Viras (2002) to investigate the weekdays and weekends variations due to the day-of-week differences in NO_x emissions. Pont and Fontan (2001) emphasized on the advection phenomena of ozone in describing the weekdays and weekends variations.

Traffic is the main source of pollution in Fraser Valley region where approximately 66 vehicles owned by every 100 population. Although most of the vehicles are equipped with catalytic converter, about 95% of carbon monoxide emissions are contributed by the traffic vehicles in LFV (GVRD, 2003). Variations in the CO emissions can be used as indicator of the traffic volume in a particular time of the day. In general, in Canada, traffic volume in the weekends is about 11% lower than the average traffic volume in the weekdays (DOT, Canada). Viras (2002)'s study also found relationships between the variations in carbon monoxide (CO) and nitrogen monoxide (NO) with respect to traffic emissions.

Analysis of the temporal and spatial level of the pollutants particularly based on the days–of-the-week may provide important inputs for air pollution control management in the region. This study aims at investigating the relationship between variations of ozone level during the weekdays and weekends with the influences of traffic volume and emission of ozone precursors.

2.0 STUDY METHODOLOGY

Ambient air pollution data for carbon monoxide, nitrogen oxide, and surface level ozone has been provided by the Greater Vancouver Regional District (GVRD) authority. GVRD collects air pollution data continuously from about 34 monitoring sites of the FV of British Columbia and stored in the database on hourly aggregated form. For this study, we did factor analysis using principal component (PCA) method based on the distribution of ambient surface ozone level in all the monitoring sites and finally selected nine monitoring sites for the investigation. We have used data between the period of 1998 and 2002. However, most of the selected monitoring sites are located in the lower mainland (also called Lower Fraser Valley) where majority of the population lives. Figure 1 shows

the map of the Fraser Valley region of British Columbia showing the ambient air monitoring sites.

Figure 1: Map of the Fraser Valley region of British Columbia showing the ambient air monitoring sites

All the gathered data has been aggregated again according to the days of the week, daily, monthly, quarterly (seasonal) and annual basis. Days of the week data has again been aggregated as weekdays and weekends. Missing data have been replaced with the mean level of the dataset.

GVRD emission inventory data shows that about 95% of the total carbon monoxide emissions in the Lower Fraser Valley are from the traffic vehicles (GVRD, 2003). Carbon monoxide remains almost inert in the photochemical reactions process that results in ozone formation. So, comparison of daily mean level of ozone between weekdays and weekends were done as a relative assessment of emissions from traffic vehicles. In addition, correlations analysis between nitrogen oxide and carbon monoxide was done to indicate the relative contribution of traffic emissions on the ozone levels of the region.

3.00 RESULTS AND DISCUSSION

3.1 Diurnal Variations of Ozone, Carbon Monoxide and Nitrogen Oxide Pollution

Figure 2 shows comparative diurnal pattern of ozone, CO and NO_x during the weekdays and weekends where pollution levels have been averaged for weekdays and weekends

respectively. Higher averages values of ozone were found in weekend's afternoons compared to that of weekdays. During the morning lean period of ozone level, there were corresponding higher level of CO and NO_x. However, unlike the distinct morning lean period of ozone level in the weekdays, there is a gradually elevated level of ozone in the weekends. Similarly, there were distinct morning peak in CO and NO_x level during the weekdays and comparatively higher level on the weekdays than on the weekends.

