Investigation of a Possible Natural or Artificial Barrier to Reduce Urban CO_2 Concentration

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ABSTRACT: As the population and CO_2 level in urban areas are increasing day-by-day, attention should be given to identify sources, sinks and influence of CO_2 in urban areas. This research focuses on identifying a possible natural or artificial barrier to reduce urban CO_2 concentration, mainly produced due to the urban traffic. The study was done along byroads in Ratmalana, Dehiwala and Wellawatta urban areas and the CO_2 variations on these roads were compared with the physical features besides these roads. The results of this study reveal a relationship between physical features and CO_2 variation along byroads. Vegetation cover, arrangement of the buildings and the building size are very much related with the CO_2 variation along byroads. Presence of thick vegetation fences rather than walls beside the roads and more space between buildings help to reduce a significant amount of CO_2 concentration. Existence of high buildings and high walls increase CO_2 concentration at those locations.

1 INTRODUCTION

Urban areas are rapidly growing population centers where large amount of energy is consumed. According to the WHO (2015), the urban population in 2014 account for 54% of the total global population. The urban population is expected to grow by 2.5 to 3 billion by 2050, and major cities are expected to grow substantially in surface area. Urban areas accounts for 67-76% of global energy use, being responsible for the largest proportion of anthropogenic emissions such as carbon dioxide, methane, nitrous oxide as they rapidly urbanize and industrialize.

Among these anthropogenic emissions, CO_2 is the most dominant air emission and urban areas contribute to global CO_2 emissions, both through direct emissions in the local environment and also through vehicle emissions and other stationary energy sources. According to IPCC-AR5 (2014), urban areas account for between 71-76% of CO_2 emissions of global final energy use. The combined effect of increased CO_2 levels in the atmosphere and urban land use change from urbanization, results in the urban warming phenomena. Furthermore, increased levels of CO_2 with other greenhouse gases enhance the greenhouse effect resulting in the global warming.

The combined effects of both urban warming and global warming has become a problem for urban dwellers by creating problems such as heat stress related illnesses. Moreover, the increased level of air pollutants such as CO_2 has created problems related to air borne diseases such as Severe Acute Respiratory Syndrome (SARS), which occurred in April 2003 alarming the whole world. Exposure to and inhaling very high concentrations of atmospheric CO_2 were studied by Idso et al (2003). According to results of that study, exposure to and inhaling very high concentrations of atmospheric CO_2 can induce a state of hypercapnia in people creating illnesses such as headache, nausea, visual disturbances. Moreover, sometimes exposure to high CO_2 concentration can be fatal.

The behavior of CO_2 fluxes in urban areas have been studied with many of different factors. Grimmond et al (2003) have studied the urban CO_2 variation with vehicular activities, land use pattern or spatial arrangement (commercial, downtown, industrial, suburban, etc.). According to the studies by Halwathura et al (2012) vegetation cover in urban areas is very helpful to reduce urban CO_2 concentration. Gratani et al (2005) have studied the positive relationship of characteristics of urban buildings such as size, shape and separation from one another, sources of CO_2 emission such as vehicles, power plants and their emission characteristics, number of residents or the population etc. Moreover, the CO_2 concentration is time dependent and is related with weather conditions.

As the CO_2 level and population in urban areas are increasing day-by-day attention should be given to identify sources, sinks and influence of CO_2 in urban areas, so that management and planning within urban areas can be adjusted appropriately to minimize negative human and environmental impacts.

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2 OBJECTIVE

The main objective of this research is to find the variation of urban CO_2 concentration along byroads in urban areas, mainly produced due to urban traffic. Hence to, identify a possible natural or artificial barrier to reduce urban CO_2 concentration. Even though there are many factors to be considered, mainly the following factors were considered during this research.

- Variation of CO_2 concentration along byroads in different urban ecosystems
- Effect of characteristics of buildings such as size and their arrangement on CO_2 variation along byroads
- Effect of vegetation on urban CO_2 variation along byroads

3 METHODOLOGY

To achieve the objectives the following methodology was carried out.

