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Impact of Vegetations in Urban Green Spaces for Automobile-discharged Particles Removal

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ABSTRACT

Urban forest is a term to represent the landscape and vegetation of a city and provide numerous benefits. One of the benefits is reducing city air pollution. Traffic-related pollutants are the most significant elements which contribute to the high airborne pollutant concentration. Various methods could be applied to alleviate the pollutant concentration in ambient air and one of the most efficient and environmentally method is by planting the vegetations in urban areas which are closely connected to the busy roads of a city. In fact, urban forest is the best particulate scavenger to reduce the level of air pollutant concentration to ameliorate the air quality of urban areas that will create a healthy living and pleasant community and natural ecosystem. This study attempts to view on the capabilities of urban forest in filtering the atmospheric environment by reducing the airborne particulates concentration. It provides an overview on the sources of the airborne pollutants, the consequences towards human health and living ecosystem and how to quantify the urban forest's ability in reducing the concentration of particulate matter through various scientific methodological ways.

Key words: Urban green spaces, traffic emission, airborne pollutants, particulate matter (PM_{10})

INTRODUCTION

Malaysia is one of the countries which have been affected by the air pollution mainly due to the human-induced activities as well as the natural disasters. In order to achieve the goal to be an industrial country by the year 2020, there are numerous industrial activities that tremendously developed to boost up the economic growth. Power plants are widely generated and developed throughout the cities in Malaysia. The development of economic growth in various aspects demand numbers of employee as it generates job vacancies. Due to this reason, residential population increases which resulting into the increase of transportation usage for both public and private transports (Saadatabadi and Bidokhti, 2011). As a consequence, environmental degradation occurred especially to the atmospheric condition as automobiles discharge various types of pollutants into the air (Okunola *et al*., 2011). Since the air pollution has become serious problem in Malaysia especially in urban areas, human health, crops, forest ecosystem as well as the other living things have also being affected.

Researchers have found that airborne pollutants may cause adverse effects on human health such as hypertension, stroke and mortality (Allen *et al*., 2009; Suruchi and Khanna, 2011). Afroz *et al*. (2003) stated that the total number of patients affected by respiratory diseases such

as asthma and bronchitis (Ainuddin and Chong, 2008) in Selangor has increase significantly during haze on September 1997. The major airborne pollutant that causes those diseases is PM_{10} which is well known as a respirable airborne particulate matter. PM_{10} is a very tiny dust which cannot be seen individually with the naked eyes. In Malaysia, studies on PM_{10} are very scarce as well as the precautions to remove the airborne particulate from the atmospheric environment. In order to control the particulate matter into satisfied level, standard policies or framework should be well-established as this problem is very complex. It encompasses the identification of pollutants sources, emissions, analytical methods and risk management (Wolterbeek, 2002) which these matters should be coordinated into specified control programme.

Air quality in urban areas is significantly being affected by traffic-related pollutants resulting from the increase use of transportation. The industrial stationary sources are another major source which contributes to this problem. The airborne pollutants emitted by these sources are contaminating the atmospheric environment along the street canyons due to the limited air exchanged within the canyons resulting from the isolation effect of the buildings on the air flow (Salim *et al*., 2009; Saadatabadi and Bidokhti, 2011). This situation creates a greater impact on human health and other living ecosystem as the pollutants' concentration exceeds environmental guideline values. Moreover, the air pollutants are dispersed within the human ambient exposure which is approximately 2 m above ground (Cavanagh *et al*., 2009). Hence, vegetations should be planted along the roads and boulevard to mitigate the contaminated ambient air. Salim *et al*. (2009) stated that urban forest creates less ventilation, reduced dispersion of particulate matter and increase blockage on the restricted air flow. In addition, some plants are able to survive in extreme environment especially in polluted areas (Ainuddin and Najwa, 2009).

This study presents a brief review on the functional character of urban forest in filtering the atmospheric environment by reducing the airborne particulates level. It provides an overview on the sources of the airborne pollutants, the consequences towards human health and living ecosystem and methods to quantify the urban forest's ability in reducing the concentration of particulate matter.