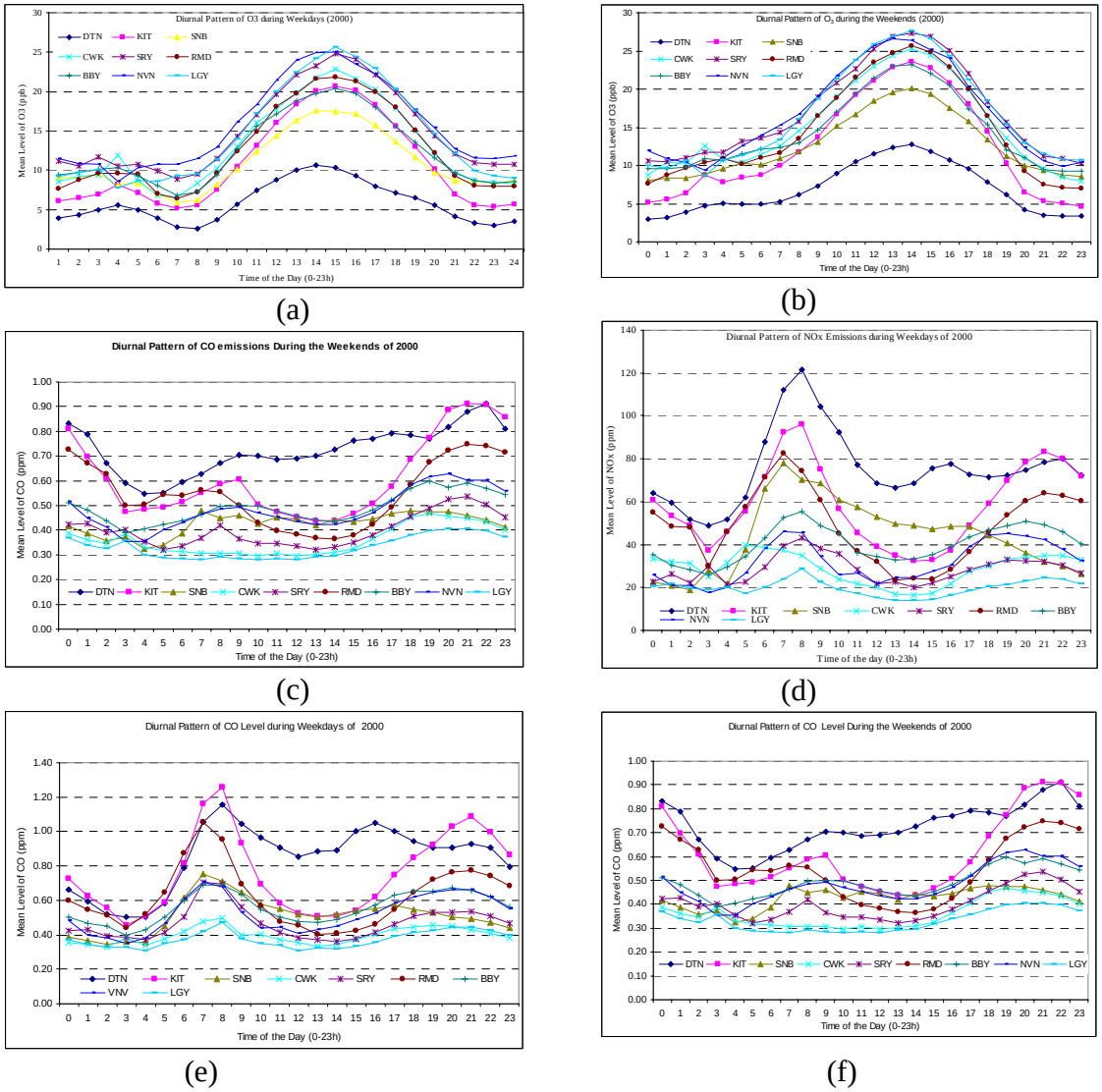


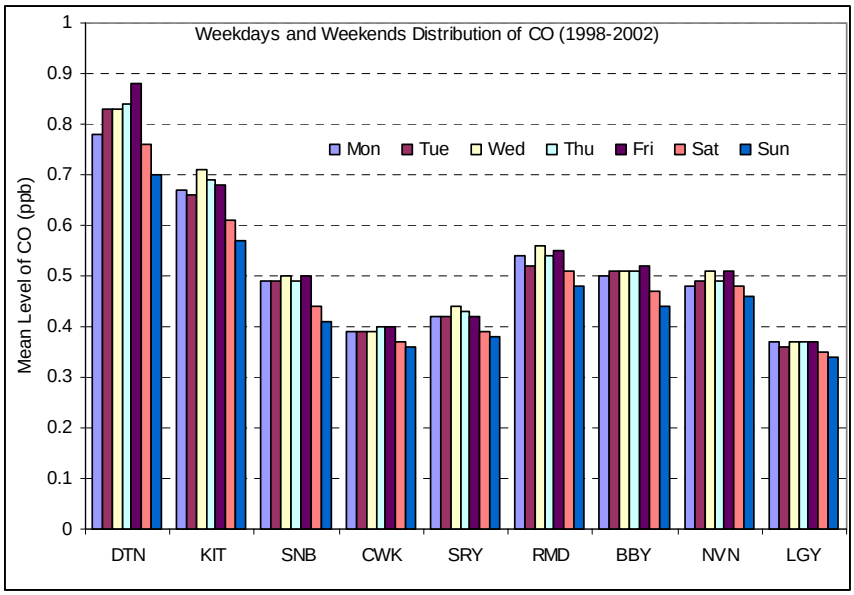
Figure 2: Variations in diurnal pattern of pollution Level between weekdays and weekends for the year 2000: (a) Ozone-weekdays, (b) Ozone-weekends, (c) NOx-weekdays, (d) NOx-weekends, (e) CO-weekdays and (f) CO-weekends

3.2 Weekdays and Weekends Variations

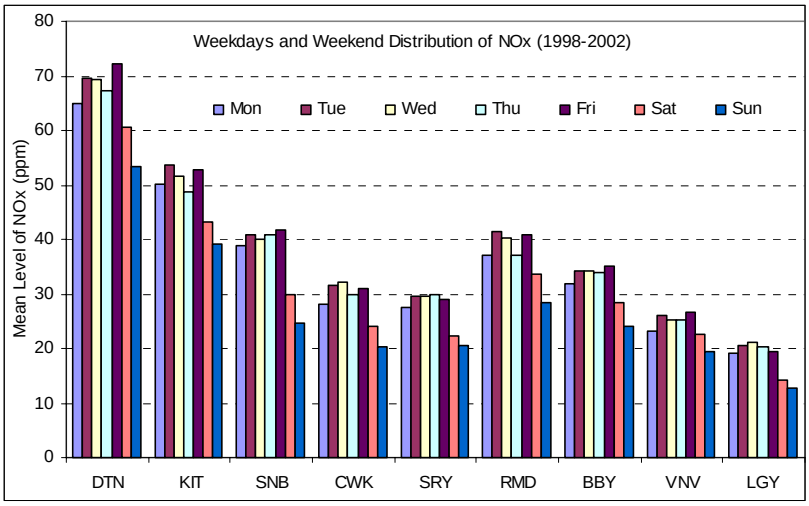
Mean level of O_3, CO and NO_x have been aggregated for the days of the week as shown in the Figure 3. Similar pattern was found for CO and NO_x level where Downtown

Vancouver experienced higher level and Langley with lowest level during all days of the week. Downtown is followed respectively by Kitsilano, Richmond, Burnaby, Second Narrow Bridge, North Vancouver, and Surrey. This pattern of CO and NO_x level grossly in compliance with the relative intensity of traffic volume and other commercial activities of these areas. However, within the week, relatively lower level was found in the weekends when relatively lower level of traffic volume was observed in those areas. Pollution level gradually increases as the weekdays proceeds. Tuesdays, Wednesdays and Fridays were frequented with higher level of pollution indicating a specific pattern of the traffic and commercial activities of the Fraser Valley area.

