Impact of heat waves (HWs) on air pollution (case study for HWs episode in July-August 2010 in the Kiev city (Ukraine)

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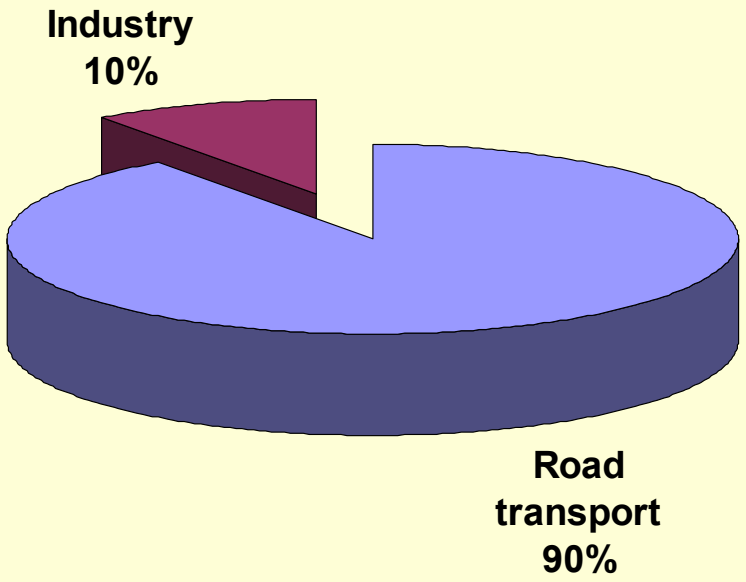
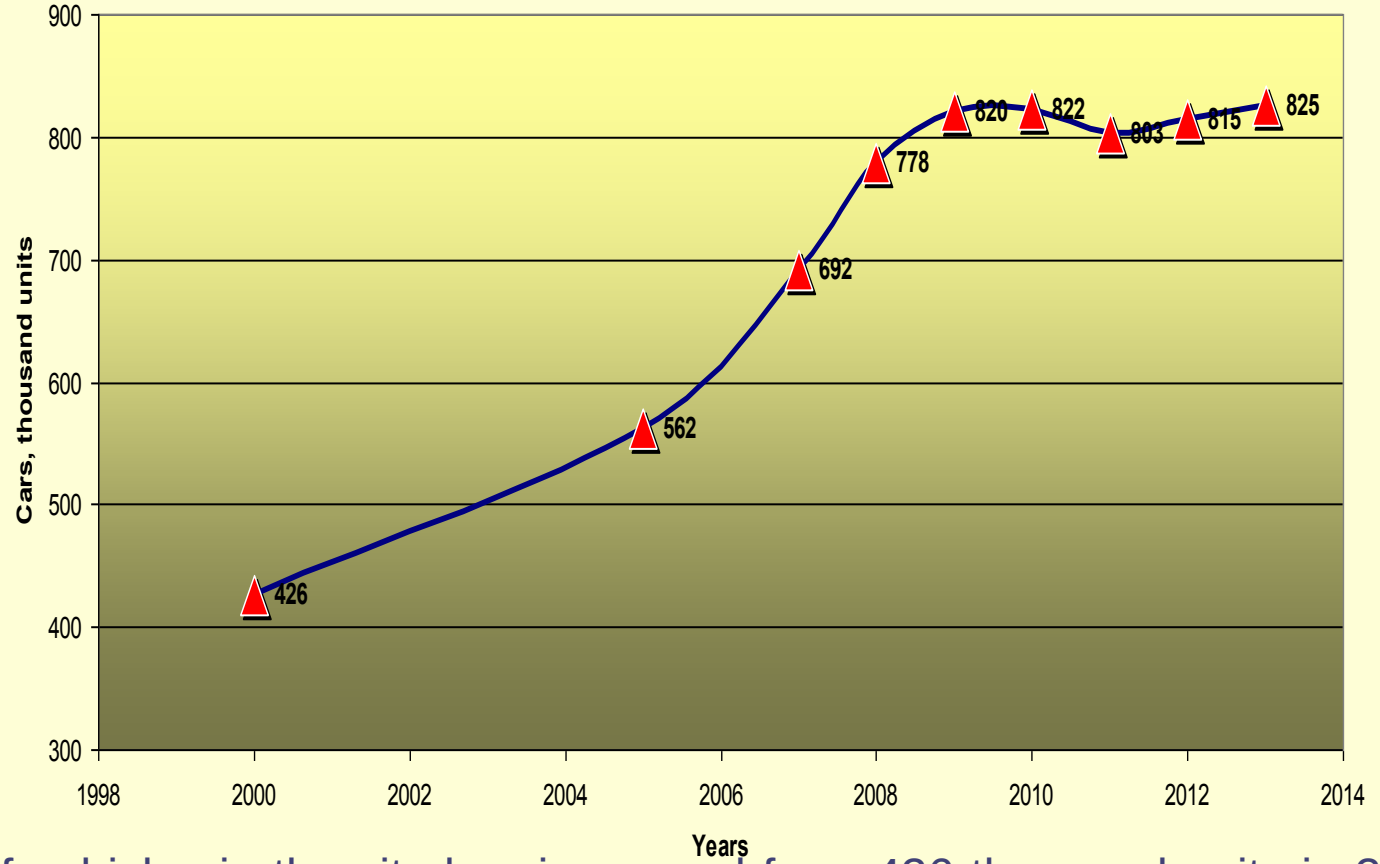
Kiev has a population of 3,14 millions and occupies an area of more than 840 square kilometers

