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Spatial Trend of Particulate Matter (PM) in the Near Roadside Environment: A Case Study of Milton Keynes, Buckinghamshire, United Kingdom

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Abstract

Particulate Matter (PM) are emitted into the ambient air through several sources such as vehicular emission, emissions from power plants, dust emissions from construction sites, industrial processes emissions and many more. The concentration of PM with respect to distance from roadside environments in Milton Keynes, United Kingdom was determined in this study using the Osiris particulate monitor. This instrument measures the mass concentration of PM_{10}, $PM_{2.5}$ and PM_1 in micro-grams per cubic meter ($\mu g/m^3$). The sampling locations were major roads and bus stops within Central Milton Keynes. The results from the particle sampling campaign showed a higher concentration of PM on non-grid roads. The $PM_{2.5}$ and PM_{10} mass concentration decreases with respect to distance from the road side environment. Also, low vehicles speed at traffic light junctions and bus stops caused an increased in concentrations of PM in major bus stops. The decrease in $PM_{2.5}$ and PM_{10} concentrations with respect to distance from the road side environment is attributed to increased particle dilution and dispersion in air. It was observed that PM concentrations in any of the sampling locations did not exceed the WHO, EU and the UK air quality standards. It is recommended that appropriate distance of about 15 m is require from the traffic road side environment for housing development, this will reduce exposure to traffic generated particulate matter. Also further study should be carried out both in the winter and summer months to enhance the understanding of PM trends in the near road side environments and the extent of contribution of traffic emitted PM to the total ambient PM concentrations.

Keywords:
Particulate matter, Particle number, Mass Concentration
Traffic emissions
Road side environment

Introduction

Particulate Matter (PM) from road traffic emissions is one of the major contributory sources of air pollution in the urban atmosphere. The emissions from vehicle exhausts are the by-products of the combustion of fossil fuels in engines; these significantly contribute to air pollution in most urban city centres. Emissions from vehicles contained Carbon dioxide (CO_2), Carbon monoxide (CO), Volatile organic compounds (VOCs), Particulate matter (PM), Ozone (O_3) and other compounds.

The US EPA defines particulate matter as a "complex mixture of small particles and liquid droplets (aerosols) known as pollutants" (Fierro, 2000). It varies in sizes and composition, the physical and the chemical composition of PM depends on its source of origin, its location, time of the year and the weather condition at a particulate place in time. Particulate matter (PM) is made up of both coarse (≥10 μm) and fine particles size (10 ≥2.5 μm).

PM is classified based on their aerodynamic diameters; it is this property that determines the rate of transport, the rate clearance and the atmospheric behaviours of PM. Particulate matter comes from both natural and anthropogenic sources. Natural sources of PM emissions include emissions as a result of volcanic eruption, forest fire, wind-blown dust and sea salts etc. Anthropogenic sources are referred to as man-made sources; these include emissions from vehicles, industrial stacks, industrial plants, gas stations and construction activities (Sapkota et al., 2005).

Particulate matter can be characterised based on their sizes into; PM_1, $PM_{2.5}$, PM_{10}, fine and ultrafine particles due their ability to either be inhalable or respirable upon exposure. The $PM_{2.5}$ is a particle with an aerodynamic diameter of 2.5 μm and below, PM_{10} are particle of size with aerodynamic diameter less than 10 μm diameter. Also PM is one of the most studied atmospheric pollutants in the world, this is because of its pathway of exposure is the air (Athanasius, 2008). Exposure to PM can result into some adverse health effects such as systemic effects or direct pulmonary and cardiovascular effects, (Chen *et al.,* 2013).

It has been globally accepted that particulate air pollution create serious burden to public health (WHO, 2003). The level of particulate pollution in the ambient air have drastically reduced globally, this is as a result of global emission reduction strategies such as the ban on the use of coal as energy generating sources and the introduction of catalytic converted in vehicles, legislations and enforcement of strict regulations in developed world, (Pope III and Dockery, 2006). Despite all these measures, the burdens of health effects of PM exposure are still very high among the public, most especially traffic generated particulate, (Maynard, 2013). Some the acute and chronic health effects includes Cardiopulmonary diseases and heart variability, Respiratory tract infections, Decreased lung function, Myocardial and other systemic infection, Lung Cancer, chronic respiratory diseases and Chronic obstructive pulmonary diseases.

The aim of this project was to measure concentrations of PM with respect to distance from the roadside environment in Milton Keynes, United Kingdom. This was to enhance the efficacy of Milton Keynes Council planning and development policy of leaving certain distances from roadside environment before granting permission for housing development, which was done to protect residents from exposure to PM emissions from traffic emissions.

