URBAN REHABILITATION AT THE MUNICIPALITY OF ACHARNES, GREECE

Niki Gaitani *[1], Mat Santamouris[1], Ioannis Pappas[2], Costas Cartalis[1], Fotini Xyrafi[3], Elena Mastrapostoli[1], Panagiota Karahaliou[1], Chrysanthi Efthymiou[1]

1 National & Kapodistrian University of Athens, Faculty of Physics, Building of Physics-5, University Campus, 157 84, Athens, Greece
**Corresponding author: ngaitani@phys.uoa.gr*

2 Green- evolution, 501 Vouliagmenis Avenue, 163 41, Ilioupolis, Athens, Greece

3 ALD, Dinokratous 103, Athens, Greece

ABSTRACT

The raise of sustainability in the urban design is a key-factor for addressing the challenges in response to climate change, resource availability, environmental degradation and energy consumption. Urban planners need comprehensive microclimatic information in order to take decisions. This paper addresses the rehabilitation at the municipality of Acharnes, one of the largest municipalities of Attica, built at the southern foothills of Mt Parnitha, and 10 km north of Athens. The reintegration approach included field measurements of the thermal characteristics in the examined area. The data collected from the field measurements were analyzed according to the bioclimatic design targets of the area. The results contribute to the improvement of thermal comfort conditions and to the quality of life in municipal open spaces.

KEYWORDS

Urban design, Cool materials, Thermal Comfort

1 INTRODUCTION

The Mediterranean area has been the subject of several research studies in terms of climatic variations. The Attica basin is characterized by significant climate change as the ambient temperature has risen and the frequency of heat waves has increased (Cartalis, 2001, Santamouris, 2001). A climatic conscious design of outdoor spaces and the appropriate use of bioclimatic components are key elements to reduce the outcome of unsound development of urban areas where impermeable surfaces and denuded landscapes determine undesirable climatic effects and unhealthy environments (Gaitani, Santamouris, 2007). Various mitigation techniques have been proposed involving the use of highly reflective materials, increased plantation and the use of cool sinks large applications with cool pavements have been applied and evaluated with promising results (Akbari, 1992; Santamouris, 2007, Fintikakis,2011).

The present paper addresses the rehabilitation at the municipality of Acharnes. The main contribution of the present study is the development of an integrated approach towards the bioclimatic design of open spaces in the urban environment that ensure thermal comfort conditions at pedestrian level. A concise description of the procedure presented herein is formulated as follows: Initially, the existing microclimatic conditions are measured. Thermal comfort conditions of pedestrians are computed by implementing special thermal comfort indices.

2 FIELD SURVEY

A field survey was carried out with measurements (April-May, 2013), in three urban areas in the Municipality of Acharnes, Greece. As concerns the weather conditions, a temperate Mediterranean climate dominates, which corresponds to hot and dry summers and cool, humid winters.

2.1 Area of interest

Acharnes, is the most populous municipality in East Attica as according to the 2011 census, has a population of 107,500 inhabitants. The municipality is located about 10 km due north of Athens. (http://www .acharnes.gr/el). The regeneration approach included field measurements of the thermal characteristics in three urban areas in the centre of the municipality. The three areas under rehabilitation are shown in Fig. 1.