Sources of air pollution in Kiev

- The main sources of air pollution in Kiev are cars. In Kiev, road transport provides almost 90% of all harmful emissions into the atmosphere.

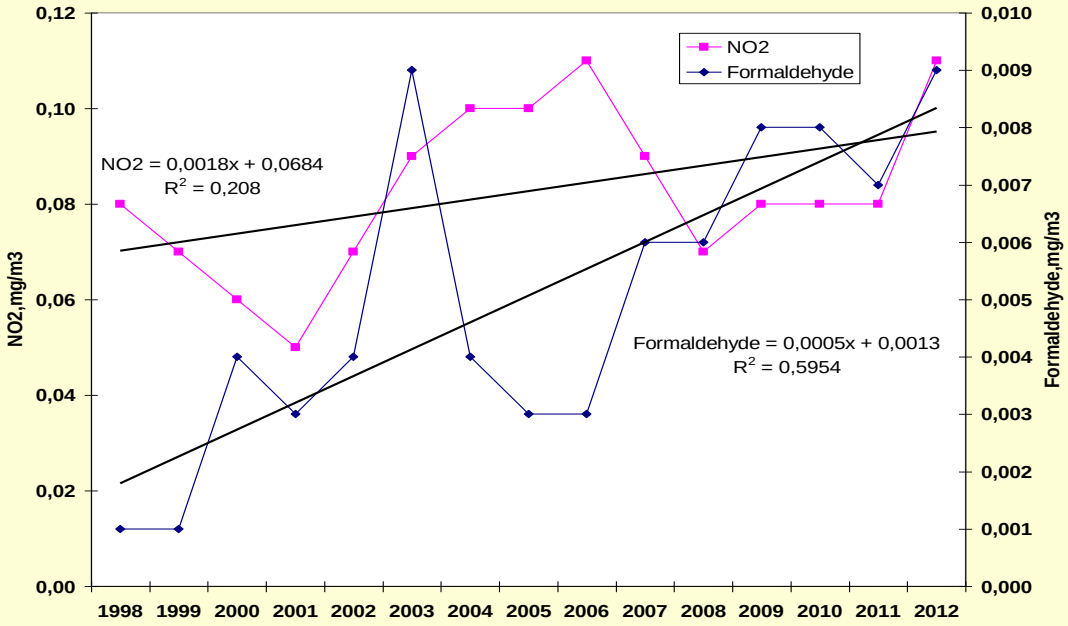


Increasing of numbers of vehicles in the city



Number of vehicles in the city has increased from 426 thousand units in 2000 to 825 thousand units in 2013. In the same time amount the incoming pollutants into the atmosphere from road transport increased from 160 thousand tons in 2000 to 236 thousand tons in 2010.

