Environmental Pollution 195 (2014) 73–83

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

The impact of an urban park on air pollution and noise levels in the Mediterranean city of Tel-Aviv, Israel

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ARTICLE INFO

Article history:
Received 29 June 2014
Received in revised form
5 August 2014
Accepted 13 August 2014
Available online 6 September 2014

Keywords:
Urban vegetation
Air pollution
Noise attenuation
AQI
PM_{10}

ABSTRACT

This study examines the influence of urban parks on air quality and noise in the city of Tel-Aviv, Israel, by investigation of an urban park, an urban square and a street canyon. Simultaneous monitoring of several air pollutants and noise levels were conducted. The results showed that urban parks can reduce NO_x, CO and PM_{10} and increase O_3 concentrations and that park's mitigation effect is greater at higher NO_x and PM_{10} levels. During extreme events, mean values of 413ppb NO_x and 80 μG/m^3 PM_{10} were measured in the street while mean values of 89ppb NO_x and 24 μG/m^3 PM_{10} were measured in the park. Whereas summer highest O_3 values of 84ppb were measured in the street, 94ppb were measured in the park. The benefit of the urban park in reducing NO_x and PM_{10} concentrations is more significant than the disadvantage of increased O_3 levels. Furthermore, urban parks can reduce noise by ~5 dB(A).

1. Introduction

The accelerated urbanization of modern cities creates environmental nuisances in the urban environment (Evance, 1983; Lam et al., 2005) aggravates microclimate and thermal discomfort, deteriorates air quality and increases noise levels. These nuisances are a direct result of intensive transportation, construction, industry and cultural activity and critically influence the health and well-being of the cities' inhabitants (Grimm et al., 2008; Paoletti et al., 2011).

Urban greenery has been recognized as an effective tool for microclimate improvement, air purification and noise attenuation (Givoni, 1991; Blound and Hunhammer, 1999; Chiesura, 2004). Urban parks' cooling effect can reach up to 4 °C in Mediterranean climate (Zoulia et al., 2009; Cohen and Potchter, 2012). The urban parks cooling effect can affect the micro built-up environment up to few hundred meters from the park's edge (Saito et al., 1991; Potchter et al., 1999).

It appears that many studies have investigated the environmental effect of urban parks but focused on one type of nuisance, while only a few investigated air pollution and noise nuisances simultaneously in specific urban sites and their effect on human beings. Since people in urban open spaces are concurrently exposed to several environmental nuisances, examining the impact of urban vegetation on air and noise pollution is of high importance (Cohen et al., 2014).

1.1. The effect of green spaces on air quality

Previous studies have demonstrated that urban vegetation can mitigate urban air pollution and improve local air quality (Freiman et al., 2006; Nowak et al., 2000, 2006; McDonald et al., 2007; Bealey et al., 2007). Many studies that demonstrated the effect of urban vegetation on air pollution were based on models or estimations (Beckett et al., 2000; Powe and Willis, 2004; Donovan et al., 2005; Yang et al., 2005; Nowak et al., 2006; McDonald et al., 2007; Amorim et al., 2013). Later studies claimed that the attenuation effect of urban parks on air pollution levels requires more systematic and quantitative examination (Cavanagh et al., 2009; Yin et al., 2011).

Studies based on direct air pollution measurements in built-up urban areas and urban parks simultaneously, indicated lower concentrations of pollutants within the parks in comparison to the adjacent street canyons (Kuttler and Strassburger, 1999; Lam et al., 2005; Yin et al., 2007, 2011; Cavanagh et al., 2009; Cohen and Potchter, 2012). Studies also indicated an increase in Ozone

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http://dx.doi.org/10.1016/j.envpol.2014.08.015
0269-7491/

concentration in urban green areas during the summer in comparison to its values in the nearby built area (Kuttler and Strassburger, 1999). However, there is a dearth of systematic investigation of the seasonal and environmental impact of urban vegetation on several air pollutants simultaneously in order to evaluate the benefit of urban vegetation as a tool for air quality improvement.

1.2. The effect of green spaces on noise

Studies have also examined the effect of urban vegetation on reducing noise levels in the urban environment (Fang and Ling, 2003, 2005; Papafotiou et al., 2004; Lam et al., 2005; Bucur, 2006; Maleki and Hosseini, 2011; Pathak et al., 2011). These studies demonstrated that noise level attenuation can range between 6 and 27 dB(A). The attenuation depends on the noise level at source, distances from source and on vegetation features. Bucur (2006) concluded that planting a combination of trees and shrubs at a high density can cause an efficient reduction of noise levels within the urban tissue. Nevertheless, the existing literature has paid inadequate attention to the seasonal and environmental impact of urban vegetation on noise levels.

