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Considerations on the influence of micro urban heat islands to the temperature - humidity index in Craiova

Adrian ROŞCA[1,*], Daniela ROŞCA[2]

[1] University of Craiova, Agriculture and Horticulture Faculty, 13, Al. I. Cuza Street., 200585, Craiova, Romania
[2] University of Craiova, Electrical Engineering Faculty, 107, Decebal Bld., 200404, Romania
* *Corresponding author*, adrosca2003@yahoo.com

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Abstract

According to National Administration of Meteorology, July month of 2015, will represent one of the longest periods with canicular temperatures in the last decades. In Oltenia region and in Craiova city, too, yellow or orange code warning, had to be declared. To determine thermal discomfort sensation felt by the population of Craiova, experimental research concerning micrometeorological measurements of the real temperature and relative humidity that contribute to the local Temperature - Humidity Index (THI) value was performed. According to the experimental research results, con-firmed by using thermovision too, within Craiova, four micro urban heat islands were identified. Despite the low mean value of relative humidity, due to the temperature's high mean value, in these hot spots the THI average was 94.93, and the thermal discomfort sensation would have made necessary special protection measures. The same air micrometeorological parameters in these four hot spots were compared with the ones recorded in English Park where due to vegetation and trees' shadow, the THI average was 84.87, thus the thermal discomfort sensation would have made necessary adequate protection measures. The paper proposes several practical methods that would be utilized in order to decrease the pavements' and buildings' walls temperatures, or to increase the vegetation surfaces that contribute to the THI de-creasing in the micro urban heat islands of Craiova city.

Keywords: *Micro urban heat islands, hot spots, thermovision, Temperature - Humidity Index*

Rezumat. Consideraţii privind influenţa insulelor de căldură urbane asupra indicelui temperatură - umiditate din Craiova

Conform Administraţiei Naţionale de Meteorologie, luna Iulie a anului 2015 va reprezenta una dintre cele mai mari perioade cu temperature caniculare din ultimile decade. In Oltenia, precum şi în oraşul Craiova, a trebuit să fie anunţate avertizări de cod galben sau portocaliu. In vederea evidenţierii stării de discomfort termic resimţită de populaţia din Craiova, au fost efectuate cercetări experimentale privind măsurări micrometeorologice pentru determinarea temperaturii şi umidităţii reale care contribuie la stabilirea indicelui de confort termic local. În conformitate cu rezultatele cercetărilor experimentale, confirmate şi prin utilizarea termoviziunii, în centrul Craiovei au fost identificate patru insule de căldură local urbane. Chiar şi pentru valori reduse a umidităţii, datorită temperaturilor mari, in aceste zone fierbinţi media indicelui de confort termic a fost 94.93, şi senzaţia de discomfot termic ar fi făcut necesare măsuri speciale de protecţie. Parametrii micro-meteorologici determinaţi în aceste patru zone fierbinţi au fost compa-raţi cu cei obţinuti în English Park, unde datorită prezenţei vegetaţiei şi a umbrei arborilor, valoarea medie a indicelui de comfort termic a fost de 84.87, deci senzaţia de discomfort termic af fi necesitat măsuri de protecţie adecvate. Lucrarea prezintă câteva metode practice care ar putea fi utilizate pentru reducerea temperaturii pavimentului şi a pereţilor clădirilor, sau pentru creşterea suprafeţelor de vegetaţie care contribuie la scăderea indicelui de comfort termic din insulele de căldură local urbane din oraşul Craiova.

Cuvinte-cheie: *Insulele de căldură local urbane , zone fierbinţi, termoviziune, indice temperatură - umiditate*

Introduction

Heat wave in Oltenia

Craiova is located Oltenia Region, in the south-western part of Romania, at the intersection between the parallel 44 o19'01.70" northern latitude, with the meridian 23o47'50.99" eastern longitude (Fig. 1) (www.googleearth).

As one of the largest city in the country, with a population of about 280,000 in a built - up gentle relief plain area of approximately 32km2, from 92 to 117m a.s.l., Craiova has a maximum extension on the N – S direction (9.0 – 9.4km), and a minimum extension on the E - W direction (4.8 – 5.2km). Bălăciţa Piedmont height (158.5 - 165m) delineates the Jiu River lane to the West, and the Olteţ Piedmont heights (191.5 – 209.5m) are the eastern Craiova city border (Cocean, 2011). Due to continental – temperate climate, during the warm season, but especially in the June – August period, in Craiova there were registered the monthly largest mean temperature in July (28.5oC), and maximum absolute monthly temperature 41.5oC (July 1916), respectively (Cocean, 2011; Boengiu, 2008).

The term of canicula characterizes weather condition in which air temperature, measured in standard conditions at meteorological stations reaches or even exceeds the threshold of 35°C (it is also said that weather is canicular) manifested on extended areas.

In Oltenia Region, the drought period started in January 2000 lasting until July 17, 2002. It was interrupted by three short rainy periods in 2001 in which rains were followed by sunny days with wind gusts, which contributed essentially to the evaporation of soil water and the reappearance of water deficit in arable layer. The summer of 2000 marked for Oltenia the occurrence of canicula (also accompanied by drought) on extended periods of time. The drought of 2000 in Oltenia was in general extremely intense and associated with extended periods of canicular weather and heat waves in the intervals: June 6-10, 21-25, July 2-12, 22-27, August 3-7, 17-24. It affected the entire social life, causing the increase of all life prices (Marinică and Marinică, 2014).