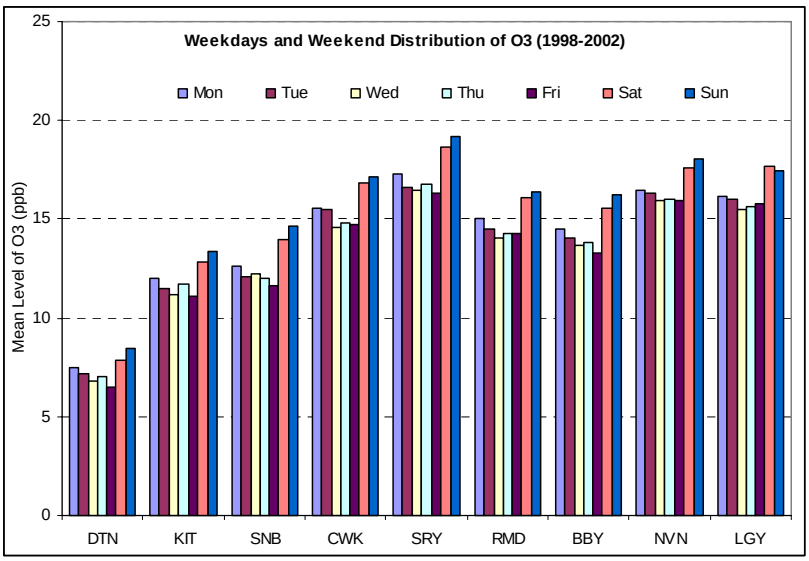
On the contrary, mean level of ozone in the area shows opposite pattern to the CO and NO_x pollution level where weekends were experienced with relatively higher level of ozone compared to the weekdays. In addition, minimum level of ozone were found in the Downtown Vancouver as maximum destruction of ozone may occur in the area due to higher amount of traffic emissions of nitric oxide(NO) in all the days of the week and transport of the pollutants to the neighboring areas by wind. As shown in the Figure 3, maximum weekdays as well as weekend ozone level in the areas like Chilliwack, Langley, Surrey and North Vancouver might be the result of comparatively less traffic vehicles emissions of NO_x and less destruction rate of ambient ozone transported by the downward wind. Day of the week pattern of ozone level shows highest level on Sunday followed by Saturday, and Monday.



(a). Carbon Monoxide (CO)



(b). Nitrogen Oxide (NO_x)



(C). Ground Level Ozone (O_3)

Figure 3: Days of the week distribution of mean level of (a) Carbon Monoxide (CO), (b) Nitrogen Oxide (NO_x), and (c) Ozone (O_3) for the period of 1998-2002

3.3 Exceedance Events of O_3, and other Pollutants

Weekdays and weekends variations in the hourly ozone exceedance events were examined for the period of 1998-2002 shown in the Figure 4. As shown in the figure, Chilliwack, Langley, North Vancouver, Surrey, and Richmond show similar pattern in maximum exceedance events. In these sites, even within the week days, higher number of hourly standard exceedance events occurred in Monday, Tuesday, and Wednesday compared to Thursday and Friday. During the weekends, maximum exceedance occurred on Sunday.