Methodology

Study Area

Milton Keynes Figure 1 is a town located in north Buckinghamshire, which is about 72km North West of London. Its covers an area of about 90 km^2 and incorporates the existing towns of Bletchley, Wolverton, Newport Pagnell and Stony Stratford. Milton Keynes forms the county boundary with Northamptonshire to the north and west and with Bedfordshire to the east, and to the south of the Borough is the Aylesbury Vale District of Buckinghamshire. The area coverage of Milton Keynes accounts for about one third of the Borough and contains about 80% of the total population of the borough.

Milton Keynes has an estimated population of about 226,180 with a growth rate of 17.1% between 2001 and 2011 (Milton Keynes Council statistic, 2012). The design of Milton Keynes city was dated back to 1960 and designated a new town in 1967. The grid roads

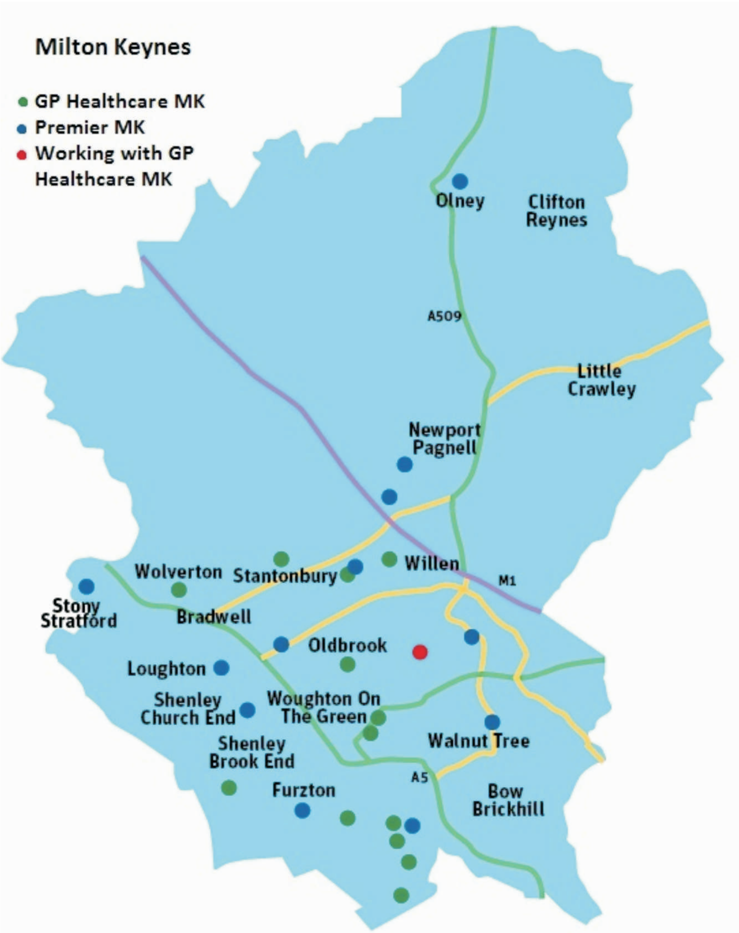

Fig. 1 : Map showing the study areas in Milton Keynes Council, United Kingdom

planning principle for Milton Keynes was to be both traffic and pedestrian friendly and to be well structured and accessible for homes and businesses; this was aimed at providing a high quality life to all the city dwellers (mkweb, 2012).

Milton Keynes is expanding rapidly particularly with major housing developments on the eastern and western flanks of the city. The major pollution source is from Road traffic emissions. The M1 motorway, the A5 trunk (a major trunk road) Road and the west coast mainline electrified railway from London Euston to Glasgow runs through the Borough.

Data collection Method

This instrument used for PM concentrations is the Osiris Particulate Monitor, this was designed and manufactured by Turnkey Instrument Inc. it measure mass concentration of total suspended particle (TSP), PM_{10}, $PM_{2.5}$ and PM_1 particle sizes respectively. It is designed to measure the mass concentration of particle in µg/m^3 in a specified time interval. This instrument is mostly used in the outdoor environment, it can also be deployed permanently or semi-permanently to study both short term and long term PM pollution in cities pollution hotspots.

Two major roads were identified in Central Milton Keynes; the Midsummer Boulevard and Silbury Boulevard. These roads are example of grid road type within Milton Keynes Borough. The field sampling instrument was placed at different sampling points for an approximate time of about 5 hours and concurrently in specified distances intervals (5m) from the road side environment up to 30 m distance. This is to understand the trend of PM concentrations with respect to distance from roadside environment. Also, within Central Milton Keynes, major Bus stops were identified along Midsummer Boulevard and PM sampling was carried out on these Bus stops for an approximately 8 hours at each of the Bus stop, keeping tract on the number of Buses that arrived during the PM sampling period.

