Air quality and bioclimatic conditions in Lublin (2015-2019)

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Every year, inhabitants of urbanized areas are exposed to the low air quality of the atmospheric environment, subject to increasing changes. These changes concern both the chemical and physical composition (dust), but also result from planning activities related to the reduction of biologically active areas and an increase in the share of artificially transformed areas. Due to contemporary climate changes, the latter element not only contributes to the increase in pressure related to the occurrence of heat stress, but also contributes to a further increase in air pollution. Lublin, as the largest city located east of the Vistula River, is not free from the processes described above. It is the city with lower than average share of green areas in Poland. Each year, Lublin is in the group of cities where significantly exceeded concentrations of air pollutants that are harmful to the health of residents are recorded.

The study attempts to indicate the relationship between biometeorological conditions and selected air pollutants. The Universal Thermal Climate Index (UTCI) was used to characterize the biometeorological conditions. It takes into account the combined influence of air temperature, relative humidity, wind speed and solar radiation conditions on human heat balance. The analysis of aerosanitary conditions was based on the concentrations of the following air pollutants: NO_2, O_3, CO, SO_2, PM10 and PM2.5. They were used to calculate the Common Air Quality Index (CAQI). In addition, we analysed the episodes of the highest air pollution and the situations characterized by the highest heat load of the human body.

UTCI is based on the multi-node model of the human heat balance, the so-called Fiala Model (Fiala et al. 2001; Fiala et al. 2011), considering two parameters of heat exchange regulation between the human organism and the surroundings. The first one, called passive, involves the transport of heat inside the organism and on the body surface. The second one, called, active, determines the physiological mechanisms of thermoregulation. The index can take the form of the following function:

$$UTCI = f(Ta, vp, va, dTmrt)$$

where:

Ta – air temperature [°C],

vp – water-vapour pressure [hPa],

va – wind velocity at a height of 10 m above the ground [$m \cdot s^{-1}$],

dTmrt – difference between the mean radiation temperature and air temperature [°C].

The classes of heat loads of the human body according to the UTCI index are presented.

The calculation of the CAQI is based on a review of a number of existing air quality indices, and it reflects EU alert threshold levels or daily limit values as much as possible.

The scale of the estimation of air quality according to CAQI calculation grid (van den Elshout et all., 2014)

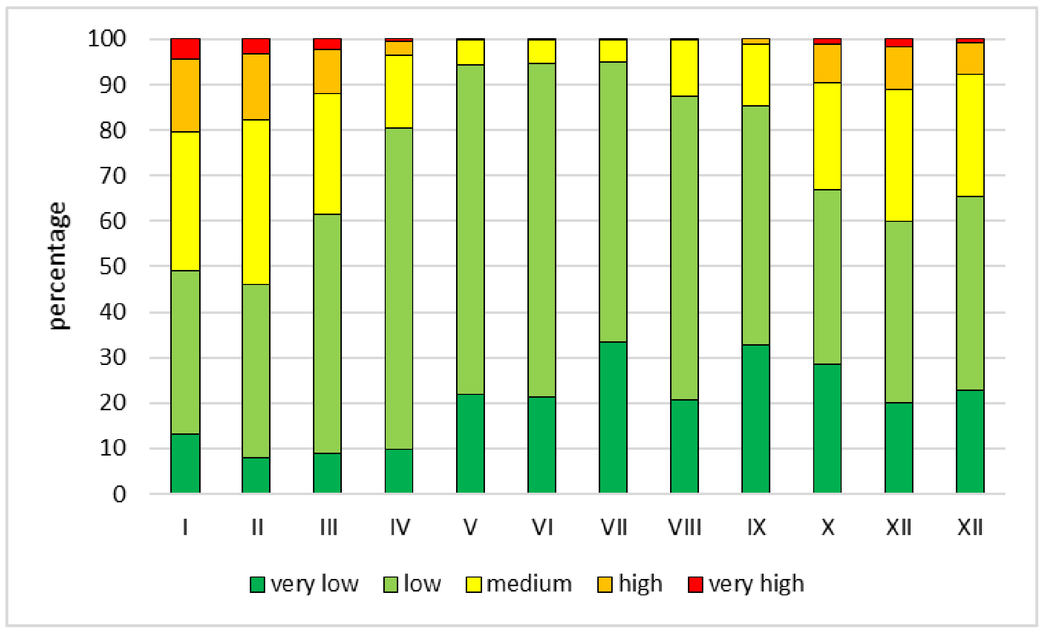
Index class	Grid	City Backround					
		Core Pollutants			Pollutants		
		NO_2	PM10	O_3	PM2.5	CO	SO_2
very low	0	0	0	0	0	0	0
	25	50	25	60	15	5000	50
low	25	50	25	60	15	5000	50
	50	100	50	120	30	7500	100
medium	50	100	50	120	30	7500	100
	75	200	90	180	55	10000	350
high	75	200	90	180	55	10000	350
	100	400	180	240	110	20000	500
very high	>100	>400	>180	>240	>110	>20000	>500