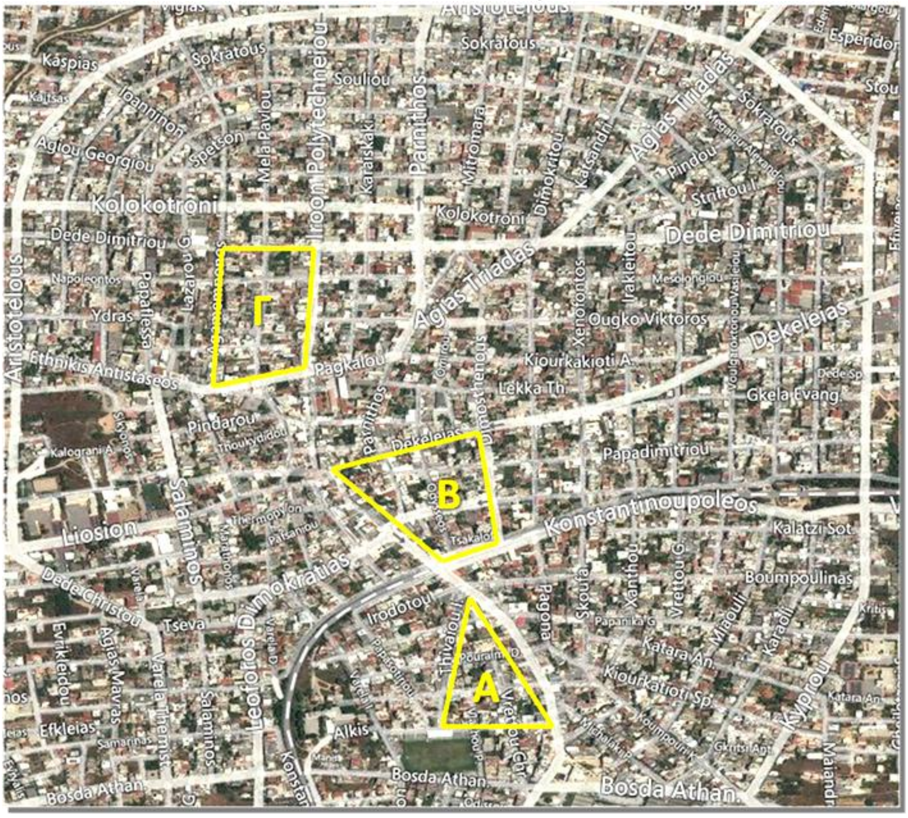


Figure 1: Survey area in GOOGLE EARTH

Local authorities have decided to regenerate the area using sustainable bioclimatic strategies. The main objective is the improvement of microclimatic conditions with the decrease of ambient temperatures during the summer period and enhancement of the thermal comfort conditions.

2.2 Field measurements of microclimatic parameters

The environmental parameters monitored were wind speed, air temperature, and relative humidity. The elements of the terrain affect the wind either by decreasing the speed and changing the direction, or by increasing the wind speed. The wind also affected by the size, the position, the orientation, the porosity and the vicinity of the buildings. For the area A the measurements indicated that the wind was varied between 0.4 m/sec to 2.7m/sec, for area B varied from 0.3m/sec to 2.9m/sec while for the area C the wind variation was in the range 0.4m/sec to 2.4 m/sec.

The monitoring procedure included measurements of the air temperature and humidity at selected locations for each of the three areas, using data loggers (Tiny Tag TGP-4500). The data loggers were placed into weather stations located at a height of 1.80 m.

The air temperature and humidity measurements for the area A, were performed on 26th of April, 2013. The results indicated that the mean maximum air temperature was 30.0°C while the mean minimum was 24.5°C. These temperature ranges related with the geometrical characteristics of the road and the construction materials. Furthermore the anthropogenic heat that emitted during the day affected the temperature profile. Regarding the relative humidity measurements of the mean maximum value was recorded 31% while the mean minimum was 24%.

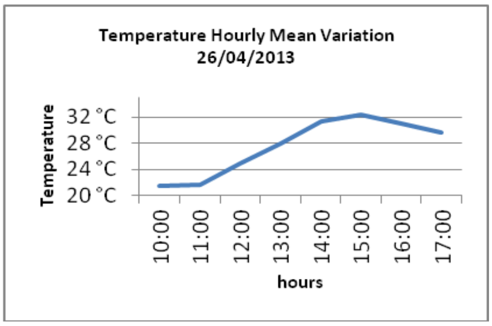


Figure 2: Maximum temperature range

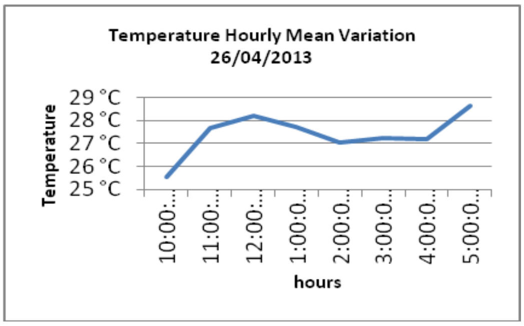


Figure 3: Minimum temperature range

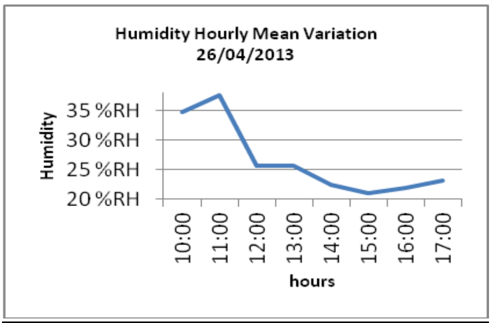


Figure 4: Maximum humidity range

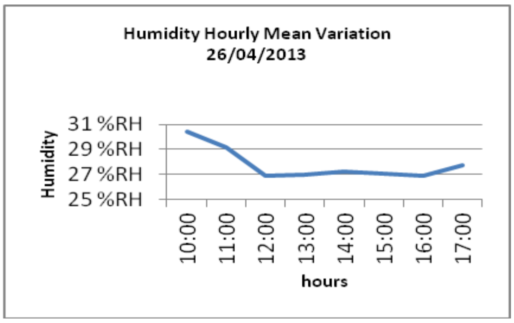


Figure 5: Minimum humidity range

The air temperature and humidity measurements for the area B were performed on 29th of May, 2013. The results indicated that the mean maximum air temperature was 31.9°C and the mean minimum was 27.0 °C. Regarding the humidity measurements the mean maximum relative humidity was 42% and the mean minimum was 35%.