Temporal dynamics of main pollutants concentrations in the ambient air in the city of Kiev



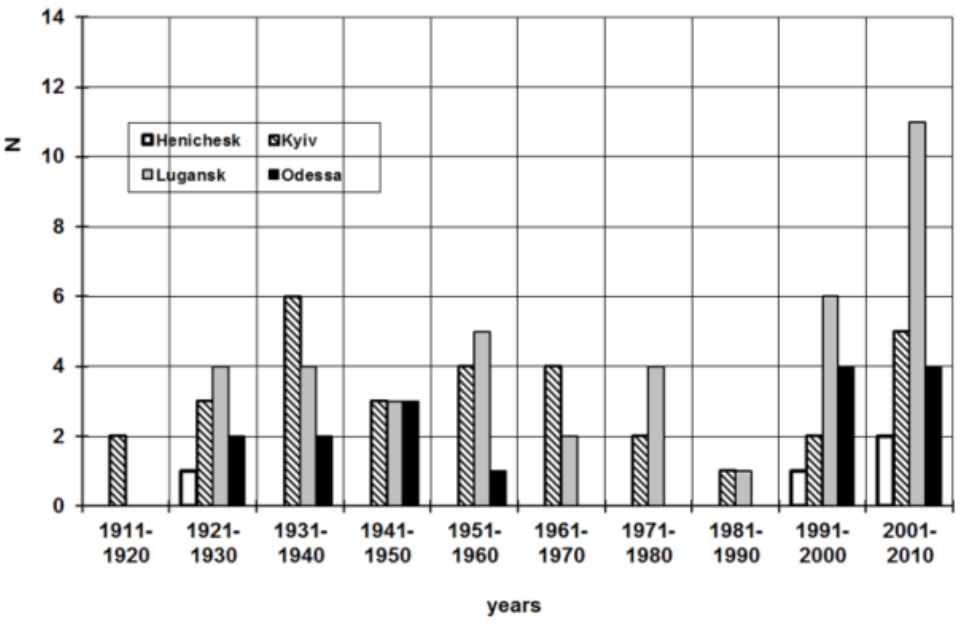
In Kiev were detected a significant increasing in the concentration of some pollutants, especially NO2 (by 50%) and formaldehyde (by 200%) due to the increasing number of road transport in the city.

Mean annual concentrations of formaldehyde in the air have increased in last period **3 times** and concentrations of NO_2 increased in 1,5-2,0 times.

High concentrations of nitrogen dioxide in the air contribute to the formation of photochemical smog. During HWs periods by accelerating photochemical processes it take part as ozone-precursor in photochemical reactions.

Dynamics of Heat wave cases in Kiev

A period of more than 5 consecutive days with daily *T*a,max more than 5 ◦C above the mean daily *T*a,max for the normal climatic period 1961–1990 is dicated as a HEAT WAVE (according to the recommendation of the IPCC).