Fig. 1: Craiova down-town (www.googleearth)

In the summer of 2007, in Oltenia, weather was extremely changeable. Among the most important weather aspects there must be mentioned six heat waves in the intervals: June 19-26; July 2-4; 8-10; 15-24; 27-30; August 22-25. Two of these had a great intensity, the one in the interval June 19-26 and that in the interval 15-24 July. The heat wave in the period July 15-24, 2007 was the most intense for this month of the entire period since meteorological observations are carried out and marked the exceeding of the monthly absolute maximum thermal value of July with 0.8°C (registered at Calafat on July 24, 2007, 44.3°C which in that period war the absolute maximum thermal value of July in Romania; the old absolute maximum thermal value of July in Romania was 43.5°C registered at Giurgiu on July 5, 2000). The maximum air thermal value, monthly absolute thermal value of July, registered in the last century on July 5, 1916 was 42.9°C in Alexandria and was exceeded with 0.6°C after 84 years on July 5, 2000 (Marinică and Chimişliu, 2009; Marinică and Marinică, 2014).

It must be noticed that in July 2007, for the first time, the air temperature reached and exceeded the climatologically threshold of 44°C. Values of 44°C and higher were registered in Romania one time in all the history of meteorological observations, only on August 10, 1951 when at four Romanian meteorological stations the value of 44°C was reached and exceeded (in Bărăgan, in Râmnicelu commune at Ion Sion farm 44.5°C, which is the absolute maxi-mum air temperature value in Romania, and 44.0°C in Amara - Slobozia and Valea Argovei). In July 2007, values higher or equal to 44°C also registered at three meteorological stations in Oltenia: Băileşti 44.0°C, Bechet 44.2°C and Calafat 44.3°C, which means a more extended area of hot air than in the last century. At soil surface, the maximum thermal value registered in Calafat was 69.0°C, and in Băileşti 71.0°C, the diurnal thermal amplitude being of about 45°C (Marinică and Marinică, 2014).

In Oltenia Region, September 2012 was excessively warm, when for 14 days, the maximum temperature values were comprised between 30o and 35oC (tropical days) (Marinică and Marinică, 2013).

Urban Heat Island

An urban heat island (UHI) describes the characteristic warmth of both the atmosphere and surfaces in urban areas compared to their non urbanized surroundings. There are three different types of heat islands: canopy layer heat island (CLHI), boundary layer heat island (BLHI), surface heat island (SHI). The first two refer to a warming of the urban atmosphere; the last refers to the relative warmth of urban surfaces. The urban canopy layer is the layer of air closest to the surface in cities, extending up-wards to approximately the mean building height. Above the urban canopy layer lays the urban boundary layer, which may be 1 km or more in thickness by day (shrinking to hundreds of meters or less at night). BLHI forms a dome of warmer air that ex-tends downwind of the city, and wind often changes the dome to a plume shape. Heat island types vary in their spatial shape, temporal (related to time) characteristics, and some of the underlying physical processes that contribute to their development. Scientists measure air temperatures for CLHI or BLHI directly using thermometers, whereas the SHI is measured by remote sensors mounted on satellites or aircraft (Voogt, 2002; Voogt, 2004).

The progressive replacement of natural surfaces (often composed of vegetation and moisture soils) by built surfaces constitutes the main cause of UHI formation (www.urbanheatislands.com).

These highlight the important role that the land cover types have on the thermal pattern of the UHI, and the relationship between the temperature radiated by the land surface and the temperature of the atmosphere situated immediately above it (near surface air temperature), due to the transfer of energy emitted from the former to the latter. Over the last decades, remotely sensed thermal infrared data have contributed to address the UHI through the estimation of land surface temperature, thus originating the study of the surface UHI. Nevertheless, it has been found that atmospheric and surface UHI are coarsely related, and they can exhibit quite different spatial and temporal patterns. Moreover, within the urban atmosphere the heat island may present significant variations between the canopy and boundary layer (www.urbanheatislands.com/).

Therefore, characteristics such as development, growth, intensity, and spatial pattern of the UHI will differ depending on where the measurements are made. The atmospheric UHI usually reaches its highest intensity in summer, and under calm air and a cloudless sky. This is because construction materials exhibit a high thermal inertia (a low response to temperature changes), and consequently, they continue releasing heat slowly after sunset and even near dawn, when most of the rural surfaces have cooled down. On the other hand, light winds are not capable of driving turbulent exchanges of heat, while clear skies enhance rural cooling by allowing radiative heat loss to the relatively cold night sky. The UHI measured at the canopy layer may exhibit high spatial and temporal variation as a result of the variable thermal properties of the urban construction materials, which in combination with the three-dimensional geometry of built-up surfaces modifies neighboring air temperatures. Since urban temperature is strongly commanded by the high thermal inertia of the construction materials, the surface UHI usually reaches its highest intensity in the afternoon, when the urban surface has sufficiently warmed-up, thus maximizing its heat release (Sham et. al., 2012; http://www.urbanheatislands.com/).

In order to study the intensity and spatial pattern of the UHI, in the last two decades, world-wide thermal infrared remote sensing was used to observe the surface of urban heat island as a reliable indicator of the atmospheric urban heat island. Therefore, close relationships between the near surface air temperatures and land surface temperatures have been found (Lo, Quattrochi and Luvall, 1997; Voogt and Oke, 2003; Weng, 2009; Nichol, 2009; Pérez Arrau, 2007; www.urbanheatislands.com/).