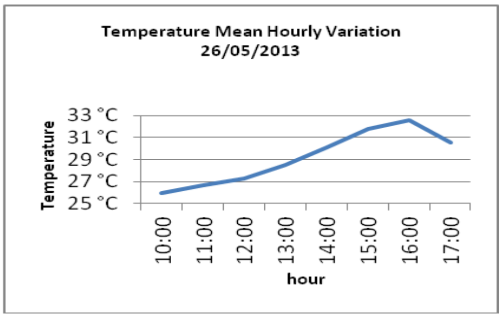


Figure 6: Maximum temperature range

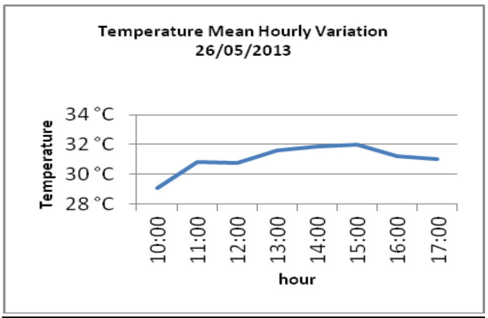
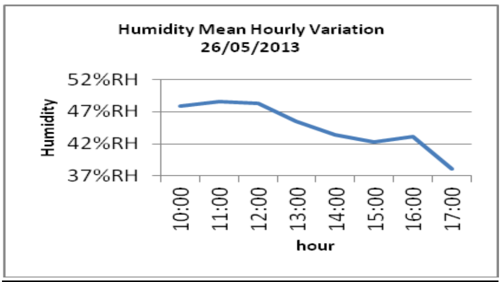


Figure 7: Minimum temperature range



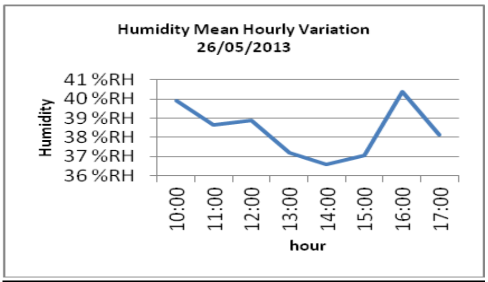
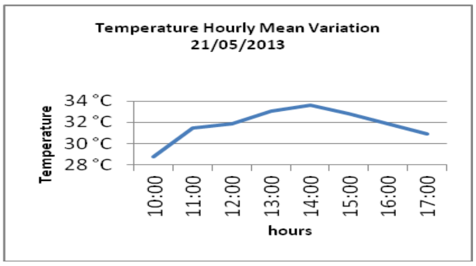


Figure 8: Maximum humidity range

Figure 9: Minimum humidity range

The air temperature and humidity measurements for the area C were performed on 21th of May, 2013. The results indicated that the mean maximum air temperature was 33.1°C and the mean minimum was 28.5°C. Regarding the humidity measurements the mean maximum relative humidity was 39.6% and the mean minimum was 25.9%.



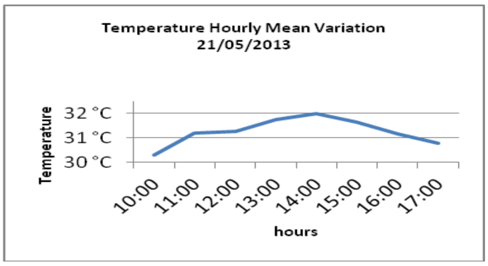
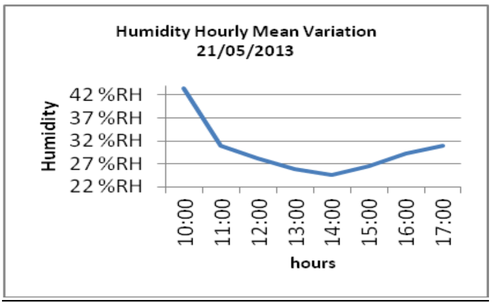