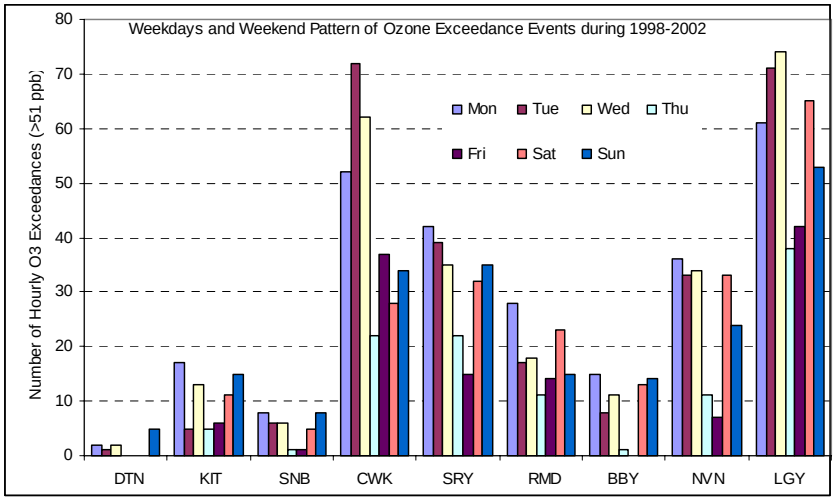
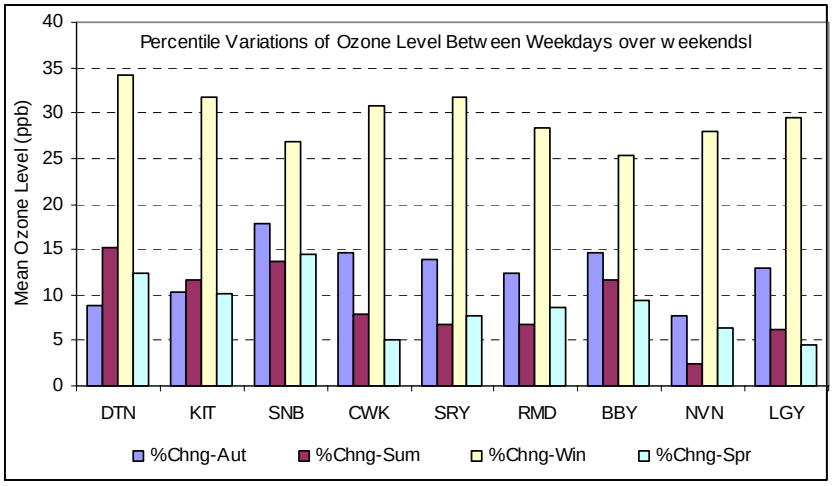


Figure 4: Hourly Ozone Exceedance Events (>51 ppb) during weekdays and weekends

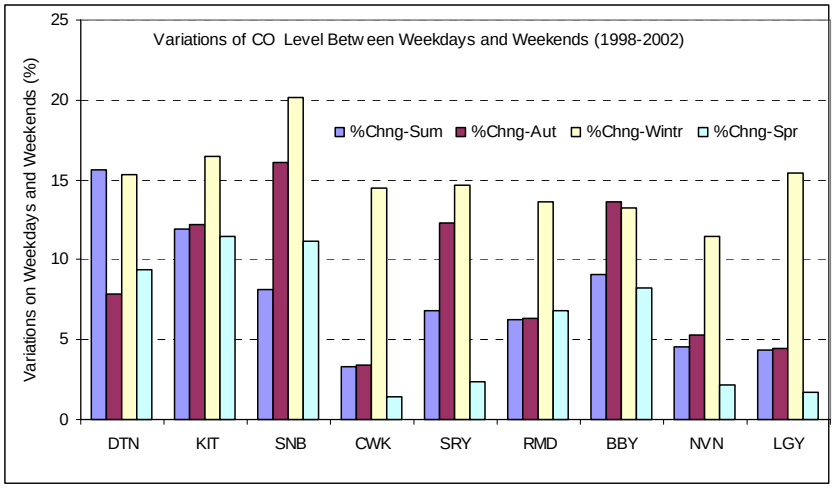
As shown in the Figure 4, minimum number of standard exceedance events occurred at busy commercial areas like Downtown, Kitsilano, Burnaby, and Second Narrow Bridge sites. However, in the case of exceedance events, these sites also experienced higher number of exceedance events during the weekends compared to the weekdays.