Data collection was done along byroads in Colombo city limit where there is high traffic. The CO_2 concentration was measured using a portable CO_2 meter and variation of CO_2 generated by traffic was measured at a distance of 10m along the byroad. The readings were taken upto a total length between 180m-200m on the byroad. Other than the CO_2 concentration also the onsite temperature and humidity were measured from point to point. In the meantime features of the urban physical features such as presence of vegetation, size of the building and arrangement along the byroad were recorded.

Data was collected during daytime on weekdays at peak traffic durations. Furthermore data was collected on byroads where there were no automobile activities to obtain constant conditions during the data collection.

3.1 *Site Description*

The study was carried out within the Colombo city limits in Sri Lanka.

Colombo is the main economic and most urbanized city in Sri Lanka. It has a 54.6% urban population and is urbanizing day by day as other cities in the world. Colombo is situated at 6°56'04"N and 79°50'34" and altitude of Colombo is very low as it is located very close to the sea. It experiences tropical wet and dry climate throughout the year.

The mean temperature is around 27°C. The average annual rainfall is about 2400mm/yr. Ratmalana, Dehiwala and Wellawatta are the main urban/suburban areas that were considered for this study. High traffic can be observed in these urban areas as they have been located on A2 Colombo-Galle road, one of major roads in Sri Lanka. In addition, traffic jams can be observed in these areas due to a many of human activities beside the main road. The selected byroads show different physical features along them and they vary from road to road.

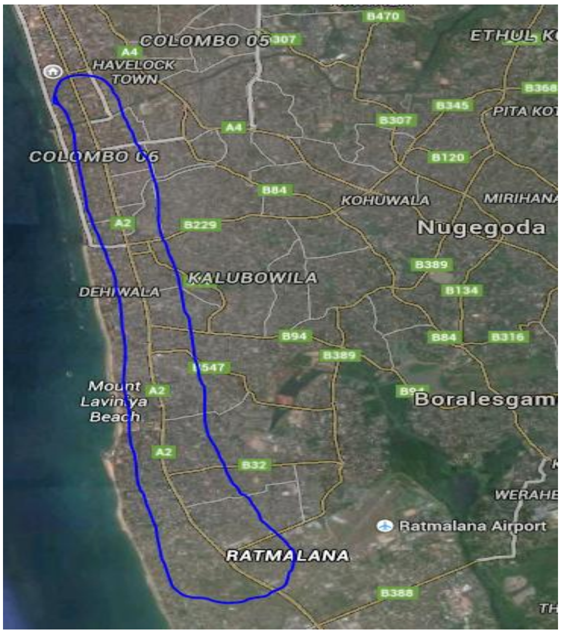

Fig. 1 Study areas in a google map. The data was obtained from byroads along A2 main road within the enclosed area

3.2 *Data Analysis*

The variation of CO_2 due to traffic along byroads was plotted with respect to the distance along the byroad and was compared with the physical features along the road to identify the possible natural and artificial barriers that help to reduce the CO_2 concentration.

The data from three urban areas were categorized considering the physical features along the byroads. The main physical features that were considered in categorizing each road in this study were the vegetation cover and the arrangement of the building bedside the byroads. Primarily byroads were categorized according to the vegetation cover and furthermore they were studied considering the spatial arrangement and the size of the building. Following are the three main categories that were considered and at least 15 samples were considered under each category.

- Category A: Low greenery roads
  The roads, which showed a less percentage of greenery along roads, were included in this type.

- Category B: Mix category
  Most of the roads in the considered three urban areas can be included into this category. Further studies on the variation of CO_2 concentration along this type of byroads were done based on the size and the spatial arrangement of the buildings.

- Category C: High greenery roads
  The roads, which showed a higher percentage of vegetation, were included in this category.

4 FINDINGS AND DISCUSSION

According to the NOAA (2015), the current global mean ambient CO_2 concentration is 401 ppm and the observed mean CO_2 concentrations in Ratmalana, Dehiwala and Wellawatta urban areas are 400ppm. The physical features along byroads in these urban areas are different from one to another due to the change of their land use patterns. Most byroads are congested with multi storey buildings at the beginning of the road, located very close to each other. The presence of greenery along byroads at the front of the roads are very low. When one goes along further down these roads, most of the time reduction of building congestion; more space between buildings and more greenery beside the roads can be observed.