Figure 10: Maximum temperature range

Figure 11: Minimum temperature range



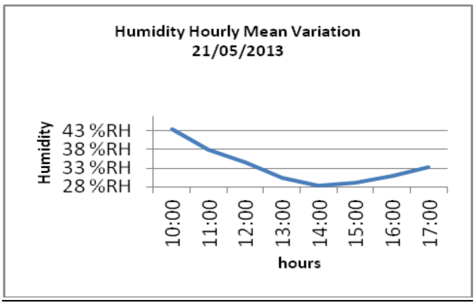
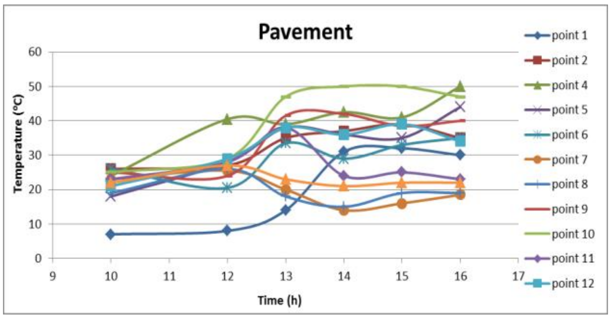


Figure 12: Maximum humidity range

Figure 13: Minimum humidity range

2.3 Study of the materials

An important role in the microclimate of an area plays the thermal properties of the materials that compose it. For this reason the surface temperatures of paving, asphalt and other building materials of the urban planning were measured on hourly basis from morning to afternoon (10:00 to 17:00), in order to understand their thermal efficiency. Measurements were performed both under clear sky and under full or partial cloud covered conditions, provided that the measured points are completely exposed to solar radiation. For this purpose three kinds of instruments were used such as thermal camera, infrared thermometer equipped with a laser beam and a contact thermometer. The measurement results showed that for the area A, the average surface temperature of the road surface ranged from 10°C in the morning hours to 50 ° C at noon. The minimum surface temperature measured for pavement equal to 7°C, while the maximum equal to 51°C. Regarding the area B, the average surface temperature of the road surface ranged from 25°C in the morning hours to 52°C at noon. The minimum surface temperature measured for paved surfaces equal to 23°C, while the maximum equal to 49°C. While for region C the corresponding values of the asphalt ranged from 27 ° C in the morning to 52°C at noon. The minimum pavement's surface temperature reach the 26°C, while the maximum the 48°C. The daily distribution of their surface temperature both for each selected measuring point and study area is shown in the following figures.



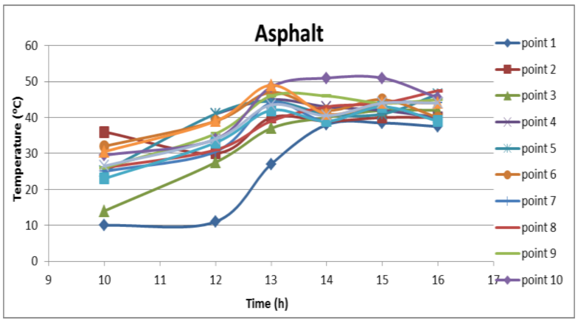
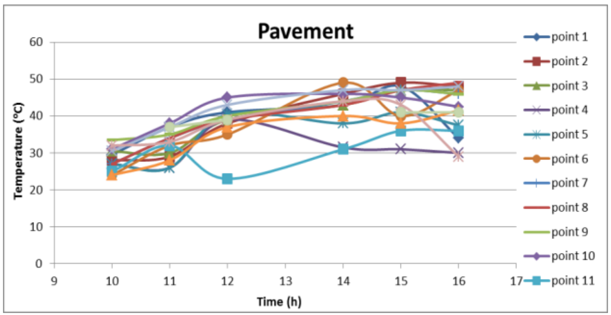


Figure 14: Comparison of daily temperature distribution a) pavement, b) asphalt of each measuring point of study area A



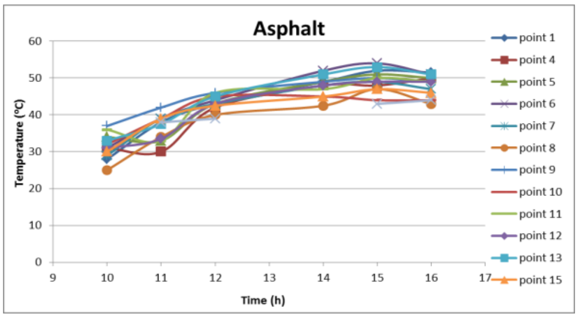
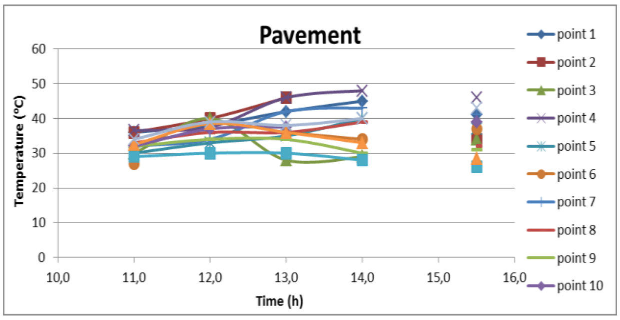