3.4 Season Based Percentile Variations between Weekdays and Weekends

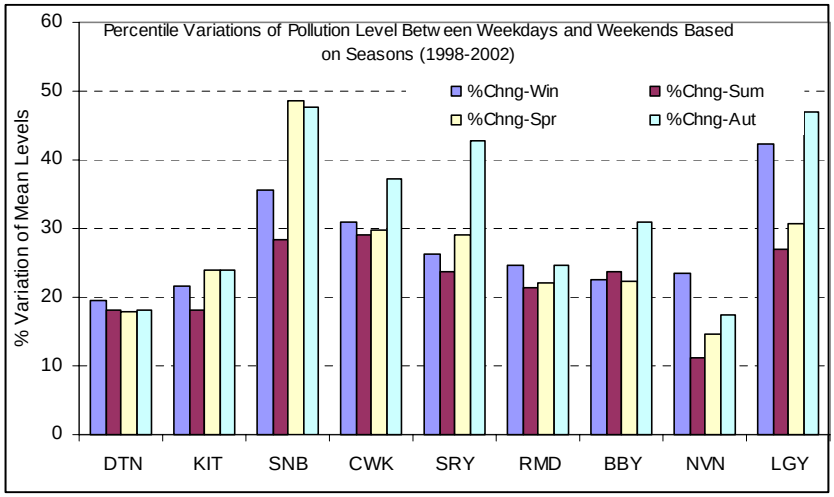
Weekdays and weekend variations of O_3, CO and NO_x level in different seasons were examined where mean values of the pollutants for all the weekdays was compared with that of the weekends. Figure 5 shows the comparative results of the percentile variations between weekdays and weekends. As regards to CO level, maximum variations occurred during the winter followed by autumn, spring and summer respectively in all the sites except for Downtown Vancouver where variations sequence was summer, winter, spring and autumn.



(a). Ozone (O_3)



(b). Carbon Monoxide (CO)



(c). Nitrogen Oxide (NO_x)

Figure 5: Percentile Variations in the Pollution Level between Weekdays and Weekends for (a). Ozone (O_3), (b). Carbon Monoxide (CO), and (c). Nitrogen Oxide (NO_x)

3.5 Correlations Analysis

Linear regression analysis has been done between NO_x and CO for the selected monitoring sites and found that relationship between NO_x and CO differs according to the topography and traffic volume of the sites. Higher level of correlations exists between CO and NO_x at Downtown Vancouver (R^2= 0.70), Kitsilano (R^2=0.86), Burnaby (R^2=0.77), Richmond (R^2=0.75) whereas comparatively low correlations exists at Chilliwack (R^2=0.35), Surrey (R2=0.45), Langley (R^2=0.51). High correlations between CO and NO_x indicates that higher level of NO is contributed by the traffic vehicles while areas with low correlations indicate that components of NO_x (i.e. NO and NO_2) are contributed more by the other point or area sources of emissions than the traffic perhaps by biogenic emissions of volatile hydrocarbons.

