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ARTICLE

Influence of Temperature and Relative Humidity on Air Pollution in Addis Ababa, Ethiopia

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ABSTRACT

In this paper we access the effects of two atmospheric variables (temperature and relative humidity) on two important pollutants in the atmosphere (Nitrogen oxides (NOx) and carbon monoxide (CO)) by using one year (2016) data of Addis Ababa. Temperature has impact on atmospheric mixing and cause for the reduction of NOx as temperature increases. There are positive correlation between temperature and CO concentration from January to April with (R^2 = 0.69), negative correlation from May to August with (R^2 = 0.92) and no correlation for the remaining months. NOx and CO have moderate positive and negative correlation with relative humidity during the months January-April (R^2 = 0.294 for NOx and R^2 = 0291 for CO) and in the months May-August are R^2 = 0.97 and R^2 = 0.15 for NOx and CO respectively. But there are no clear correlation between the NOx and CO with relative humidity from September-December. NOx concentrations during wet season was almost about twice that of the dry season, but no such difference was observed in the case of CO. The seasonal average air temperature in wet season is relatively lower than dry season. NOx exhibited positive and CO negative seasonal correlations with relative humidity.

1. Introduction

Meteorological parameters such as temperature and relative humidity play a significant role in affecting air pollutants in urban environment [1]. Air pollution occurs within the atmospheric planetary boundary layer under the combined effects of meteorological factors, earth surface topographic features and the release of air pollutants from various sources [2,3]. Meteorological parameters are having great importance in transportation, dispersion and natural cleaning of the air pollutants in the atmosphere [4,5,6,7]. The most important role of meteorological parameters are in the dispersion, transformation and removal of air pollutants from atmosphere [8,9,10]. High pollution levels can be expected during fair weather conditions resulting from local wind system and strong temperature inversions [11,12].

In developing countries like Ethiopia, the transport sector accounts for 49% of NOx emissions and the power sector 25%, the industrial sector 11%, the residential com-

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mercial sectors 10% and other sources 5% [13,14,15,16]. Nitrogen oxides (NOx) are mixes of gases that are composed of nitrogen and oxygen. Two of the most toxicologically significant nitrogen oxides are nitric (NO) and nitrogen dioxide (NO_2) and collectively represented as NOx, which are emitted by vehicles. The reaction of nitrogen dioxide with chemicals produced by sunlight leads to the formation of nitric acid which is a major constituent of acid rain. Nitrogen dioxide also reacts with sunlight which leads to the formation of ozone and smog conditions in the air we breathe. Carbon monoxide (CO) is a colorless and odorless gas that can be harmful when inhaled in large amounts and its greatest sources are cars, trucks and other vehicles or machinery that burn fossil fuels (petrol), wood and coal (from home heating and industry) [17,18,19,20,21]. Carbon monoxide is the primarily pollutant which is emitted from its sources directly to the atmosphere [22,23,24,25,26].

Nowadays, vehicles and factories are increasing in Addis Ababa and many of vehicles are second-hand (old) with out emission controls and they are considered as major air polluters of the city . According to National Meteorological Agency (NMA) of Ethiopia most vehicles have no emission controls and about 53% of the total vehicles in Addis Ababa are more than 20 years old. Old vehicles emit hydrocarbons and smoke to the atmosphere up to five times the rate of emissions from new vehicles [27,28,29,30]. Such interventions require appropriate policy framework and institutional capacity for implementation. In this regard, the Roads Transport Authority (RTA) has power to prepare standards relating to smoke gas and vapor emitted from the exhaust pipes of vehicles, as per the requirements of Environmental Policy of Ethiopia (EPA). EPA on the other hand is expected to formulate Air Quality Standards (AQS) in consultation with the RTA.

Thus, this study focuses on the influence of temperature and relative humidity on concentrations of NO_x and CO in one year data (2016) of Addis Ababa. Air pollutants such as nitrogen dioxide has been linked to increases in asthma symptoms and reduced lung development and function in children[31]. Nitrogen dioxide can decrease the lungs' defenses against bacteria, making them more susceptible to infections. Carbon monoxide is readily absorbed by the lungs and interferes with the blood's ability to carry oxygen. Therefore knowing concentrations of these two gases are a paramount importance [29,32]. Besides, finding meteorological parameters that have influences on their concentrations is also necessary to control their concentrations. Hence, this study has a wide range of significant for the researcher, city administer, Addis Ababa Environmental Protection Authority (AAEPA), Federal Transport Authority (FTA), National Meteorological Service agency (NMSA) and for the society.