The mass concentration of PM was sampled at roadside (0 m) and at 5 m distance interval from roadside environment up to 30 m distance. The concentration difference at each sampling interval was compared statistically with respect to the concentration at roadside (0 m) using unpaired t-test. This is done to understand the significant difference in concentration at each interval with reference to the roadside concentration.

Two major limitations were observed during the course of this research work, these include; Instrument limitation and Time limitation. The field sampling equipment used can only measure PM mass concentrations and particle number concentration in the ambient air, it does not indicate the sources of emission of the PM and this makes it difficult to make a decisive conclusion that the PM concentrations measured by this instrument were emitted only from traffic source. The period for this research work was conducted during the summer months in the UK; the results might not indicate seasonal variations of PM concentration in the ambient air within Milton Keynes, United Kingdom.

Results and Discussion

Particulate matter concentration on grid roads

Figure 2 shows the results of PM_1, $PM_{2.5}$, PM_{10} and TSP concentrations in µg/m^3 on grids roads within Central Milton Keynes. The average PM concentrations on this road as estimated from the Field Sampling Instrument were; PM_{10} is 15.5 (±4.1) µg/m^3 and $PM_{2.5}$ is 5.99 (±2.7) µg/m^3. When these concentration values were compared with the concentration values from the background Air Quality Monitoring Station for PM_{10} mass concentration, it can be deduced that traffic contributed substantially to the total PM concentration in the ambient air. The trends of PM in Figure 2 shows increase in PM concentration between the hours of 12:00 and 14:00 BST. This can be attributed to the fact that, the period is the official launch time in the UK, thus, there was an increased in numbers of vehicles on the roads at this period. This leads to an increased in the average PM concentrations in the ambient air. Therefore, it can be deduced that increase traffic volume causes an increase PM concentrations in the ambient air at a particular time.

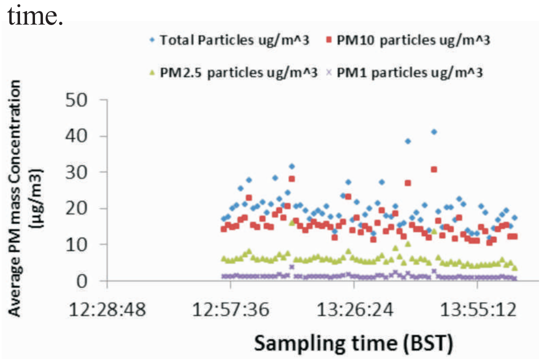

Fig 2: Average PM Concentrations on grid roads in Central Milton Keynes

Particulate matter concentration along Bus stops

The PM concentrations and particle number concentration sampling in major Bus stops within Central Milton Keynes is done to establish the potential exposure of Bus users to particulate pollution emitted by stop-over Buses. Figure 3 is the summary of the average PM concentrations measured in major Bus stops within Central Milton Keynes. Figure 3 shows the average number of Buses at major Bus stops during the particle sampling period.

Observations from figure 3 shows that particulate matter concentration is higher in Bus stop E3 as compared to other Bus stops within Central Milton Keynes. The relationship between figure 3 and figure d shows that Bus stop E3 has the highest number of stop-over Buses during the sampling period. This showed that traffic volume contributes significantly to the particulate matter concentrations in the ambient air. The increased in concentration of PM in each Bus stop when compared to the background PM concentration was higher, this is as a result of stop-and-go pattern of Buses during passenger pick-up, thus leading to PM concentrations accumulation resulting from the agglomeration of smaller emitted particles size. This support the idea that increases in traffic volume can result into increase in emitted particle concentrations.

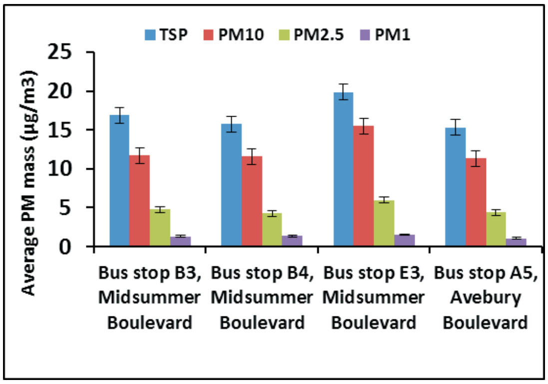

Fig. 3: PM Concentrations in Major Bus stops in Central Milton Keynes

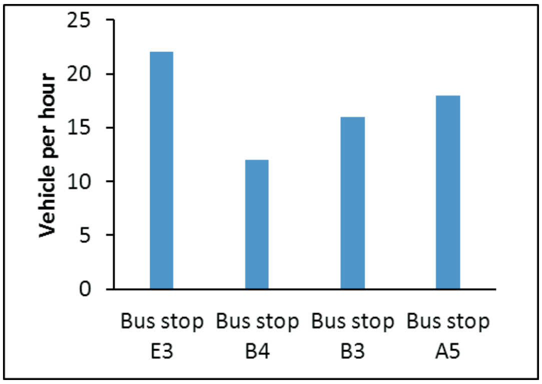

Fig. 4: Number of Buses that arrived during the PM concentration sampling in major Bus stops

Particulate matter concentrations with respect to distance from the roadside environment

PM concentrations was sampled with respect distance from the road side environment, this is done to understand the trends in PM from the source of emission. Figure 5 shows the result of PM concentration with respect to distance from the roadside environment. The results from this sampling showed that there were decreased in concentrations of PM_{10} as we sample further distance from the roadside environment.