Category A: low greenery roads

Data were collected from fifteen roads and the CO_2 variations along these roads had a mean value between 410ppm-400ppm after reaching a certain distance along the road. Although these CO_2 levels reach nearly a constant value, they have not reached the ambient CO_2 concentration. Most of these roads contain high walls beside the road, at several locations along the road. These high walls may act as obstacles for the movement of CO_2 in lateral directions that can result in increase of CO_2 level at those locations. In addition, although vegetation beyond these walls could be observed, the effect of that greenery on reduction of CO_2 along the road is insignificant as these walls reduce the contact between CO_2 and vegetation. Another road under this category is front loaded with multi storey buildings and show less vegetation throughout the road. The least CO_2 concentration on this road is 404 ppm, which is also higher than the ambient value. CO_2 variation has taken 30m to reach a smaller value from the source location. The CO_2 variation along this road shows a sudden increase at the middle of the road after reaching a value near the ambient value. When these variations are compared with physical features along the road it could be observed that several eight storey buildings exist on both side of the road at those locations.

Category B: Mix category

This category was again evaluated under three sub categories namely front loaded roads with multi storey buildings, both front and back loaded roads with buildings and roads with considerable spacing between buildings (not congested) considering the arrangement and sizes of the buildings along byroads. In, front loaded roads with multi storey building category, as its name implies the front of the roads are heavily congested. As these roads are less congested at the back more vegetation and more space between buildings can be observed. A sudden drop of CO_2 concentration generated due to the traffic cannot be observed. It has to move more than 30m along this kind of road to obtain a reduced CO_2 level. The CO_2 variation shows an insignificant variance at the back of the road and comes to a value very close to the ambient CO_2 level. This variation shows a significant relationship with the physical features along the byroads in this category. The low gradient of CO_2 reduction may be due to the congested buildings at the beginning. When compared of with Category A, the effect of vegetation for the ambient CO_2 concentration can be observed.

Most of the roads, which are loaded with buildings throughout the road, show a very little gradient in reducing the CO_2 concentration along the byroads. In addition, it can be observed that there are fluctuations in the reduced CO_2 level according to the arrangement and size of the building beside the road. It can also be observed that a rise in CO_2 concentration occurs near multi storey buildings with more stories. According to the observations, roads which have more space between buildings show a sudden drop within first 20m.Beyond that, the CO_2 variations is insignificant and the CO_2 concentration come to a constant value very close to the ambient value. When there is more space between buildings, it promotes the greenery and reduce the CO_2 concentration by allowing CO_2 to move on any direction and allowing CO_2 to mix properly with air.

The existence of thick vegetation fence along byroads on Category B shows a significant reduction of CO_2 concentration confirming the effect of vegetation in urban areas for the reduction of urban CO_2 concentration.

Category C:high greenery roads

The variations of CO_2 concentration along high greenery roads are very much similar to the roads, which have more space between buildings. Unlike other byroads, a sudden drop within first 10m in this category can be observed.

5 CONCLUSIONS

Urban areas are rapidly growing and they consume a large amount of energy. According the WHO (2014) reports, world urban population will be around 3 billion by 2050. As urban areas consume large amount of energy, they are important sources of enhanced CO_2 concentrations, which have created adverse effect to both human health and environment. The significant variation of CO_2 concentration in urban areas are influenced by the distribution of anthropogenic sources (automobiles and fixed) and the characteristics of the urban environment.

The findings of this research show a significant relationship between CO_2 variations along byroads in Ratmalana, Dehiwala and Wellawatta urban areas with the physical features along those roads.

- The findings of this research clearly show the effect of vegetation along byroads. A significant reduction of CO_2 concentration near thick vegetation fences along congested roads can be observed.
- A reduction of effect of vegetation in adjacent lands along the byroads could be observed due to the existence of high walls which create a barrier for the contact of CO_2 and vegetation.
- It could be observed that an increase of CO_2 concentration occurs after reaching the ambient value in the middle of the byroads due to the existence of multi storey buildings at those points.
- In addition, observations of this research clearly show a significant reduction of CO_2 variation where there is more space between buildings.

This research mainly deals with a qualitative analysis to identify the variation of CO_2 concentration produced by the traffic along byroads. The observations reported here are for a very short period and limited range of conditions. The effect of wind on these observations was not considered and many more studies of urban areas are needed to document the spatial and temporal variability of CO_2 concentration in urban areas.

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