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Vertical gardens as swamp coolers

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Abstract

This paper explores the potential of a vertical garden to function as a swamp cooler, passing an airflow through the substrate, in much the same way as in a direct evaporative cooler. The 2011 ASHRAE handbook [1] provides guidance on the use of evaporative coolers. They are presented as a low energy contender for air conditioning systems in hot, dry climates. The most basic and direct evaporative coolers (a.k.a. swamp coolers) work by converting sensible heat in the air into latent heat, by passing air through a saturated pad (i.e. the energy required to evaporate water into the air). The concept presented here is that a vertical garden can act as a swamp cooler. This concept is based on the research by Davis & Ramirez [2] on vertical gardens. Davis & Ramirez [2] found that a vertical garden had the potential to act as a swamp cooler. However, there were complications in quantifying the effectiveness of the cooling, due to a suspected pre-heating of the incoming airflow because of glass fronting to the vertical garden. This paper sets out to build on Davis & Ramirez's work, where the experiment is replicated without the glass fronting and where improved measurements of temperatures and relative humidity levels are taken. Thus, a more reliable efficiency is determined for a vertical garden as a swamp cooler.

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Keywords: Sustainable energy; Vertical gardens; Direct evaporative cooling; Swamp cooler; Substrate

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1. Introduction

Cities all over the world are growing, leading to an increase in the phenomenon known as the urban heat island effect, whilst at the same time urban vegetation is in decline [3]. Urban vegetation has many benefits, including air purification [4], a reduction in stress levels [5], increased productivity and a heightened sense of well-being [6]. Santamouris [7] tells us the heat increase in urban areas can be up to 15ºC when compared to non-urbanized surroundings. He adds how this will often be coupled with an increase in electricity demand for cooling the interiors of urban buildings to comfortable temperatures. For every degree of temperature increase in peak cooling hours there is a subsequent increase in electricity used by the HVAC system [7]. Urban vegetation can mitigate this however, by reducing the heat transfer between a building and its surrounding environment, in addition to providing solar shading that absorbs radiation from the sun [8].

Nomenclature

b	= breadth gap behind the substrate [m]
ε	= effectiveness of the cooler [-]
T_{db}	= temperature of the incoming air before passing through the pad or vertical garden substrate [°C]
T_{cooled}	= Temperature of the outgoing air after passing through the pad or vertical garden substrate [°C]
T_{wb}	= wet bulb temperature of the air [°C]
RH_{db}	= Relative humidity of the incoming air before passing through the vertical garden substrate [%]
V	= air velocity at the inlet [m/s]
w	= width of vertical garden [m]

1.1. Vertical gardens as passive air conditioning systems

The use of vertical greenery as a cooling system for buildings is a fairly new area of research [9]. Overall it has been shown that the building's energy consumption dedicated to cooling is reduced with vertical greenery being incorporated into the building envelope, due to the cooling effects of evapotranspiration and solar shading [10]. Ottelé [11] shows how a dense vertical layer of greenery on the building façade acts as an insulator, due to a stagnant layer of air forming between the foliage and the façade. Additionally he shows how plant leaves retain water on their surfaces longer than most building materials, providing an additional thermal buffer. This is then taken a step further by Stec [12], where he studies the use of plants as bioshading systems in double skin facades. He shows how the plants' latent heat contribution greatly reduces the sensible heat gains the building would otherwise receive.

Perez et al. [13] go on to summarize four manners in which vertical gardens act as passive cooling systems.

- Shadow produced by the vegetation.
- Protection against solar radiation provided by the vegetation and substrate.
- Evaporative cooling by evapotranspiration.
- A reduction in heat losses related to wind acting on the building, due to the protective barrier of the vertical garden.

1.2. Vertical gardens as evaporative coolers

An active vertical garden is defined for this research as a vertical garden that is connected to a building´s mechanical air conditioning system in order to act as an evaporative cooler.

In the 1980's Wolverton [4] put forward the possibility of connecting pot plants to an activated carbon filter and ventilation system for air purification in urban households. This was further investigated by Wood [14] and