2. Data and Methods

Addis Ababa is a capital city of Ethiopia and the city has a complex mix of highland climate zones with temperature differences of up to 10°C (18°F), depending on elevation and prevailing wind patterns [40]. Addis Ababa is located at geographic location in 9.00° N and 38.80° E and it is one of the most traffic-related pollutant cities in Ethiopia. The main contributors to air pollution in the city are domestic heating, private cars and public vehicles. In this study, the data of NO_x and CO concentrations was collected from Ethiopian Meteorological Agency at Addis Ababa station as secondary data. Meteorological parameters (temperature and relative humidity) were also obtained from the National Meteorological Services Agency (NMSA) of Ethiopia. The data was recorded during the year 2016 from Ethiopian Meteorological Agency at Addis Ababa station.

The data of meteorological parameters (temperature and relative humidity) and concentrations of NO_x and CO were organized using Microsoft Excel and the averaged value of pollutant concentrations and meteorological parameters were averaged to obtain seasonal values over the entire year. Time series of monthly and seasonal variability of the concentrations of NO_x and CO were plotted using Matlab software. Regression analyses between concentrations of NO_x and CO and air temperature and relative humidity were also determined by using Matlab software.

3. Results and Discussions

3.1 Influence of Temperature and Relative Humidity on Monthly-averaged Concentration of NOx and CO

The influence of temperature on monthly-averaged NOx and CO concentrations are shown on Figure 1. The plots show weak negative correlation (R^2 = 0.30) and no collection (R^2 = 0.01) for NOx and CO respectively. Similarly, Hosseinibalam and Hejazi [33] have found that weak negative collection (R^2 = 0.18) in Isfahan at Azadi station. The relative humidity shows weak negative correlation (R^2 = 0.14) and (R^2 = 0.07) for NOx and CO respectively as shown in Figure 1.

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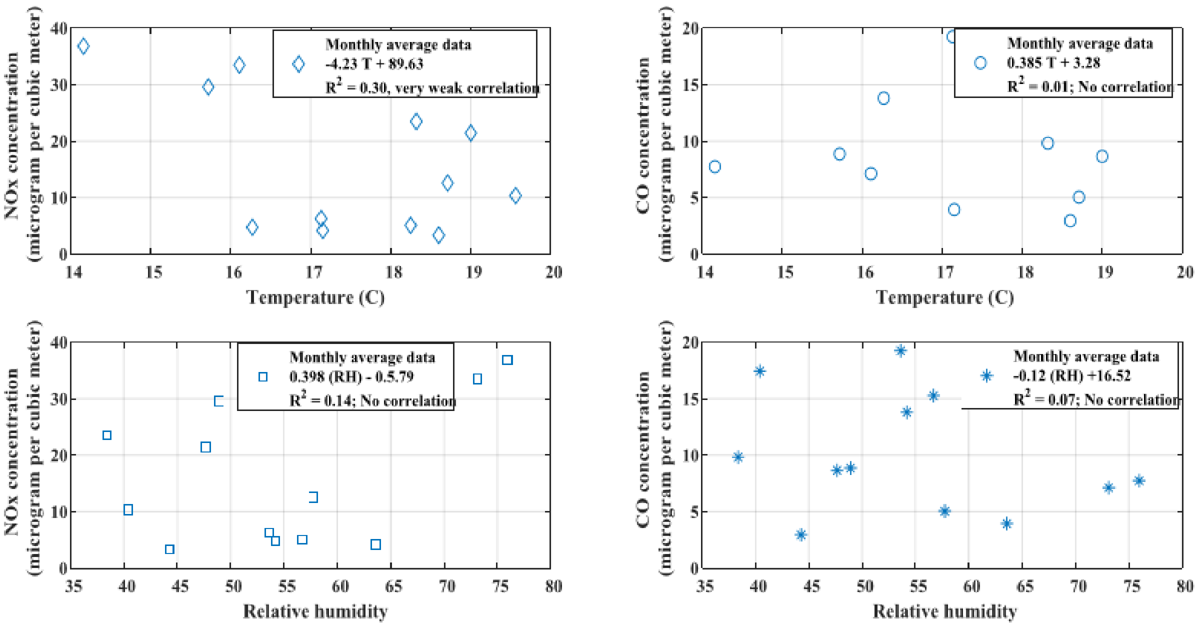