The scale of the estimation of heat stress of the organism according to UTCI (Błażejczyk, Kunert 2011)

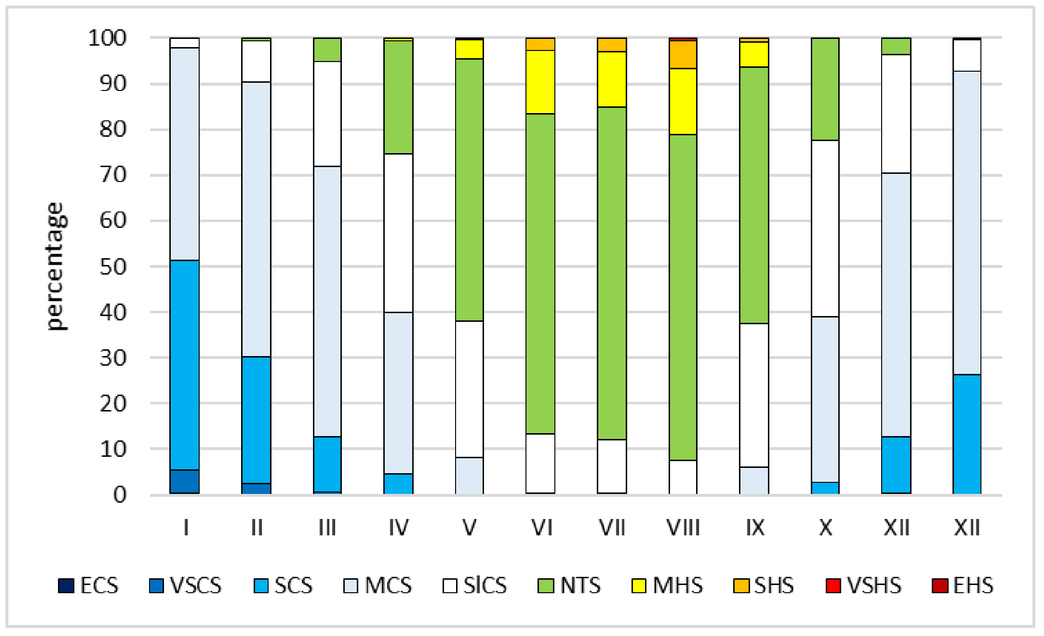
UTCI [°C]	Stress category	Recommendations for protection
> 46	extreme heat stress	periodical cooling and drinking > 0.5 $l \cdot h^{-1}$ necessary; stay without activity
38.1 – 46.0	very strong heat stress	periodical use of air conditionic or shaded sites and drinking > 0.5 $l \cdot h^{-1}$ necessary; reduce activity
32.1 – 38.0	strong heat stress	drinking 0.25 l/h^{-1} necessary, use shade places and reduce activity
26.1 – 32.0	moderate heat stress	drinking 0.25 $l \cdot h^{-1}$ necessary
9.1 – 26.0	thermoneutral zone	physiological thermoregulation sufficient to keep comfort
0.1 – 9.0	slight cold stress	use gloves and cap
-12.9 – 0.0	moderate cold stress (MCS)	increase activity, protect extremities and face against cooling
-26.9 – -13.0	strong cold stress	strongly increase activity, protect face and extremities; use better insulated clothing
-39.9 – -27.0	very strong cold stress	strongly increase activity, protect face and extremities; use better insulated clothing; reduce stay outdoor
< -40.0	extreme cold stress	stay indoor or use heavy, wind protected clothing

RESULTS:

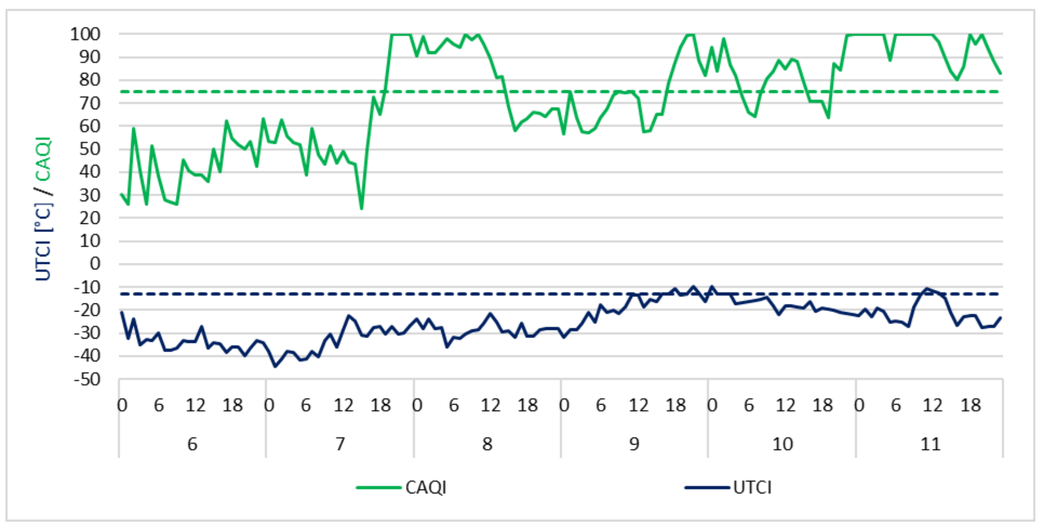
- In analysed period (2015-2019) in Lublin CAQI index most often was low class of air pollution.
- In the annual course high and very high class of CAQI index was observed in cold half of the year, with maximum in January and February.
- The highest values of the index (75 grid) was connected to PM2.5 and PM10 concentration. Other pollutants had minor influence on air quality in Lublin
- High values of CAQI index were often accompanied by unfavourable biothermal conditions (strong heat stress in summer months and strong cols stress in winter months).
- During cold wave of January 2017, strong cold stress was accompanied by low air quality, which intensified the adverse impact of the atmospheric environment on the human body.
- During mega-heat wave of August 2015 there was distinct diurnal course, when strong heat stress conditions were accompanied by elevated level of O3 and PM2.5 and PM10 concentration.
- Due to contemporary climate change there is an increase of biometeorological situations, which combined with low air quality, adversely affect human health.



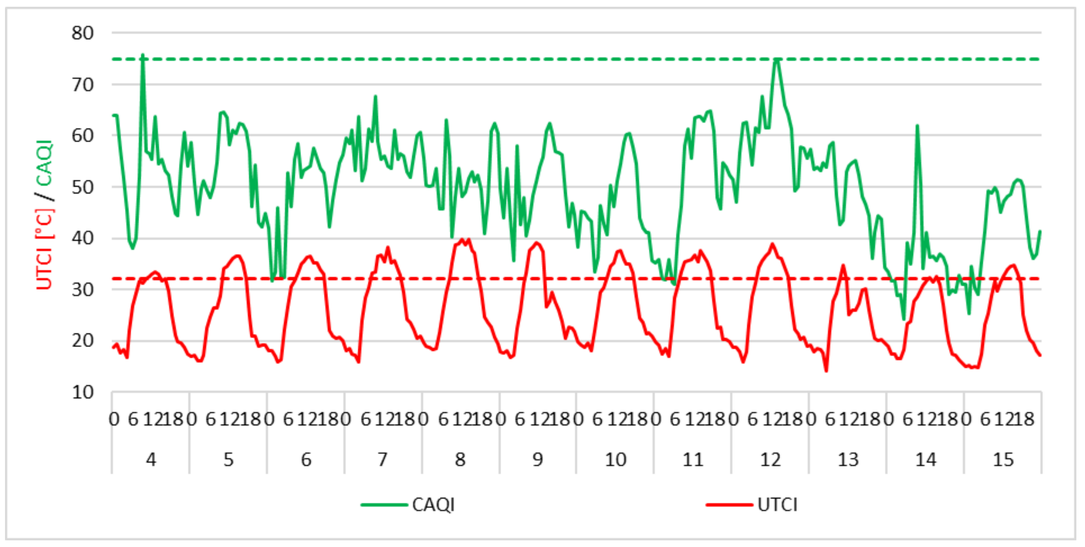
The frequency of occurrence of air quality classes (CAQI) during the day



The frequency of UTCI heat load classes per day



Course of CAQI and UTCI indicators during the cold wave in Lublin on January 6-11, 2017.



Course of CAQI and UTCI indicators during the heat wave in Lublin on August 4-15, 2015.

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