Micro urban heat islands (MUHI) refer to urban hot spots as poorly vegetated, parking lots, non-reflective buildings materials, material and colour of pavement and asphalt roads. MUHI are strongly affected by micro climate factors, therefore remotely sensed data (thermovision) are more suitable than atmospheric data for identifying heat spots (Synnefa et al., 2006, 2007, 2009; Stathopoulou et. al., 2005, 2009; www.urbanheatislands.com/).

As a consequence of canicular heat wave or MUHI, the temperature-humidity index (THI) has to be considered. THI, also known as thermal comfort index, represents an extremely used index in world-wide mass-media nowadays; it renders an apparent temperature, namely the temperature felt by human body that cools slower at higher values of the relative humidity due to the reduction of the evaporation rate.

THI is calculated on the base of several formulas, which corroborate air temperature and relative humidity, the critical threshold being 80. If THI is smaller than 65, it means comfort state; 66-79 means alert state; higher than 80 means discomfort state (Teodoreanu and Bunescu, 2007; Vlăduţ, 2011).

In the last decade, the Romanian researchers focused their interest for THI effects in Oltenia region. According to statistical data supplied by the Craiova Regional Meteorological Center, it was observed that the years with the highest number of days (51 days in 2000, 47 days in 2001, and 41 days in 2007) with THI values above 80 were 2000, 2001, and 2007 for the entire studied territory, when, during July and August, the region was affected by numerous heat waves, which led to the frequent exceeding of the 40°C value (Burada and Sandu, 2009; Marinică and Marinică, 2008, 2009; Teodoreanu and Bunescu, 2007; Vlăduţ, 2011).

Aims

In order to participate in the competition "European Cultural City 2020", the municipality of Craiova has benefited of funds coming through the financing of an European Project. The goal of this project was the rehabilitation of the old down town, thus some streets became only for small shops, pubs and restaurants activities, and for people walking use. Rehabilitation took into account the structure and the facade of buildings, pavement and all the infra-structure (electricity, water, sewerage). Facades of buildings (more than 100 year old houses; about 60 years old ground floor and 4 floors blocks) have been rehabilitated (light colors, architectural ornaments), and the old pavement was replaced with a new one made in synthetic granite cubes (gray, dark gray, dark red) and artificial marble tiles (beige, dark white).

This study presents an overview concerning temperatures, humidity and THI, too, in July 2015, for MUHI conditions of Craiova, for some buildings and pavement in four hot spots and in a public park’s canopy.

The study considers Craiova MUHI for five places: three recent rehabilitated streets (Panait Moşoiu Street, Lipscani Street, Theodor Amann Street), Prefecture Square, and English Park, respectively.

The experimental research considered the direction and the geometry of these five places: Panait Moşoiu Street (magenta line in Fig. 1) - direction N - S, length about 120m, mean width

15m, mean height of the buildings 12m, with no vegetation; Lipscani Street (red line in Fig. 1) - direction E - W, length about 330m, mean width 12m, mean height of the buildings 10m, with no vegetation; Theodor Amann Street (dark pink line in Fig. 1) - direction N - S, length 130m, mean width 22m, mean height of the buildings 18m, with very poor vegetation; Prefecture Square (yellow line in Fig. 1, but without the Unirii Street that starts in the southern part of this Square, yellow, too) - open space 60 x 80m, with the Prefecture Building (30m height) to the East, an open green park with artesian fountains to the West, shops and 4 floors blocks (25m height) to the South, shops and 4 floors blocks (20m height) to the N, with no vegetation; English Park - open public green park 60 x 60m, with the Prefecture Building (30m height) to the West, Theodor Amann Street (shops and 4 floors blocks, 22m height) to the East, shops and 4 floors blocks (15m height) to the South; Craiova City Hall (15m height) to the North.

Material and Method

According to the weather forecast provided to the media by the National Administration of Meteorology, for large regions of Romania, in July 2015 canicular heat wave was settled, with daily maximum thermal values exceeding 32 - 34^{o}C. Therefore in all these regions, and in Oltenia and in Craiova, too, yellow or orange code warning had to be declared.

The daily micrometeorological measurements were represented by four observations (from 60 to 60 minutes) in the midday (when maximum temperature occurred) between 13.30 and 16.30, for the MUHI' five places conditions, above presented.

Experimental research targeted air temperature and air relative humidity measurements, and for the buildings, pavement and trees canopy temperatures by using thermal infrared camera (thermovision), too, in 10 canicular days of July 2015 (13, 14, 15, 16, 22, 23, 24, 25, 26, 27).

In the selected days the air velocity was less than 1m/s (measured at 1...1.2 m height above the ground, by using a hot wire anemometer Lutron YK - 2005AK: air velocity accuracy ± 1% full scale; temperature accuracy ± 0.8^{0}C), and clear sky.

Air relative humidity and air temperature were measured by using a hygrometer (Lutron HT - 3009: humidity accuracy ± 2% R.H; temperature accuracy 0.5^{0}C).

The temperature measured during the experimental research was compared with the temperature provided by National Administration of Meteorology (accuweather.com/en/ro/craiova/287856/july).

This paper presents the air temperature and air relative humidity recorded on the middle length of each rehabilitated street, in the center of the Prefecture Square, and three different places in English Park.