Figure 1. Influences of temperature and relative humidity on monthly-averaged NO_x and CO concentrations in the year 2016

Despite the weak correlation the negative slope manifests inverse linear relationship as shown in Figure 2, which is less concentration (more dispersion) as temperature increases. Similar weak correlation was also obtained by Bathmanaban [4] in between the NOx and temperature. Ocak and Demircioglu [37] have obtained a more satisfactory correlation with R^2 = 0.73 between the NOx and temperature. It is obvious that NOx concentrations decrease with increasing temperature but what Akkaya and Pazarlhoglu [38] have observed for pre and post monsoon seasons is contrary to this result. However, their result for the rainy seasons agree with this finding.

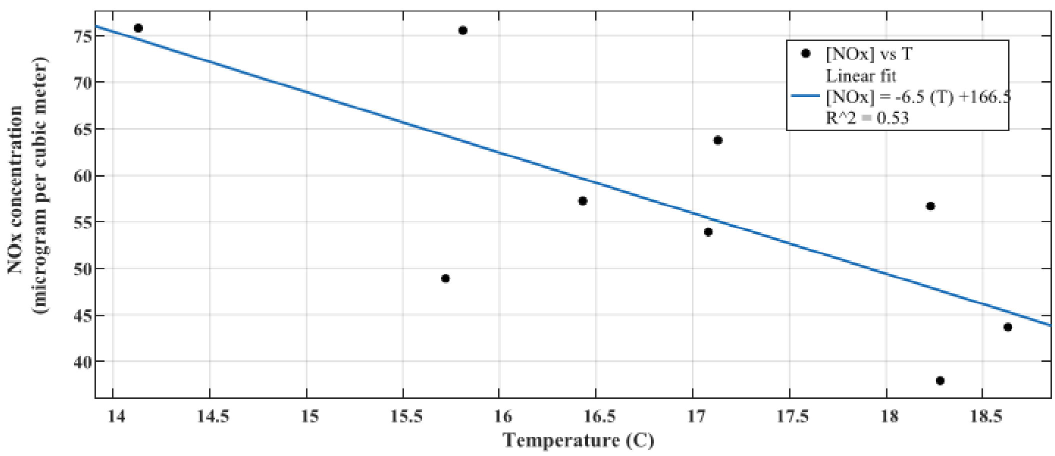

Figure 2. Linear regression between temperature and monthly-averaged NOx concentration using averaged data of months

3.2 Influence of Temperature on NOx and CO Concentrations

As shown in Figure 3 the daily-averaged data of CO over the entire year shows no correlation between CO concentration and temperature. But other studies such as Witz and Moore [34] showed the relationships between the temperature and CO and found regression coefficients that varied between 0.68 and 0.73. Observation of Figure 3 reveals positive correlation between temperature and CO concentration from January to April with (R^2 = 0.69), negative correlation from May to August with (R^2 = 0.92) and no correlation for the remaining months.