Figure 15: Comparison of daily temperature distribution a) pavement, b) asphalt of each measuring point of study area B



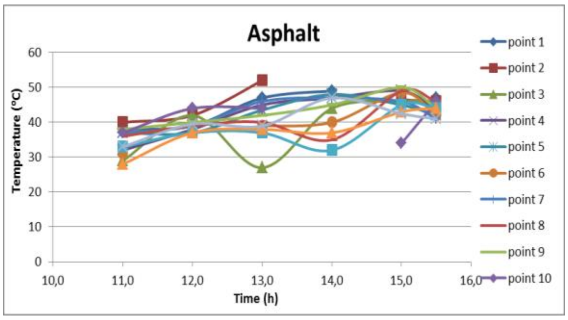


Figure 16: Comparison of daily temperature distribution a) pavement, b) asphalt of each measuring point of study area C

It is well known that sidewalks and roads as great part of urban surface, affect strongly the urban climate. The above experimental results show that the surface temperatures of the two most commonly used urban materials reach very high levels even during times of relatively low ambient air temperatures. The analysis must be taken into consideration in selecting the appropriate materials in area's rehabilitation.

2.4 Measurements of particulate matter

Particulate matter (PM) is one of the major air pollutants in urban areas. There is a clear correlation between enhanced PM_{10} and $PM_{2.5}$ levels and adverse cardiovascular and respiratory effects (C. Arden Pope, D.W. Dockery, 2006). Measurements of the levels of particulate pollution were also performed using an instrument which records the mass of airborne particles (Osiris) of an aerodynamic diameter less than 1μm (PM_1), 2.5μm ($PM_{2.5}$) and 10μm (PM_{10}). The sampling and recording time was 5 min. The airborne particles in the outdoor air are produced by combustion processes (during the heating of buildings), by industry, by the engines of vehicles or dust and their concentration is also determined by the traffic volume, the type and quality of the fuels used. The particles of smaller diameter are more easily irrespirable and have been proven to be a source of major health problems (Kunzli, 2000, Katsoyiannietal, 2001). The limits of allowable concentration of airborne particles, established by the European Union, are 50.0μg/m^3 for PM_{10} and 25.0μg/m^3 for $PM_{2.5}$, whereas there is yet no established maximum allowed limit for PM_1. A more specific analysis of the results for each area separately is given below:

Area A

Measurements of airborne particles of an aerodynamic diameter less than 1μm (PM_1), 2.5μm ($PM_{2.5}$) and 10μm (PM_{10}) took place in the area of interest, on 26/04/2013 and during the time period 10:00 am-17:00 pm. The measured airborne particles' concentrations for area A are illustrated in box plots in the figures that follow. From the data analysis, it can be concluded that, concerning Area A, the concentrations of PM_{10} particles range in levels below the limit of 50 μg/m^3 and those of $PM_{2.5}$ and PM_1 range in levels much below the limit of 25μg/m^3.

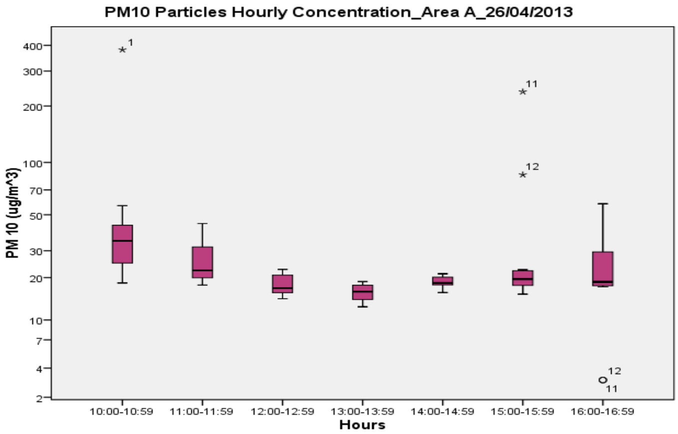


Figure 17: Mean hourly concentration of particles of diameter less than 10μm (PM_{10}) for the period 10:00 to 17:00 (26/04/2013)