ROLES OF URBAN FOREST

Urban forest consists of multiple species of vegetation which are intentionally planted or naturally grown within the urban areas. It contains a diverse mix of plant species which are arranged in heterogeneous or homogenous patterns (McPherson *et al*., 1997). The urban forest plays multiple roles both in human and ecosystem services (Wolf, 2006). Urban forest helps in maintaining the oxygen releases through photosynthesis and absorbing carbon dioxide through carbon sequestration which are improving the air quality of the urban areas (Johnson and Gerhold, 2001; Yang *et al*., 2005; McPherson and Simpson, 1999). The trees cool down the cities by shading and evapotranspiration as well as reducing the urban heat island intensity (Yang *et al*., 2005). Nowak (2000) and Sanusi *et al*. (2011) found that the trees canopy and transpiration process may alleviate the temperature of a city besides of controlling the wind speed, relative humidity and heat storage efficiently. Wolf (2006) stated that the air conditioner is one of the contributors towards global warming due to the increasing of CFC harmful gaseous in the atmosphere. In order to mitigate this problem, urban forest strategy and implementation should be planned accordingly.

The plantation of trees in the urban areas in Malaysia has been practiced since century ago. It begins with the aim of landscaping purposes only (Sreetheran *et al*., 2006). However, due to the

vast development of urban environment in Malaysia, urban forest is properly managed and developed to achieve an amenity forest landscape for the city (Justice, 1986). Besides for greening purpose, the roles of the trees have been widely studied by the scientists worldwide as the trees are able to act as ground covers, beautification, shading and slope covers (Givoni, 1991). The trees' advantages are not limited into ecosystem services as human are also gaining various benefits from the urban forest. Human will gain better lifestyle without physical and physiological stress due to noise problem as leaves, stems and branches of trees will absorb, reflect and refract the high frequency of sound (Wolf, 2006; Givoni, 1991). Urban forest provides green open spaces such as children playground, recreational sites and sports area that act as an isolation for human to escape from the stress of urban life (Givoni, 1991). Urban forest also consists of plants which are having therapeutic constituents. Farnsworth (1990) found that people live in urban areas depend on traditional medicine for their health care needs where the main source of the drug therapy is originated from the higher plants which are easily can be found in urban environment.

In Malaysia, urban forest concept is being applied throughout the cities according to the standard which is being developed in Kuala Lumpur, the National Capital of Malaysia (Justice, 1986). The concept is stressed on providing quality environment and comforts that suit best to the residents. Furthermore, the concept of urban forest in Malaysia encompasses a less-tailored plants which can be naturally acting and require minimum care. Common vegetations species that have been planted in the urban cities of Malaysia consist of the Angsana (*Pterocarpus indicus*), Bungor (*Lagerstroemia speciosa*), Bunga Tanjung (*Mimusops elengi*), Penaga lilin (*Mesua ferrea*), Rain tree (*Samanea saman*) (Sreetheran *et al*., 2006; Justice, 1986) and Red Flame (*Poinciana regia*). Greenery programme planned by Malaysia has been successfully established with the mission of "No Roads Without Trees". This effort should be accomplished timeless in order to maintain the green environment as the trees have lots of benefits especially in purifying the polluted atmospheric environment.

SOURCES AND IMPACTS OF AIR POLLUTION

The issue of the occurrence of air pollution has become an attention worldwide. Poor urban air quality is severe in Asian region where some countries have intense of population growth (high birthrates) that leads in to the increase of industrial activities and motor vehicle usage (Hopke *et al*., 2008; Mayer, 1999). Malaysia is one of the countries which has been affected by the environmental degradation. The transformation experienced by Malaysia from raw materials producer into multisector economy (ADB, 2006) has created problems to the ambient air. Generally, ambient air consists of all solid and liquid particles that varying in sizes (Givoni, 1991) including the coarse, fine and ultrafine particles. These particles have different kind of composition and origin. Common particulates are known as PM_{10} and $PM_{2.5}$ which give harmful effects towards human health and ecosystem as well (GreenFacts, 2005). Pooley and Mille (1999) categorized the airborne particulates into two which are inhalable particles and respirable particles. Inhalable particles are particles which capable to penetrate the respiratory system during breathing while the respirable particles are those particles which are able to penetrate through the alveolar of lung system. Both are extremely hazardous to the health due to the materials they contain especially in PM_{10} (particles with an aerodynamic diameter of less than 10 μm). Most of the materials it contains are potential carcinogens (Pooley and Mille, 1999).