Based on these measurements, there were calculated the average values of air temperature and relative humidity during each four daily observations steps. Finally, the Temperature - Humidity Index was calculated with the relation (Teodoreanu and Bunescu, 2007; Vlăduţ, 2011):

$$THI = (T \times 1.8 + 32) - (0.55 - 0.0055 \times U) \times [(T \times 1.8 + 32) - 58)],$$

where T - air temperature (°C), U - relative humidity (%).

Thermal infrared sensing FLIR T 440 US camera was used: FPA uncooled micro bolometer detector type; 7.5 to 13 μm spectral range; resolution 324x256 pixels; NETD < 0.045^{0}C). For each measurement, the thermal infrared camera parameters were set.

For air relative humidity (Rel. humidity) and air temperature (Atm. temp.) there were used the values measured with the hygrometer; the reflected temperature (Refl. temp.) was determined with aluminum foil, for emissivity ε = 1, distance d = 0m. In a thermal image, the material of the buildings' facades and the pavement materials are characterized by certain specific emissivity.

According to the professional emissivity tables, both for buildings' facades and for pavement materials, the mean emissivity ε = 0.92 was selected. On the other hand, according to the same professional emissivity tables, the emissivity for grass ε = 0.97, for leaves ε = 0.98, for bark ε = 0.94. Therefore, for the vegetal emissivity, the mean of those mentioned materials, ε = 0.96, was used (www.icess.ucsb.edu/modis/; www.zytemp.com/infrared/application.asp).

In order to verify the thermal infrared temperature correctness, three precision fine wire thermo-couples (Omega 5 SC-GG-K-30-36; accuracy ± 0.5%), and a temperature data - logger recorder (Lutron BTM - 4208 SD) were used: one on the pavement, placed at 1m from the building wall; one in the corner between the pavement and the building wall; one on the building wall at 1m height from the ground; for vegetal materials: one on the ground, placed at 1m from the tree trunk, one on the trunk's bark 1m height from the ground, and one in the canopy of the tree's crown, respectively.

Each thermal infrared measure was considered correct only when the difference between the temperature in the spot of the thermal image, and the temperature measured with the fine wire thermo-couples, was less than 20^{0}C.

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This paper presents some representative infrared thermal image and the specific temperature graphics for buildings and pavements, and for vegetal materials, respectively.

Results and Discussions

Craiova's MUHI took into consideration hot spots as very poor vegetated three people walking streets and Prefecture Square, determined by non-reflective and high thermal inertia of buildings materials, color and material of the pavement.

The temperature, humidity and THI recorded in the hot spots are presented in Fig. 2: the temperature and relative humidity averages are 44.56^{0}C, and 42.12%, respectively.

Despite the low value of humidity, the THI average was 94.93, and the thermal discomfort sensation would have made necessary special protection measures.

The air micrometeorological parameters in the hot spots can be compared with the ones recorded in English Park presented in Fig. 3. Due to trees canopy, temperature and relative humidity averages were 35.55^{0}C, and 46.88%, respectively.

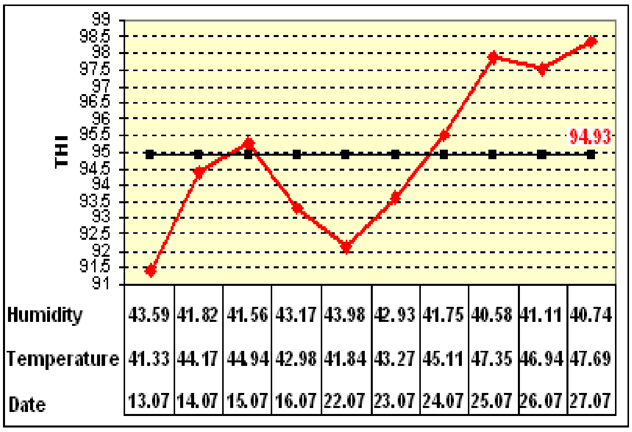


Fig. 2: Temperature, humidity and THI recorded in the hot spots

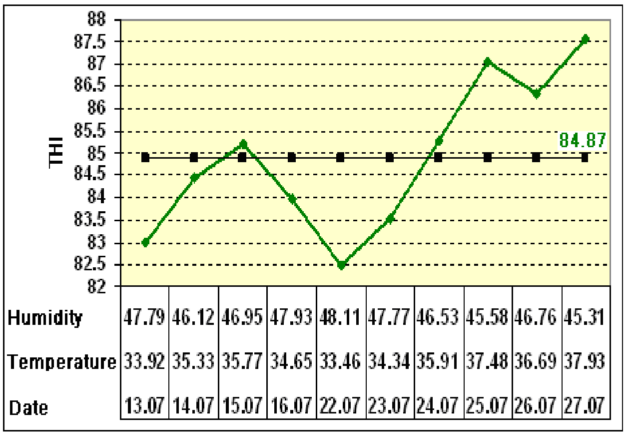


Fig. 3: Temperature, humidity and THI recorded in English Park

Even if the mean temperature was 90C lower and relative humidity 5% higher than in the hot spots, the THI average was 84.87 (10 units lower than in the hot spots), and the thermal discomfort sensation would have made necessary adequate protection measures.

Comparisons between the experimentally measured temperatures (TEXP) and the temperature announced by National Administration of Meteorology (TNAM), and the difference between those temperatures (ΔT) are presented in Table 1.