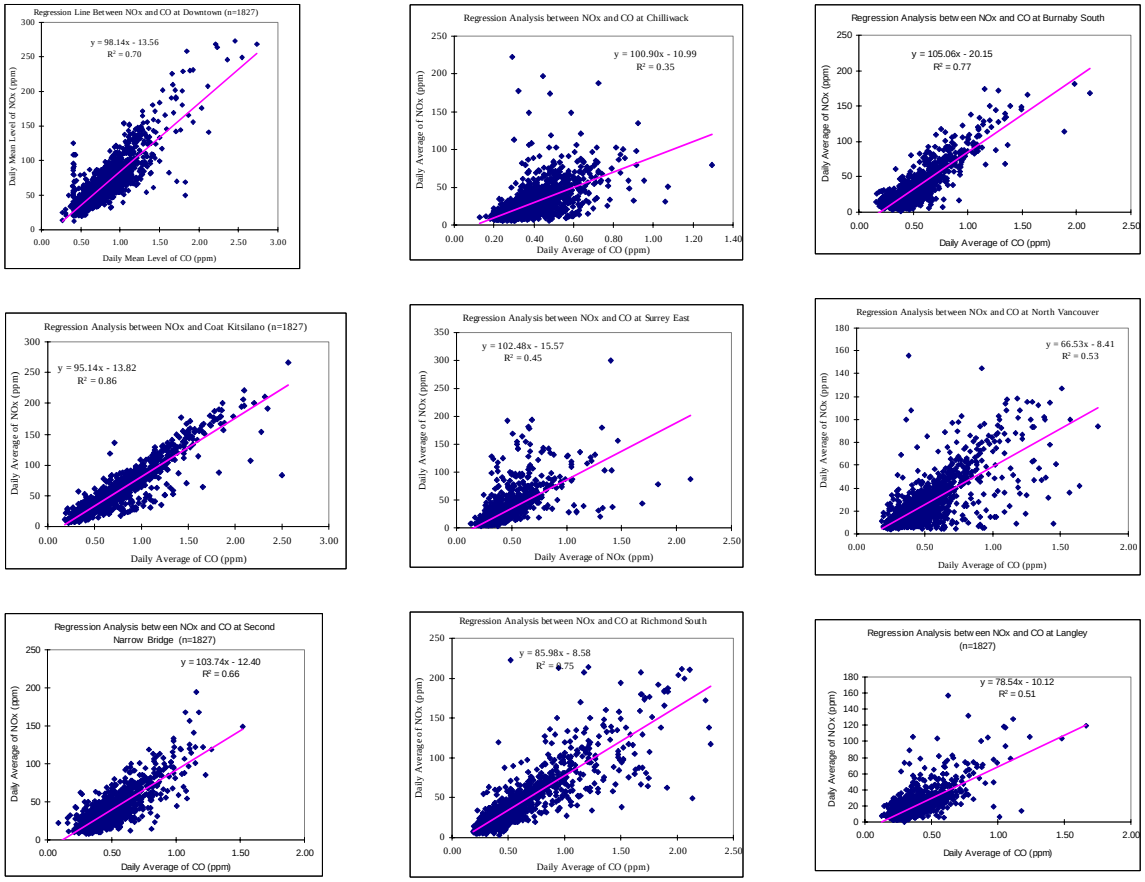


Figure 6: Results of the Linear Regression analysis between Nitrogen Oxides (NO_x) and Carbon Monoxide (CO).

4.0 DISCUSSIONS AND CONCLUSIONS

In the Fraser Valley of British Columbia, high ozone pollution values were measured during the spring season and maximum number of ozone exceedance events was also observed during the spring time. Stratospheric intrusion and increased photochemical reactions at the ground may be the reasons for the spring maxima (Vingarzan *et al*. 2003).

It is evident that surface level ozone formation passes through a complex process in the atmosphere where nitrogen monoxide and volatile organic compound (VOC) plays the vital role in the ozone production and destruction cycle. Significant correlationship between CO and NO_x indicates that traffic vehicles are the dominant source of ozone precursors at the more urbanized sites of the region (e.g. Downtown Vancouver) than the less urbanized sites (e.g. Chilliwack). Both CO and NO_x pollution level decreases during the weekends but ozone level increases during the weekends. Increase in ozone level in the weekends might be contributed by the meteorological factors such as wind transport, conversion rates of ozone precursors (e.g. NO to NO_2 and VOC to NO_2), and trapping of ozone by the mountain as evidenced by higher level of ozone at Chilliwack or Langley. In addition, comparatively less traffic volume in the area during the weekends causes less

NO emissions and subsequently less destruction of existing ozone level while VOCs may contribute in further elevation of ozone level which needs further study.

Depending on the seasons, percentile variations between weekdays and weekends ranges from 11.27 – 47% for NO_x, 1.73 – 20.14% for CO, and 4.53 – 34.26% for O_3. Maximum percentile variations were found for all the pollutants during the winter and autumn season. Higher amount of fuel consumptions by traffic, low mixing height and slow dispersions in the area usually causes elevated pollution levels and the higher percentile variations for weekdays and weekends of the winter and autumn seasons support the influence of the variations in traffic volume on pollution levels.

Finally, relationship between reductions in precursors with the changes in ozone level could not be ascertained as interaction pattern of ozone with its precursors not only depends on the NO and VOCs values but also on the ratio of the NO_2 and NO, and VOC and NOx which are also influenced by meteorological conditions. However, this study provides an indirect assessment of the influence of traffic vehicle emissions on the ground level ozone level in the Fraser Valley.

ACKNOWLEDGEMENT

The authors wish to thank Greater Vancouver Regional District (GVRD) authority for providing ambient air quality data, Japan Society for Promotion of Science (JSPS) for providing finance and Mie University for providing logistic supports for the study

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