The presence of airborne pollutants is due to the anthropogenic sources, industrial activities and the effects of natural activities such as volcanoes eruption. These sources emit both primary

(directly into the air) and secondary pollutants (formed by chemical reactions within the atmosphere) into the atmosphere (Pooley and Mille, 1999). However, according to Mayer (1999), Pooley and Mille (1999) and ADB (2006) most of the airborne particulates are emitted from the combustion of engines from vehicles contributing of at least 70-75% of the total air pollution. This happened due to the increase of the number of registered road vehicles every year which then become a dominant source of urban air pollution (Brimblecombe, 1999; D'Angiola *et al*., 2010). The emission contains carbon monoxide (CO), sulphur dioxide (SO_2), Total Suspended Particulates (TSP), Nitrogen Oxides (NO_X) and Volatile Organic Compound (VOC) (Mayer, 1999; Percy and Ferretti, 2004) as well as the particulates matter (ADB, 2006) which are released through combustion, fluid leakage, component wear and corrosion metals (Okunola *et al*., 2008).

The increase of air pollutants in atmosphere can be due to the increase of temperature. According to Roberts (2004), there is an interaction between meteorological condition and air pollution phenomenon where high temperature stimulates the level of airborne particulates concentration. Another finding is that during hot days, particulates matter has largest effect on mortality with the aid of physiological stress that alters the person's response towards toxic matter.

Urban air pollution has been seen as a potential source of health problems since the earliest times and has been addressed in numerous studies (Brimblecombe, 1999; Moundzeo *et al*., 2011). Various studies have shown that affected lung with PM_{10} and other microscopic particles will cause chronic asthma, acute respiratory illness and cardiopulmonary diseases (ADB, 2006; Aditama, 2000; Ackplakorn *et al*., 2004; Agarwal *et al*., 2006). The life expectancy could also be reduced in the long-term exposure especially to the elderly and children (GreenFacts, 2005; Cui *et al*., 2003; Dai *et al*., 2004). In addition, the epidemiological studies have shown that a rise of 10 μg m^{-3} of PM_{10} could increase mortality case up to 1% (Steward *et al*., 2005). As a whole, air pollution is an episode that causes disruption in a daily living, physical discomfort, illness and reduce life expectancy.

POLLUTANTS REMOVAL BY THE URBAN FOREST

Several studies have shown that there are various ways and technologies applied in removing the airborne pollutants by using the trees. Trees are the effective scavengers in ameliorating the pollutants concentration in atmosphere. Therefore, the trees planting scheme in a city would be the most effective way in achieving the objective of improving the air quality. Even though most of the researchers could not find the exact amount of pollutants concentration removed by the trees, the estimation gained by them is simply enough to conclude that the trees in urban areas are significant tools in removing the air pollutants in atmosphere (Sarma, 2011).

Steward *et al*. (2005) measured a rate of pollutants deposition on woodland, grassland and other short vegetation in the West Midlands conurbation for 50 years. The pollutants present as a naturally occurring radioactive compounds in the soil and atmosphere. These researchers examined the effects of trees on the deposition rate of the pollutants. They found that woodland captures pollutants three times higher than the grassland as woodland had greater leaf surface area and the trees which were located at the edge of woodland were exposed to the wind and heavy traffic. Airborne particulates can also be removed by sequestering process. Gratani and Varone (2007) determined the amelioration capability of trees towards CO_2 concentration by measuring the photosynthetic activities of the plants as well as the plant structures. These traits were being correlated with the traffic density and atmospheric CO_2 concentration at the study sites to determine whether the relation was significant or not. As a result, they found that *Platanus hybrida* Brot. which was largely distributed in the city of Rome was capable in sequestering CO_2 emitted by the

heavy traffic of about 117±13 kg year^{-1}. They recommended that the plants traits were very important to be considered in urban tree planting programme in relation to the amelioration of airborne pollutants.