Table 1: Comparison between the experimentally measured temperatures and the temperature announced by National Administration of Meteorology

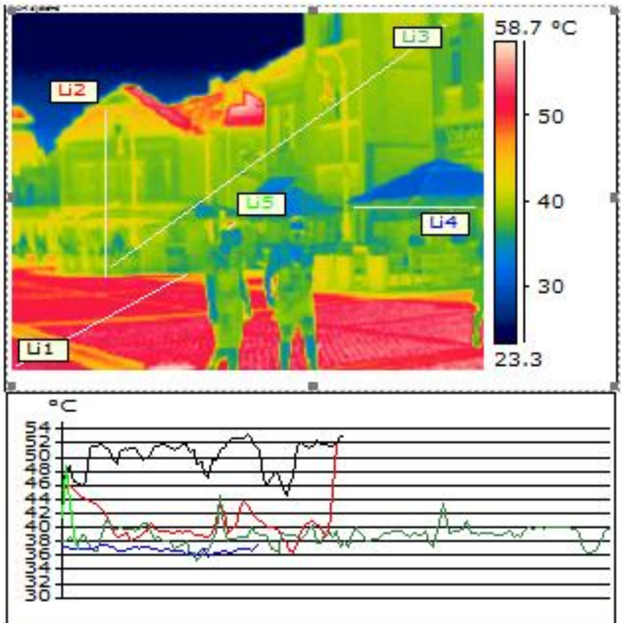
Temperature, °C					
Date	**13.07**	**14.07**	**15.07**	**16.07**	**22.07**
T_{NAM}	32	34	34	33	32
Hot spots					
T_{EXP}	41.33	44.17	44.94	42.98	41.84
ΔT	9.33	10.17	10.94	9.98	9.84
English Park					
T_{EXP}	33.92	35.33	35.77	34.65	33.46
ΔT	1.92	1.33	1.77	1.65	1.46
Date	**23.07**	**24.07**	**25.07**	**26.07**	**27.07**
T_{NAM}	33	34	36	35	36
Hot spots					
T_{EXP}	43.27	45.11	47.35	46.94	47.69
ΔT	10.27	11.11	11.35	11.94	11.69
English Park					
T_{EXP}	34.34	35.91	37.38	36.39	37.93
ΔT	1.34	1.91	1.38	1.39	1.93

In the hot spots (three rehabilitated streets and Prefecture Square) the difference between experimentally measured temperature (TEXP) and the temperature announced by National Administration of Meteorology (TNAM) was ΔT = 9.33…11.94°C, while in English Park it was only ΔT = 1.33…1.93°C. As expected, the real temperature at which the people are exposed while walking in the hot spots areas is much higher than that announced by NAM (mean 10.63°C), while the real temperature at which persons sitting or walking in English Park are exposed is only 1.6°C higher than that announced by the NAM.

Natural surfaces utilize a relatively large proportion of the absorbed radiation in the evapotranspiration process and release water vapors that con-tribute to cool the air in their vicinity. In contrast, built surfaces are composed of non-reflective and water-resistant construction materials, and consequently, they tend to absorb a significant proportion of the incident radiation, which is released as heat, and very large values for THI occurred. Vegetation intercepts radiation and produces shade that also con-tributes to reduce urban heat release. The decrease of parks vegetated areas, not only reduces these benefits, but also inhibits atmospheric cooling due to horizontal air circulation generated by the temperature gradient between vegetated and hot spots urban areas. On the other hand, the narrow arrangements of buildings along the city's streets form urban canyons that inhibit the escape of the reflected radiation from most of the three-dimensional urban surface to space. This radiation is ultimately absorbed by the building walls, thus enhancing the urban heat release and micro urban heat islands occurring.

All the above considerations were better emphasized by thermal infrared remote sensing that was used to observe the surface of urban heat island as a reliable indicator of the atmospheric parameters of micro urban heat islands.

Fig. 4 and Fig. 5 present representative thermal images and temperature graphics recorded for Panait Moşoiu Street where canyon effect was observed (no tree; white, light yellow and light orange colors for the buildings' facades; dark gray and dark red colors for synthetic granite cubes of the pavement).

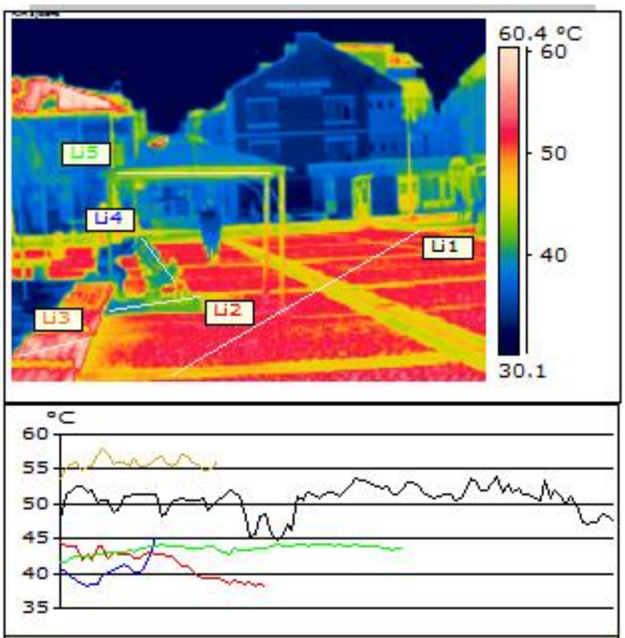


Label	Min	Max	Avg
Li1	44.4	53.2	50.1
Li2	36.2	52.0	40.6
Li3	35.0	44.5	38.7
Li4	35.7	37.3	36.7
Li5	36.5	48.6	41.7

Fig. 4: Thermal images and temperature graphics recorded in Panait Moşoiu Street buildings

Even if the buildings' facades are in light colors, the temperature of those surfaces was 35...52ºC (in Fig. 4: Li2 and Li3). Due to dark colors of the pavement, the temperature of this surface was 44.4... 53.6ºC (in Fig. 4 and Fig. 5: Li1). Due to this very high value, even under the umbrella's shady canopy the temperature was 37.9...44.3oC (Fig. 5: Li2) and on the child body into the baby trolley the temperature was also too high 38.1…45.1ºC (Fig. 5: Li4).