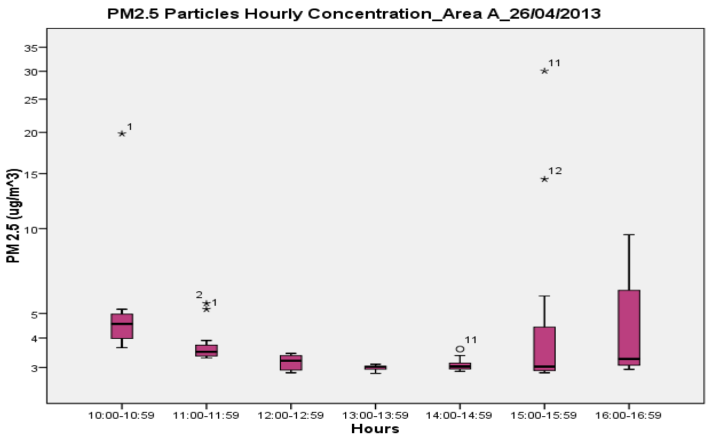


Figure 18: Mean hourly concentration of particles of diameter less than 2.5μm ($PM_{2.5}$) for the period 10:00 to 17:00 (26/04/2013)

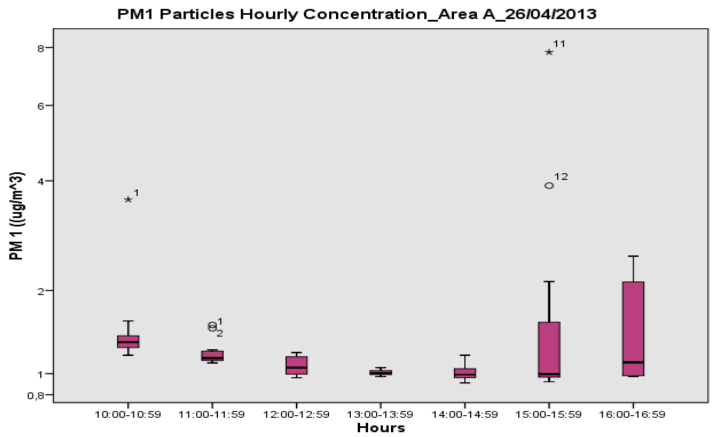


Figure 19: Mean hourly concentration of particles of diameter less than 1 μm (PM_1) for the period 10:00 to 17:00 (26/04/2013)

The maximum values occurred at 10:00 for PM_{10} and at 16:00 for $PM_{2.5}$ and PM_1 and they are much higher than the mean values as they correspond to moments when a machine was used to cut the grass of the court where the equipment was installed. The minimum values took place at 13:00 for PM_{10}, at 14:00 for $PM_{2.5}$ and at 14:20 for PM_1. The mean hourly concentration is found to be maximum from 11:00 to 11:00 for PM_{10} and from 15:00 to 16:00 for $PM_{2.5}$ and PM_1, whereas it was minimum from 13:00- 14:00 for all three types of particles.

Area B

For the second area of interest, measurements of airborne particles of an aerodynamic diameter less than 10μm (PM_{10}) took place, on 29/05/2013 and during the time period between 10:00 am and 16:00 pm. The measured airborne particles' concentrations for area B are shown in box plots in the following figures:

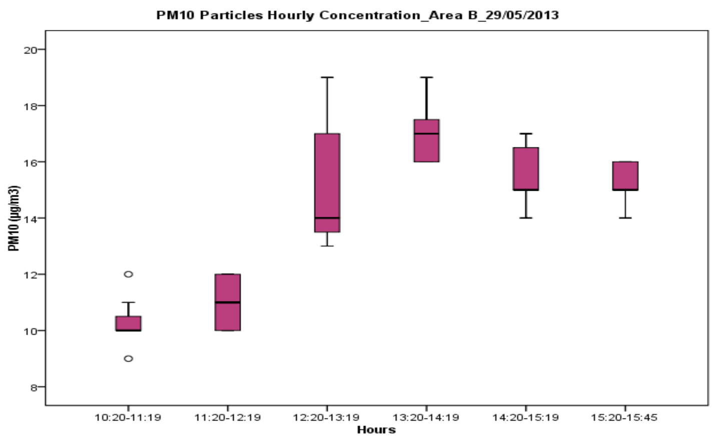


Figure 20: Mean hourly concentration of particles of diameter less than 10 μm (PM_{10}) for the period 10:00 to 16:00 (29/05/2013)

From the data analysis, it can be concluded that, concerning Area B, the concentrations of PM_{10} particles range in levels below the limit of 50μg/m^3. The mean concentration of PM_{10} particles is 13.88μg/m^3, the maximum value is 19μg/m^3 and occurred at 13:15 and the minimum value is 9μg/m^3 and appeared at 10:55.