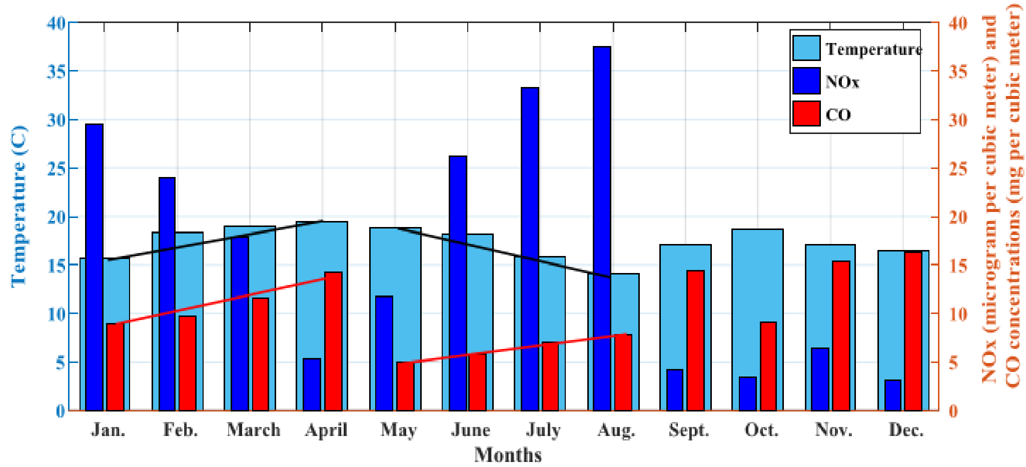

Figure 3. Correlations between temperature and concentrations of NOx and CO

3.3. Correlation between Concentrations of NO_x and CO with Relative Humidity (RH)

Correlation between NOx concentrations and relative humidity is very weak correlation (R^2 = 0.15). This is in agreement with Jayamurugan et al. [35] have no significant correlation was found between humidity and NOx in all seasons. The correlation R^2 = 0.15 shows that the independent variable of relative humidity included in the model are able to explain 15% of the variation in the dependent variable of NOx. The NO_x concentration has a very weak dependence and this means that 15% of NO_x depends on relative humidity and 85% is indeterminate. The correlation between CO and relative humidity over days of the year 2016 was investigated by linear regression analysis and the scatter plots are shown in Figure 1. There is no correlation between CO concentration and relative humidity. However, monthly bar plots show some sort of pattern between both gases and RH as shown in Figure 4. But according to Ocak [39] relative humidity is a moderately linked parameter to concentrations of NOx and CO pollutants.

The results of the regression analysis revealed that NO_x and CO have moderate positive and negative correlation with relative humidity during the months January-April (R^2 = 0.294 for NO_x and R^2 = 0291 for CO) respectively. As shown in Figure 4, the relative humidity is a moderately linked parameter to concentrations of NO_x and CO pollutants. The correlations in the months May -August are R^2 = 0.97 and R^2 = 0.15 for NOx and CO respectively. But from September-December there are no clear correlation between the NOx and CO with relative humidity. The concentration of CO decreases with increasing relative humidity and the concentration of NOx increases with increasing relative humidity as observed by [37].

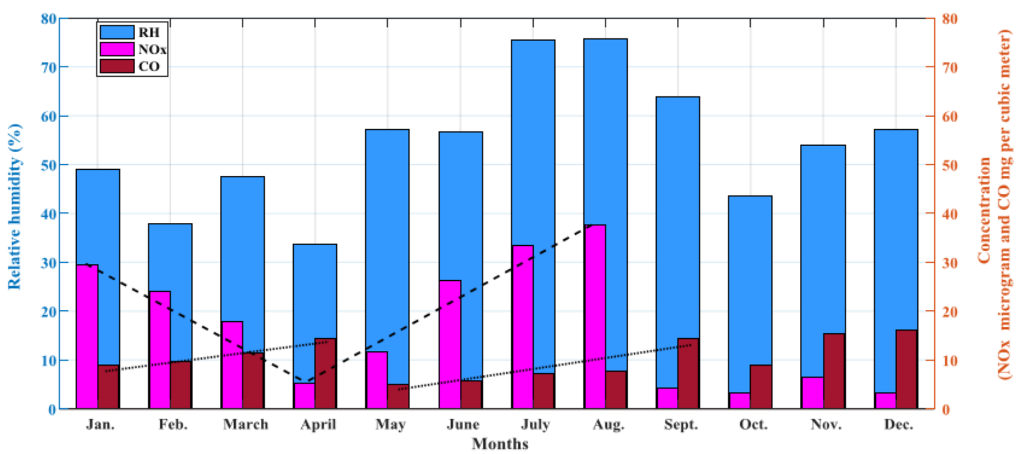

Figure 4. Monthly-averaged concentrations of NO_x and CO shown with relative humidity in the year 2016

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3.4. Seasonal Variations of Temperature, Relative Humidity, NOx and CO Concentrations

Seasonal variability (in this case the relatively dry and wet seasons) is important to understand the influences of moisture in the atmosphere on pollutant concentrations. Relatively dry months are October, November, December, January and February and relatively wet months are March, April, May, June, July, August and September [36]. Figure 5 depicts how the concentrations of both gases change with temperature and relative humidity during relatively dry and wet seasons. As shown in the Figure 5, there is a difference between NO_x concentration during relatively dry and wet seasons.

The seasonal average air temperature in wet season is relatively lower than dry season. Since temperature and NO_x concentrations are negatively correlated (however weak it may be), this must have resulted in increase of NO_x concentration during the wet season. This is in agreement with Bathmanaban [4] work since they also obtained negative correlation between the temperature and NOx during the rainy season. CO exhibited only slightly small seasonal correlation with temperature. Both NOx and CO exhibited positive and negative seasonal correlations with relative humidity respectively. The concentrations of the two gases are also positively correlated.