No one should wonder why on the wooden bank (dark brown color), presented in Fig 5 (Li3) no person was sitting, as long as the temperature was 53.7...57.8ºC.



Label	Min	Max	Avg
Li1	44.6	53.8	50.6
Li2	37.9	44.3	41.2
Li3	53.7	57.8	55.8
Li4	38.1	45.1	40.2
Li5	41.5	44.2	43.4

Fig. 5: Thermal images and temperature graphics recorded in Panait Moşoiu Street open space

Not even under the umbrella's shady canopy the temperature was unbearable at 41.5...44.2ºC (Fig. 5: Li5). When a sprinkle water fog system was installed on a pub's external terrace, under the umbrella's shady the temperature was more bearable at 35.7...37.3ºC (Fig. 4: Li4).

Thermovision emphasized the same canyon effect for Lipscani Street (no tree; white, light yellow and light orange colors for the buildings' facades; dark white color for artificial marble tiles of the pavement), too. In thermal image and temperature graphics presented in Fig. 6 it is observed that even if the buildings' facades and pavement's, too, are in light colors, the temperatures of those surfaces were 33.1...44.8ºC(Li1) and 42.8...49.1 (Li2), respectively.

When a sprinkle water fog system was installed on the pub's external terrace, the temperature under the umbrella's shady, however was 34...40.9ºC (Li3).

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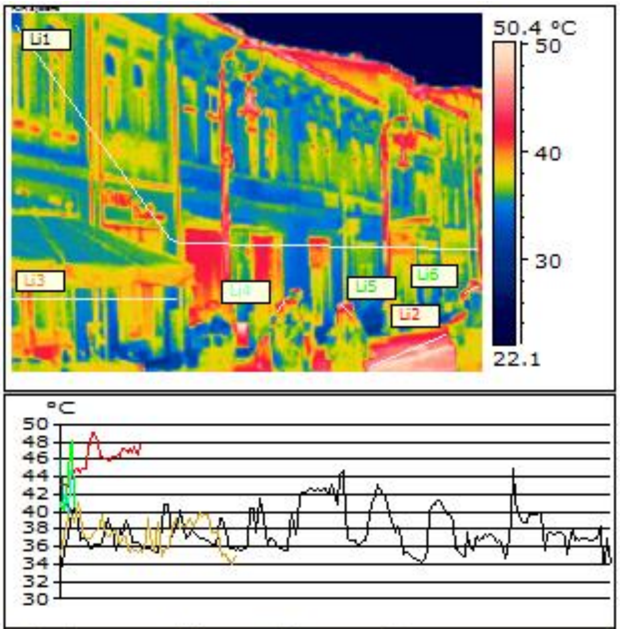
Very high temperatures were recorded on the top head of three walking persons, those maximum values reaching 45.9...48°C (Li4, Li5, Li6).



Label	Min	Max	Avg
Li1	33.1	44.8	37.8
Li2	42.8	49.1	45.9
Li3	34.0	40.9	37.3
Li4	39.8	46.5	42.1
Li5	39.3	45.9	41.4
Li6	40.0	48.0	43.0

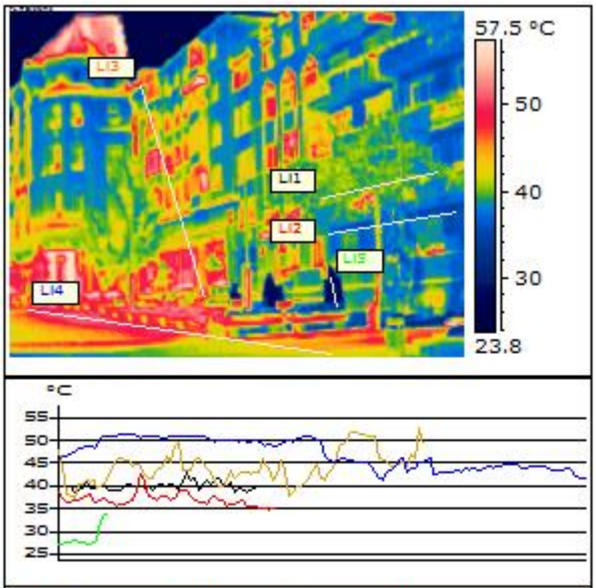
Fig. 6: Thermal images and temperature graphics recorded in Lipscani Street

The same canyon effect for Theodor Amann Street (very low vegetated; white, light yellow and light orange colors for the buildings' facades; dark white color for artificial marble tiles and gray color for granite cubes of the pavement) was observed. In thermal image and temperature graphics presented in Fig. 7 it is observed that even if the buildings' facades and pavement's, too, are in light colors, the temperatures of those surfaces were 37.2...52.48°C (Li3) and 41.3...51.2°C (Li4), respectively. The temperatures on the tree's crown was 38.8...42.9°C (Li1), and on the buildings' facades shady by the tree was 34.7... 42.4°C (Li2), respectively, and the water sprinkle of the fountain was 27...33.5°C (Li5).