The decrease in concentrations at each sampling interval showed an extreme significant difference statistically with respect to roadside mass concentration except for concentration at 5 m distance, which showed that there was no statistical significant difference with respect to roadside concentration having p-value of 0.5127. The decrease in average PM_{10} mass with respect to further distance from roadside may be due to decrease in the turbulence effects created by moving vehicles, and also as a result of increase rate of particle dilution from the emission point.

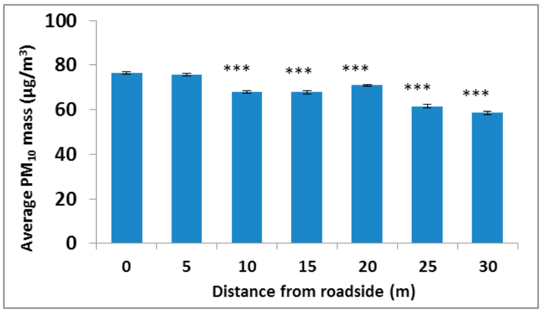

Fig. 5: *PM_{10} concentration (µg/m^3) with respect to distance from the roadside environments on Midsummer Boulevard, n= 90 (90 min sampling time at 1 min average measurement), ***P< 0.001when compared to 0 m from roadside Error bars represent standard error of means (SEMs).*

From figure 6, the concentration of $PM_{2.5}$ decreases with respect to further distance from roadside environment. The results showed that the concentration difference in all intervals with respect to roadside concentration is statistically significant, with p-values less than 0.05. The level of significant difference becomes extreme from distance 10 m sampling interval, having p-values less than 0.01 at each sampling interval. The decrease in mass concentration of $PM_{2.5}$ as we sampled further distance from emission source (traffic road side) is attributed to the short atmospheric resident time of $PM_{2.5}$ particle sizes. It is suggested that particle coagulation and dilution due to dispersion from point of emission can also cause decrease in concentrations from the emission source.

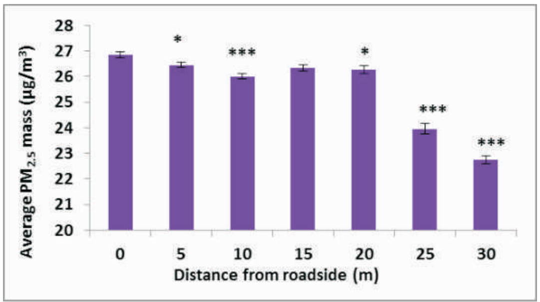

Fig. 6 : *$PM_{2.5}$ concentration (µg/m³) with respect to distance from the roadside environments on Midsummer Boulevard, n= 90 (90 min sampling time at 1 min average measurement). ***P< 0.001, *P< 0.05 when compared to o m distance Error bars represent standard error of means (SEMs).*

Conclusions and Recommendations

The results of $PM_{2.5}$ and PM_{10} concentrations sampling within Milton Keynes in United Kingdom showed that emissions from traffic sources is one of the major source of particulate pollution in the ambient air. The $PM_{2.5}$ and PM_{10} mass concentration measured at the near road side environment exceeded the background concentration measurements by a factor of 2 to 3.

The decrease in $PM_{2.5}$ and PM_{10} mass concentration with respect to further distance from roadside as observed from this research can be attributed to the increase in the rate of dilution of particle during particle dispersion; it could also depend on other meteorological factors such as wind speed, temperature and precipitation. Therefore it can be concluded from this study that the potential exposure to particulate pollution from traffic generated emissions depends on the road type, traffic volume, traffic speed and the distance of buildings from the road side environments.

The following recommendations was deduces based on the results from PM sampling campaign in this field work;

1. A setback distance of about 15 m from the road side environment is recommended for residential or building development, this will reduce the potential of exposure of human to traffic generated particulate matter emissions.
2. Particulate Matter indicative instruments should be deployed with other PM monitoring equipment to give a better understanding of emission source of the measured concentrations during the particle sampling procedure.
3. Particulate Matter sampling procedures should be done during the winter months to enhance the understanding of the seasonal influence on PM concentrations in the near road side environment.

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