



Effect of green roof on ambient CO₂ concentration

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ARTICLE INFO

Article history:

Received 26 January 2010

Received in revised form

24 May 2010

Accepted 24 May 2010

Keywords:

Green roof

Air quality

CO₂ absorption velocity

Numerical simulation

Field measurement

Chamber experiment

ABSTRACT

Plants can improve air quality by removing pollutants. The air purification capability of plants has been receiving increasing attention because of the rapid deterioration of the environment. However, research on evaluating quantitatively the effect of plants on the environmental pollutant concentrations is still scarce. This paper studies the effect of a green roof on the ambient CO₂ concentration as an example to assess the benefit of urban greening. The study comprises three parts: (1) Field measurement of the difference of CO₂ concentration at a location in the middle of the plants in a small plot of green roof and one in the surrounding area, (2) Experiments to measure the plant's CO₂ absorption velocity and emission rate using a sealed glass chamber; and (3) Computer simulation of the CO₂ concentration distribution around a green roof using the measured CO₂ absorption velocity and emission rate to quantify the effects of the green roof on the ambient CO₂ concentration.

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1. Introduction

Vegetation can be in the forms of trees, shrubs and grasses and it takes up a certain proportion of land areas in cities and is an important part of the cities. It has been increasingly popular to use roofs of buildings for growing plants, not only because of aesthetic reasons, but also for improving the environment. Plants can reduce the heat reaching on buildings by increasing the reflection of radiation and shading. They also take the heat away through the process of transpiration. This results in a reduction of indoor and outdoor temperatures [1,12–14]. Plants can improve urban air quality by removing air pollutants and trapping of particulates in their leaves [1–11]. As air pollution is now a major environmental problem in many cities, the air purification capability of urban vegetation has been receiving increasing attention.

A lot of studies have been carried out to evaluate the air purification capability of urban vegetation and it is found that urban plants can improve air quality noticeably. Nowak et al. [4] estimated the total annual air pollutant (O₃, PM₁₀, NO₂, SO₂, CO) removal by US urban trees at 711,000 metric tons (\$3.8 billion value). Yang et al. [3] quantified the level of air pollution removal by green roofs in Chicago using a dry deposition model. Their result, based on the

local weather and plants conditions and air pollutants concentrations, showed that a total of 1675 kg of air pollutants was removed by 19.8 ha of green roofs in one year. Gratani et al. [2] compared the difference between the CO₂ concentrations on the road side and inside a park in Rome and calculated the amount of CO₂ absorbed by the trees at the two sites. They concluded that trees had an important effect on the difference of CO₂ concentrations between the two sites.

However, most investigations focused on estimating the amount of air pollutants removed by urban plants [3–8] and studies on the quantification of the effects of pollutant removal on ambient air pollutants concentration are still scarce. This paper uses a green roof as an example to quantify its effect on the ambient CO₂ concentration. The study comprises three parts: (1) Field measurement of CO₂ concentration at a location in the middle of the plants and 2 m away from vegetation, (2) Experiments of measuring plant's CO₂ absorption velocity and emission rate using a sealed glass chamber, and (3) Computer simulation of CO₂ concentration distribution around a green roof using the measured CO₂ absorption velocity and emission rate to quantify the effects of green roof on the ambient CO₂ concentration.

2. Field measurement

The field measurement was carried out to evaluate the difference of CO₂ concentrations at two locations: one was at the middle

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of the plants in a small plot of green roof and the other was in the surrounding area 2 m away from the plants. The purpose was to investigate the effect of green roof on the surrounding CO₂ concentration.

2.1. Measurement site and methods

Hong Kong is under subtropical monsoon climate with a mean air temperature of 27.5 °C in summer. The measurements were carried out on the rooftop of a six-storey building in Hong Kong (Fig. 1). There are four small plots, each with an area of 4 m × 4 m for growing plants. Besides the plants there are no other sinks or sources of CO₂ on and around the roof. The background of Fig. 1 is facing south. Sunshine can irradiate on the plants directly from about 7:30 to 16:00. And after 16:00 sunshine could not directly reach the plants because of the shading of nearby buildings. The CO₂ concentrations at the two locations P1 and P2 indicated in Fig. 1 were measured by a CO₂/H₂O analyzer LI-7500 in the sunny days of July and August 2009. The LI-7500 measures the concentrations of CO₂ and vapor. The analyzer consists of a control box and a sensor head. The control box is connected to a computer for real-time measurement. The accuracy of the LI7500 can reach 1 mg/m³ for CO₂ concentration measurement. P1 was located in the middle of the plants in one of the plots and P2 was 2 m away from the plot[3]. The sequence of measurement with the same sensor is as follows. First the CO₂ concentration at P1 was measured for about five to ten minutes and followed immediately by the measurement at P2. The measurement sequence was repeated throughout the day. The sampling rate of CO₂ concentration was 1 Hz.

2.2. Measurement results

The CO₂ concentration fluctuates throughout a day, with an average value of about 700 mg/m³. Fig. 2 shows the CO₂ concentration variations at P1 and P2 in a representative sunny day with some clouds and atmospheric wind of wind force 2 (wind speed of 1.6–3.3 m/s). Every point on the curves is the 10-min average value.

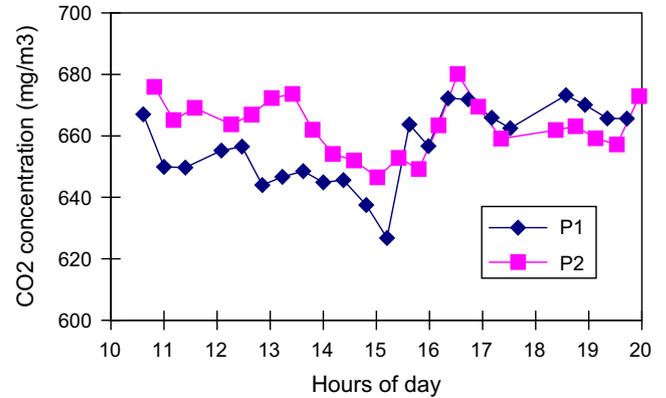


Fig. 2. CO₂ concentration curves at P1 and P2 obtained between 10:30 and 20:00 on 22 July 2009.

The differences in CO₂ between the two curves are obvious. The average CO₂ concentration at P1 was 12.9 mg/m³ lower than that at P2 before 16:00, while the average CO₂ concentration at P1 was 4.9 mg/m³ higher than that at P2 after 17:00. Fig. 3 shows the curves of CO₂ concentrations at P1 and P2 in a sunny day with modest strong wind of wind force 4 (wind speed of 5.5–7.9 m/s) in the daytime. The wind became weak in the evening. Every point on the curves is a 5-min average value. The average CO₂ concentration at P1 was only 4.3 mg/m³ which was lower than that at P2 before 16:00.

Fig. 2 shows a representative situation in a sunny day with light wind. When sunshine reaches the plants directly in the daytime, the CO₂ concentration at P1 is lower than that at P2. On the contrary, CO₂ concentration at P1 is slightly higher than that at P2 during the night time. Plants absorb CO₂ from the atmosphere for photosynthesis and release CO₂ to the atmosphere during respiration. The rate of photosynthesis is greatly dependent on the intensity of light. In the daytime with abundant of sunlight, photosynthesis is very active and plants act as a sink of CO₂,



Fig. 1. Setup of field measurement.

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