Built surfaces (buildings' facades; pavement) are composed of a high percentage of non-reflective and water-resistant construction materials. Consequently, they tend to absorb a significant proportion of the incident radiation, which is released as heat.

As a result of the variable thermal properties of the urban construction materials, that in combination with the three-dimensional geometry of built-up surfaces modifies neighboring air temperatures.

The narrow arrangement of buildings along the city's streets forms urban canyons that inhibit the escape of the reflected radiation from most of the three-dimensional urban surface to space. This radiation is ultimately absorbed by the building walls, thus enhancing the urban heat release. On the other hand, light winds are not capable of driving turbulent exchanges of heat, while clear skies enhance cooling by allowing radiative heat loss to the relatively cold night sky.



Label	Min	Max	Avg
Li1	38.5	42.9	39.8
Li2	34.7	42.4	36.8
Li3	37.2	52.4	44.0
Li4	41.3	51.2	46.8
Li5	27.0	33.5	28.6

Fig. 7: Thermal images and temperature graphics recorded in Theodor Amann Street

As a resultant consequence of all these considerations, in Prefecture Square (open space with a green park to the West; white, light yellow and light orange colors for the buildings' facades; beige color of the synthetic granite tiles) a hot spot was observed. In thermal image and temperature graphics presented in Fig. 8 it is observed that even if the buildings' facades and pavement's, too, are in light colors, the maximum temperatures of those surfaces were 61... 61°C (Li1 and Li2) and 57.8oC (Li3), respectively. The temperatures on the walls (black color artificial marble) of the fountain's water sprinkle was 27.2...37.7°C (Li4).

By comparison with the above mentioned hot spots, Figure 9 presents a representative thermal image and temperature graphics for English Park.

While on the shady Prefecture's facade it was 37.6 ...39.9°C (Li4), the temperature on the tree's crown was 33.6...41.5°C (Li1), comparable when the sprinkle water fog system was installed on the pub's external terrace, when the temperature under the umbrella's shadow, was 35.7...37.3ºC (Fig. 4: Li4) and 34...40.9ºC (Fig. 6: Li3) respectively, thus 3.3...7.5ºC lower than unbearable 41.5...44.2ºC under the umbrella's shadow (Fig. 5: Li5). On the other hand, the temperature on the shady ground was 32.3...34.4ºC (Li2) and 30.8... 34.2ºC (Li3), thus 10.5...23.4ºC lower than the pavement in the above mentioned hot spots: 44.4...53.6ºC (in Fig. 4 and Fig. 5: Li1), 42.8...49.1 (Fig. 6: Li2), 41.3 ...51.2ºC (Fig. 7: Li4) and 48.3...57.8ºC (Fig. 8: Li3).

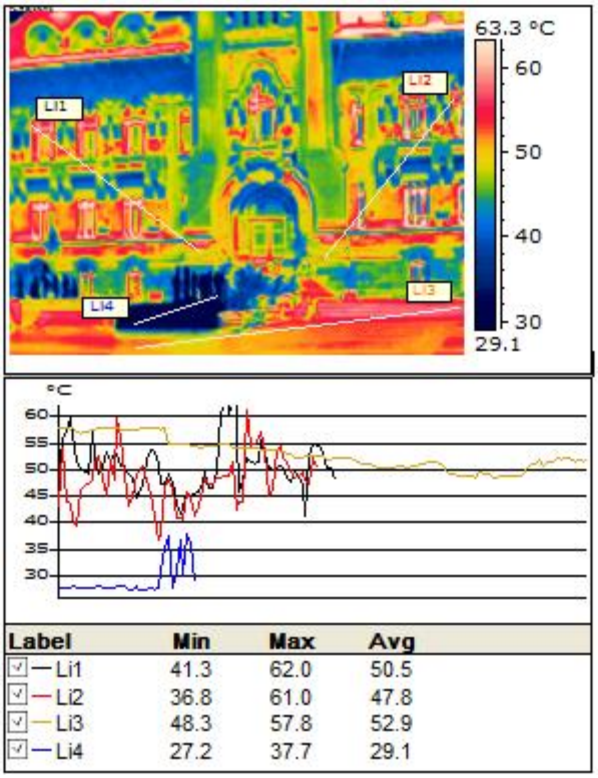


Fig. 8: Thermal images and temperature graphics recorded in Prefecture Square

In order to reduce the hot spots effects into the micro urban heat islands, two strategically methods are recommended: light colors for pavement and buildings' facades, and vegetation increasing that, in the same time, contribute to decrease the urban pollution levels, respectively.

In a large measure, the rehabilitation of the streets analyzed in this paper took in consideration the use of the light colors for built surfaces (buildings' facades; pavements).

Unfortunately, due to their non-reflective characteristics, all construction materials that have been used for this rehabilitation absorb the incident radiation, that is subsequently released as heat.

Prefecture Square is the main public square of the city used especially for social, political and cultural activities. Therefore when it was designed, no vegetation was possible.