The present study investigates the impact of urban parks on several air pollutants and noise levels in the Mediterranean city of Tel-Aviv, Israel. Since the lifestyle of Mediterranean cities is characterized by human activity in urban open spaces and urban parks throughout the year, the seasonal and diurnal impact of urban parks on air quality and noise level is of growing interest.

A better understanding of the effect of urban parks on noise attenuation and air quality can assist urban planners, landscape architects and park designers to transform cities into more pleasant environments (De Ridder et al., 2004; Lam et al., 2005; Feliciano et al., 2006; Schnell et al., 2012; Cohen at al., 2014).

The aims of this study are: (a) to examine the impact of urban parks on different air pollutant concentrations and on noise levels during summer and winter in a Mediterranean city and (b) to systematically analyze air pollution and noise levels in the urban park in comparison to non-vegetated urban open spaces using verified air quality and noise indices.

2. Methodology

2.1. Study area

The study was conducted in the city of Tel-Aviv, Israel, located at 32°06′N 34°47′E, situated along the east coast of the Mediterranean Sea. The climate of Tel-Aviv is defined as Subtropical Mediterranean (Potchter and Saaroni, 1998), characterized by two main seasons: a mild, wet winter with frequent stable weather episodes and a hot, humid, summer with high sun radiation values (Bitan and Rubin, 1994).

Tel-Aviv has 414,600 inhabitants and is the core of the largest metropolis of Israel, with a population of 3.46 million (Statistical Abstract of Israel, 2013). Tel-Aviv is a modern city that has experienced accelerating growth over the last 100 years and exhibits the typical activity which characterizes any modern metropolis.

Studies have shown the existence of an Urban Heat Island during the summer and the winter (Bitan et al., 1992; Saaroni et al., 2000) and high concentrations of air pollution and noise due to intensive transportation and energy consumption (Sharan et al. 1994–96, Zukerman, 2006).

2.2. Study time

The study was conducted over the course of one winter and one summer. A preliminary test case was conducted between June 22 and 23, 2006. The winter measuring campaign took place from January 20–23, 2009. The month of January is considered one of the coldest months of the year, with solar radiation at its lowest.

The measurements were conducted under stable weather conditions, low wind velocity (0–1.6 m/sec), with short episodes of unstable conditions characterized by an eastern wind accompanied by dust flow. The summer measuring campaign took place from June 27–30, 2010. Climate conditions were generally stable during this period, characterized by hot temperatures, clear skies, western and north-western winds at moderate velocity (0–1.9 m/sec) and sun radiation at its peak.

2.3. Classification of research units

In order to examine the impact of urban parks on air pollution concentration and noise levels, three representative types of urban open spaces were selected: an urban park, an urban square and a street canyon. All the investigation sites were located in the same urban tissue in order to prevent local diversity and in the same distance from the sea to enable similar micro-climate conditions (Fig 1):

Meir Park – a medium sized urban park (28,000 m^2), containing mature trees, bushes and lawn, with 85% tree coverage, surrounded by a high density built-up area. This is one of the most mature parks in the city center and has been constantly used for bio-climatological, noise and air pollution studies. The monitoring station was situated under a mature evergreen Ficus microcarpa tree-lined avenue, ~60 m from the eastern main road and ~55 from the western side road.

Rabin Square – a paved urban square (20,000 m^2) mostly wide-open, surrounded by a high density built-up area. The monitoring station was situated at the center of the square ~60 m from the eastern main road and ~45 m from the western side road.

King George Street – a north-south street canyon with four-story buildings on both sides (H/W = 0.8) adjacent to Meir Park. The station was situated on the eastern sidewalk.

Ibn Gavirol Street – a wide north–south street canyon with four-six storey buildings (H/W = 0.6) adjacent to Rabin Square. The station was situated on the eastern sidewalk.

Meir Park and its vicinity are located in the core of the city, were the peak of the urban heat island was observed (Saaroni et al., 2000) and at one of the most pollutant areas in the metropolis (Sharan et al., 1994–1996). The street canyons sites are parallel to the open spaces, at similar orientation (eastern to the open space, down the wind direction) and are dense traffic roads (as an air and noise traffic-related source).

3. Experimental set-up

The study included two stages: (a) In-situ measurements by simultaneous measurements of climatic variables, air pollution and noise levels that were conducted at the investigated sites on 4 consequent days in the winter and summer season (b) statistical data analysis and data indexing.

3.1. In-situ measurements

Air pollution was monitored as follows: Nitrogen oxide (NO_x) was monitored by 42C NO–NO_2–NO_x Monitor Labs 9841A, Ozone (O_3) was monitored by TEi-49C and particulate matters (PM_{10}) were monitored by TEOM1400AB and Carbon monoxide (CO) was monitored by Drager-PacIII sensors. Data was collected consecutively and stored in data loggers.

Noise levels were recorded with a Quest-pro-DL dosimeter ranging from 40 to 110_{dB}, with a resolution of 0.1_{dB}, measured as 1-