The deposition of airborne pollutants onto the trees can be occurred in two ways which are wet deposition and dry deposition. Wet deposition is a removal of pollutants by precipitation while the dry deposition is due to the gravity, impaction and diffusion which depend on the particle size. McDonald *et al.* (2007) conducted a study on the effect of urban tree planting on concentration and deposition of PM_{10} in two UK conurbations by determining which way of deposition occurred through modelling. To develop the modelling framework, these researchers applied the fine resolution atmospheric multi-pollutant exchange (FRAME) atmospheric transport model. This model was used to calculate wet and dry deposition with the use of statistical meteorology. Dry deposition rates were higher for larger particles as the particles will deposit faster especially onto the trees compared to the short vegetations. They found that dry deposition of PM_{10} in urban areas (West Midlands) was higher than the moor/grassland due to the emission of PM_{10} from road transport. Hence, the model showed that trees in that area were able to remove 39 tons of primary PM_{10} from the atmosphere. The model was also predicting that by applying a maximum planting potential (FPP_{100}) in West Midlands from 3.7 to 16.5%, the PM_{10} concentration will be reduced by 10% from 2.3 to 2.1 μg m^{-3} removing of about 110 tons of primary PM_{10} per year from the atmosphere (the behaviour and spatial distribution of primary PM_{10} were assumed to be similar with the secondary PM_{10} due to the insufficiently advanced model used).

Airborne particulates can be removed through the accumulation of particulates onto leaf surface. Trees leaf has the capability in capturing the particulates very effectively. Various studies have been carried out on the removal of particulates in atmosphere by using trees leaves. For example, Freer-Smith *et al.* (1997) conducted a study on the uptake of particulates by the oak leaves in urban woodland (Rough Wood). The objectives of their study were to measure and identify the accumulated particulates, determine the frequency distribution of different particulates sizes as well as to determine the composition and sources of particulates by an elemental analysis. Twenty leaves were collected from the lower branch of six trees which closed to a motorway. The leaves were washed with 100 mL istilled water for 3 min, vacuum filtered through pre-weighed filter papers (0.45 μm) while the water soluble ammonium sulphate and nitrates remain dissolved in the water after the filtration. The remaining 10 leaves were washed with chloroform for ten seconds and passed through PTFE filters of 0.2 μm of pore size. By using scanning electron microscope (SEM), the researchers found that the oak leaf had hairy surface which enabled it to capture more particulates from the atmosphere. They also found that there was significant correlation between distance from motorway and total number of particles ($r = 0.702$ and $r = 0.709$, respectively). Number of particles accumulated on the leaf surface was greater as the leaves were close to the motorway. The most elements present were aluminium, silicon and iron which were assumed to be derived from pulverized coal fuel from the power station while sodium and chlorine were possibly resulted from the sea salt.

Urban forest encompasses wide ranges of vegetation species being planted. However, due to some reasons, trees are likely to be more effective in capturing pollutants compared to small vegetations. Each species of trees has its own capability in reducing the airborne particulates. The relative effectiveness of these contrasting species of trees in particulates uptake has been quantified by Beckett *et al.* (2000). They conducted a study on capturing the particulate pollution by urban trees through an exposure of five trees species, pine (*Pinus nigra* var. *maritime*), cypress

(X *Cupressocyparis leylandii*), maple (*Acer campestre*), whitebeem (*Sorbus intermedia*), poplar (*Populus deltoides* X *trichocarpa* Beaupré) to NaCl droplets (1 μm diameter) at a range of wind speed in two wind tunnels. They measured the deposition velocity (Vg) and particle trapping efficiency (Cp) as well as determining the trees morphology. As a result, they found that the finer and complex structure of foliage (*P. nigra* and *C. leylandii*), the more increase on effectiveness of the conifers' ability in capturing particles. The significant complex structures of trees were broadleaved, coarse and hairy leaves. Greater deposition of particles on trees was aided by the turbulent of air flows. This was supported by the natural mechanism of leaf's boundary layer that helped the particulates to drop off onto the leaf by the inertia forces.

CONCLUSION

The establishment of urban green in a vast development of a city to achieve modernization often being overlooked by the responsible authorities. Hence, it is of utmost important to construct a framework of greening programme in urban areas in respect to the protection of environment. Various aspects need to be considered upon planting trees programme in urban areas. In order to achieve the aim of ameliorating the traffic-pollutants in urban atmosphere, diverse species of plants are recommended to be planted in urban cities. This is because, every species has its own capability in capturing the airborne particulates at different rates. However, morphological characteristics of trees like having a hairy, broad and rough leaf surface would be the most effective trees to act as a sink in removing the pollutants (Ade-Ademilua and Obalola, 2008; Tuteja *et al*., 2011). Trees with large surface areas provided by dense canopy will give an advantage in removing large amount of particulates matter in the atmosphere. In certain circumstances, there are trees which are intolerant with the airborne pollutants. Therefore, it is required for the urban planners to equip themselves with knowledge and related-beneficial information regarding to the election of pollutant-tolerant species.

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