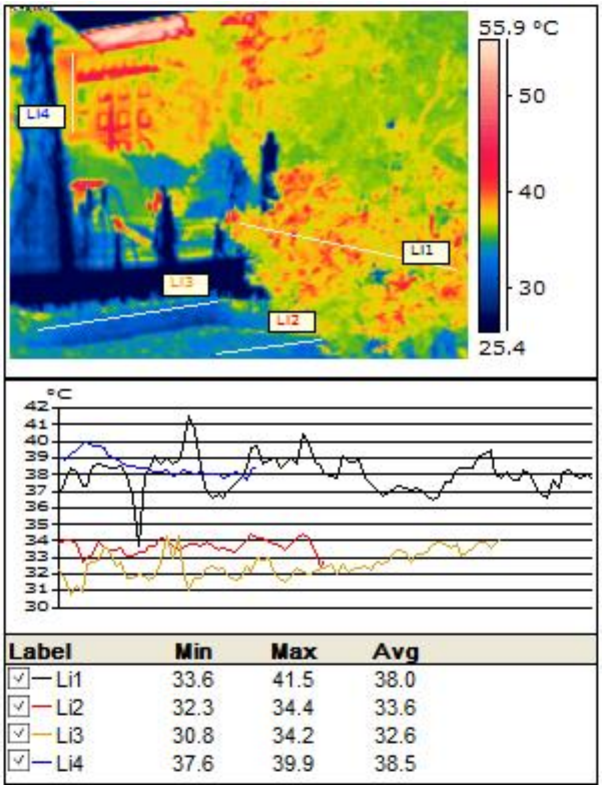


Fig. 9: Thermal images and temperature graphics recorded in English Park

In all the hot spots, a simple method that reduce the reflected radiations' escape from the buildings' walls to neighborhoods, consists in permanent or temporary retractable roofs that realize shady zones, similar with the "velarium" that, more than 2000 years ago, covered the Coliseum in Rome.

In order to decrease the pavements' temperature in the hot spots both in the Prefecture Square and on the rehabilitated streets, an operative, efficient and low cost method would be used: a water sprinkling small car, or temporary water sprinkling system similar with the one used for lawn sprinkling.

Urbanism architects who contributed to this rehabilitation design should have taken into account that in the past 15 years, the summer months in Craiova have become increasingly warmer.

Here it should be mentioned that in the total area of 8600m2 of the analyzed streets, there are only 27 trees. This very poor vegetated area in the hot spots contributes in large measure to the high temperatures and thermal discomfort sensation that people have to support.

Conclusion

According to the National Administration of Meteorology, the month of July 2015 will represent one of the longest period with canicular temperatures in the last decades.

In many regions of Romania, and in Oltenia and in Craiova city, too, yellow or orange code warning, had to be declared.

Therefore, to determine thermal discomfort sensation felt by the population of Craiova, experimental research concerning micrometeorological measurements of real temperature and relative humidity those contribute to the local Temperature - Humidity Index was performed.

According to the experimental research results, confirmed by using thermovision too, four hot spots (three rehabilitated streets and Prefecture Square) were identified in the down town of Craiova.

Despite the low mean value of relative humidity (42.12%), due to the temperature's high mean value (44.56^{0}C), in these hot spots the THI average was 94.93, and the thermal discomfort sensation would have made necessary special protection measures.

The same air micrometeorological parameters in the hot spots were compared with the ones recorded in English Park where due to trees' shadow, temperature and relative humidity averages were 35.55^{0}C, and 46.88%, respectively. Even if the mean temperature was lower with 90C and relative humidity with 5% higher than in the hot spots, the THI average was 84.87 (10 units lower than in the hot spots), and the thermal discomfort sensation would have made necessary adequate protection measures.

The experimental results confirm that due to the variable thermal properties of the construction materials (building, pavements) combined with the three - dimensional geometry of built-up surfaces, the neighboring air temperatures increase.

In the same time, the narrow arrangement of buildings along the streets determines urban canyons occurring, that inhibit to space the reflected radiation's escape from the three - dimensional buildings' shape and pavements' surfaces.

This radiation is absorbed by the building walls and the pavement, thus enhancing heat's release from the micro urban hot spots. On other hand, very light winds are not capable to obtain heat's turbulent exchanges, while clear skies enhance cooling by allowing radiative heat loss.

Vegetal surfaces utilize a relatively large proportion of the absorbed radiation in the evapotranspiration process and release water vapors that contribute to the air cooling in their vicinity.

Vegetation intercepts radiation and produces shade that also contributes to heat's release reducing. The decrease of parks vegetated areas, not only reduces these benefits, but also inhibits atmospheric cooling due to horizontal air circulation generated by the temperature gradient between vegetated and micro urban' areas hot spots.

In contrast, built surfaces are composed of non-reflective and water-resistant construction materials, and as consequence, they absorb a significant proportion of the incident radiation, which is released as heat, and very large values for THI occurred.

According to these considerations, in order to decrease the pavements temperatures in the hot spots, an operative, efficient and low cost method consisting in water sprinkling could be used.

In order to increase the vegetation surfaces in micro urban hot spots of Craiova city, a long term and expensive method would be to plant new young trees and to wait several years the crown growing, or to replant old trees from botanical parks and tree nurseries.

A cheaper and shorter term method would be to use permanent or temporary vertical walls and modular roofs made by ornamental green vegetation.

In order to increase the vegetated area in the micro urban hot spots, that will determines pollution's decrease, too, there are necessary near future concerted efforts of a consortium built of urbanism architects, meteorologists, ornamental plants and trees specialists and environment urban pollution engineers.

Acknowledgements

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