Area C

For the third area of interest, measurements of airborne particles of an aerodynamic diameter less than 10μm (PM_{10}) took place, on 21/05/2013 and during the time period between 10:00 am and 16:00 pm. The concentrations of the PM_{10} particles for area C are given in box plot. From the data analysis, it can be concluded that, concerning Area B, the concentrations of PM_{10} particles range in levels below the limit of 50μg/m^3.

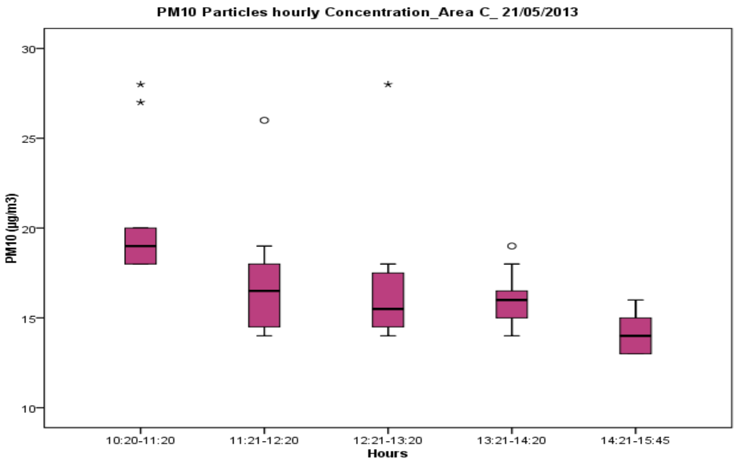


Figure 21: Mean hourly concentration of particles of diameter less than 10 μm (PM_{10}) for the period 10:00 to 16:00 (21/05/2013)

The mean concentration of PM_{10} particles is 18.26μg/m^3, the maximum value is 77μg/m^3 and occurs at 11:00 am and the minimum value is 13μg/m^3 and appears at 14:45 pm.

2.5 Thermal comfort conditions

Thermal comfort is defined as the state in which human beings feel satisfaction with the thermal environment and do not want any changes to it. The investigation and understanding of the parameters that constitute the outdoor thermal comfort is a basic requirement for the microclimatically oriented urban planning, including the planning of green areas. The extent, intensity and efficiency of activities depend on the level of comfort or discomfort experienced by humans when exposed to specific climatic conditions. Outdoor thermal comfort can be calculated using bioclimatic indices incorporating basic climatic parameters such as temperature and wind speed. In this study, in order to calculate the thermal comfort, the bioclimatic index CP is used for the selected points of the area of interest, which illustrate the different materials in the area of intervention. According to Cena, Gregorczuck, Wojcik, the CP index (in mcal cm^{-2} sec^{-1}) is calculated by the mathematical formula:

$$CP = (0.42+0.08v)(36.5-t) \quad (1)$$

Where

t: the mean air temperature in °C

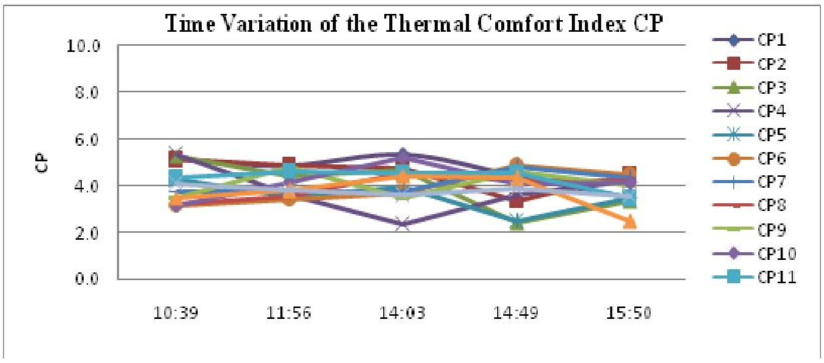
v: the wind speed in m/sec

The thermal comfort levels which are defined by the index value are given in the table below:

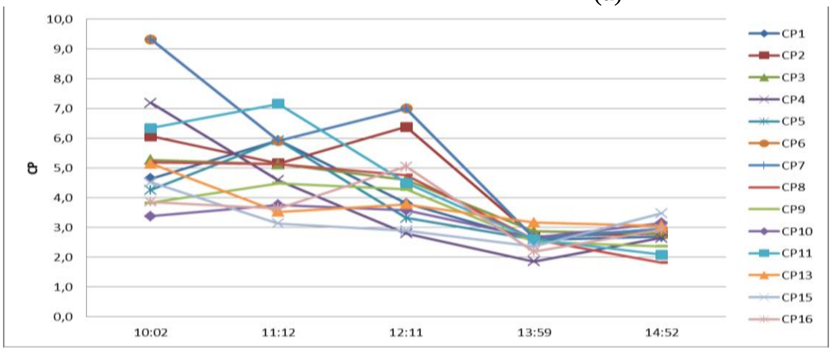
Table 1: Estimation of human – bioclimatic environmental conditions

a/a	**Values ranges of Cooling capacity (mcal cm^{-2}sec^{-1})**	**Characterization of Environment**	**a/a**	**Values ranges of Cooling capacity (mcal cm^{-2}sec^{-1})**	**Characterization of Environment**
1	< 0.6	Extremely hot	*6*	8.1 – 10.4	Tolerably cool
2	0.6 - 2.6	Very hot	*7*	10.5 – 15.4	Cool
3	2.7 – 5.1	Annoyingly hot	*8*	15.6 – 22.4	Very cool
4	5.2 – 6.4	Tolerably hot	*9*	22.6 – 30.0	Extremely cool
5	6.5 – 8.0	Comfortable pleasant	*10*	> 30.0	Glacial

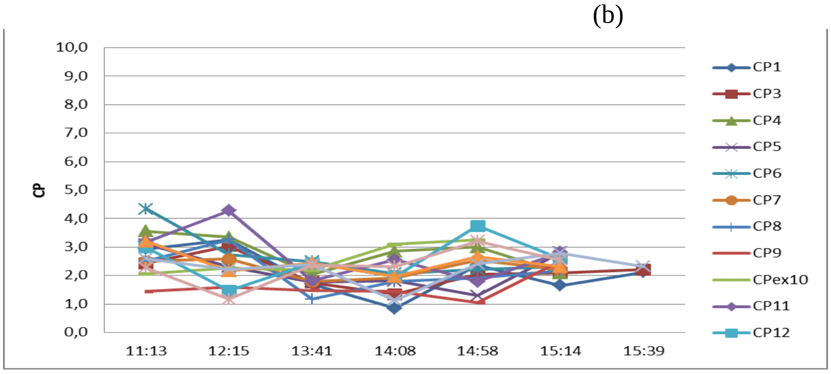
In the following figures, is given the time variation of the bioclimatic index for the three areas of interest and for the chosen positions. In that range of values, the environment is characterized as extremely hot to very hot for area A, very hot to annoyingly hot for area B and annoyingly hot to tolerably hot for area C, where its average value ranged from 3.3 to 5.6.



(a)



(b)



(c)

Figure 22: Time variation of the Thermal Comfort Index for (a) Area A (26/04/2013), (b) Area B (29/05/2013) and (c) Area C (21/05/2013)

3 CONCLUDING REMARKS

This paper presents the preliminary results of an ongoing study carried out for the integrated rehabilitation in three urban areas in the Municipality of Acharnes, Greece. The conclusions of the analysis presented herein are summarized as follows. The environmental parameters monitored were air temperature, wind speed and relative humidity. According to the spatial distribution of the temperature the streets showed significant heat strain during midday hours. The air temperature was ranged from 22.3°C to 32.3°C, at high levels considering the examined period (April-May, 2013).

The wind speed affected by the relative position and orientation of buildings and streets, was measured at pedestrian level in a range of 0.4-2.7m/sec.

To investigate the thermal comfort conditions, CP index was calculated at selected points according to the different materials in the area of intervention. The results indicated a high thermal stress on people and thermal discomfort at noon for the majority of the population.

Particulate matter with a diameter less than 1mm (PM_1), 2.5mm ($PM_{2.5}$) and 10mm (PM_{10}) were also measured and the concentrations for the examined period were below the permitted limits.

Detailed measurements were performed in order to investigate the temperature distribution of materials and to depict the differences in their thermal performance in the area of interest. The analysis of the results obtained have shown that the daily average surface temperatures of the materials used in the urban fabric varied between, 37.4°C for the pavements, and 41.8°C for the asphalt. The high levels of surface temperatures should be considered in selecting appropriate materials.

Furthermore, interventions (e.g. vegetation, cool materials, shading devices and water) will be proposed to eliminate these conditions. Finally, the architectural and bioclimatic design of the area will be accomplished and evaluated with the employment of advanced computer aided simulations.

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