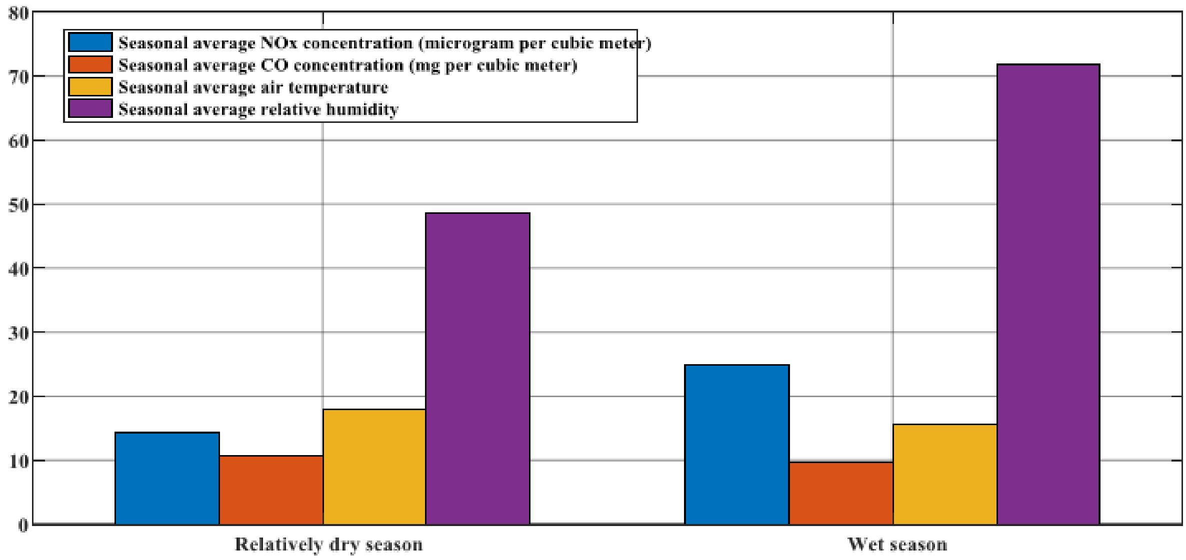

Figure 5. Variability of seasonally-averaged concentrations of NO_x and CO in the year 2016 and correlation with temperature (^oc) and relative humidity (%) in relatively dry and wet seasons

4. Conclusions

Temperature and relative humidity is responsible for vertical mixing of atmospheric pollutants. They also responsible for different atmospheric stability conditions. Nitrogen oxides (NOx) and carbon monoxide (CO) are considered as air pollutants their concentrations are assumed to be influenced by temperature. More NOx concentration was observed during wet season compared to the dry season. There seems to be other sources of NOx during the rainy season on top of those emitted from vehicles or the reduction during the dry season could be due to better atmospheric mixing. The CO concentration did not show much change between wet and dry seasons. This can be due to relatively long residence time of this gas in the atmosphere. Temperature has impact on atmospheric mixing and that is the cause for the reduction of NOx as temperature increases. Both gases showed correlations with relative humidity, but at different rates during relatively wet and wet seasons. For NOx the dependence on relative humidity is stronger during wet season and that could also be the reason for the doubling of NOx concentration during wet season. CO correlation with relative humidity is relatively weak and the slopes are also small in both dry and wet seasons. The low dependence of CO on both temperature and relative humidity could be the reason for uniformity of the concentration of this gas during both seasons.

Finally, the authors suggest that in order to decrease the effects of air pollution in city the concerned body may be :

(1) Import new vehicles with out tax or reduced tax, which burn fuel efficiently and reduce importing old vehi-

cles or appreciate and support machineries in the country (like Marathon Motor Engineering PLC and others).

(2) Participate and initiate green legacy campaign in Ethiopia and tree-planting in Addis Ababa (such as in Entoto Park, Sheger Project and others) and preserve them, which absorbs air pollutants in the city.

(3) Use vehicles appropriately such as use a less polluting and more fuel-efficient vehicles; drive at smooth accelerate and moderate speed; check up and made regular maintenance of vehicles and avoid unnecessary driving vehicles or drive less.

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