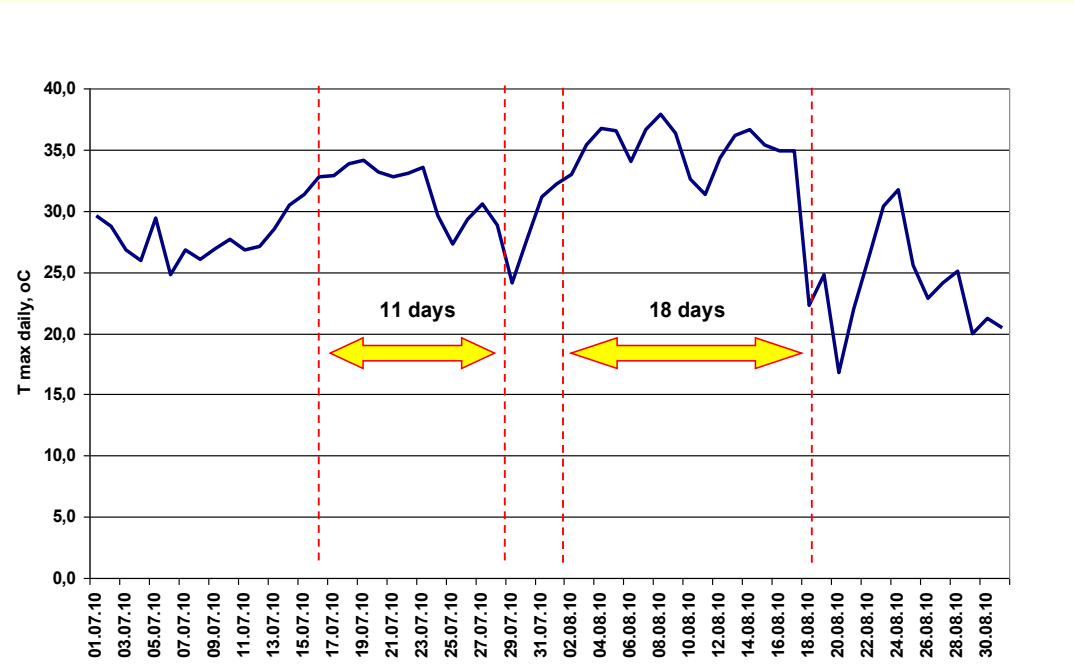


Our study of HWs in Ukraine (Shevchenko et al., 2014) for the period 1911-2011 indicate, that in contrast to other decades, the number of HW episodes was highest for almost all stations in the decade 2001–2010. Heat wave in summer 2010 was very intensitive (the more intensitive HW was observed just once).

HWs in July-August 2010 in Kiev

During July-August 2010 in Kiev were observed two HWs:

1) from 14.07 to 24.07.2010 (11 days);
2) 31.07–17.08.2010 (18 days).



In this study we analyze interactions between meteorology and chemistry for second biggest HW.

During second HW excess of the average daily temperature was at least 5°C;
- about 10 days this excess reached 8-10°C;
- maximal daily temperature reached 38,2°C (8.08.2010).

Heat waves and air pollution

Under meteorological point of view HW are generally associated with quasi-stationary anticyclonic circulation anomalies, which produce subsidence, clear skies, warm-air advection and prolonged hot conditions in the near-surface atmosphere (Fischer et al ., 2007; Barriopedro et al ., 2011).

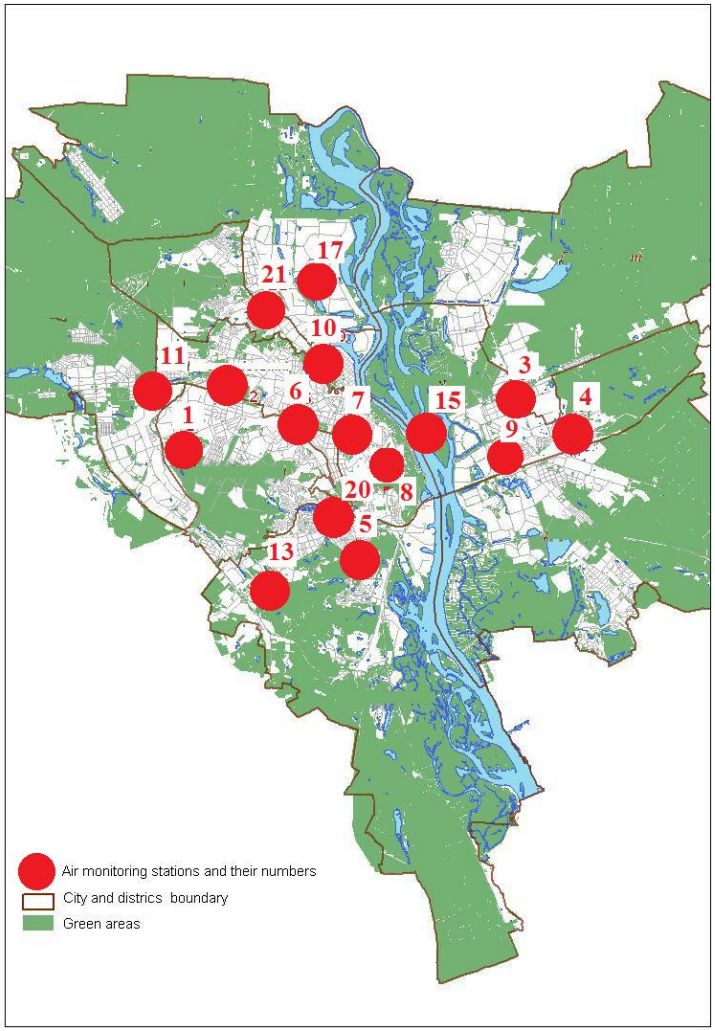
During HWs periods in urban areas created ideal conditions for the accumulation of a number of pollutants and formation of photochemical smog.

First, temperature increases favored the chemical production of ozone in the troposphere.

Second, low atmospheric humidity reduced ozone destruction, as well as the production of the hydroxyl radical, which destroys several air pollutants, including ozone precursors.

Third, the vegetation was affected by high temperature and the lack of precipitation, which led to a substantial reduction in the removal by dry deposition to the Earth's surface of ozone and other compounds

Air quality monitoring net in Kiev

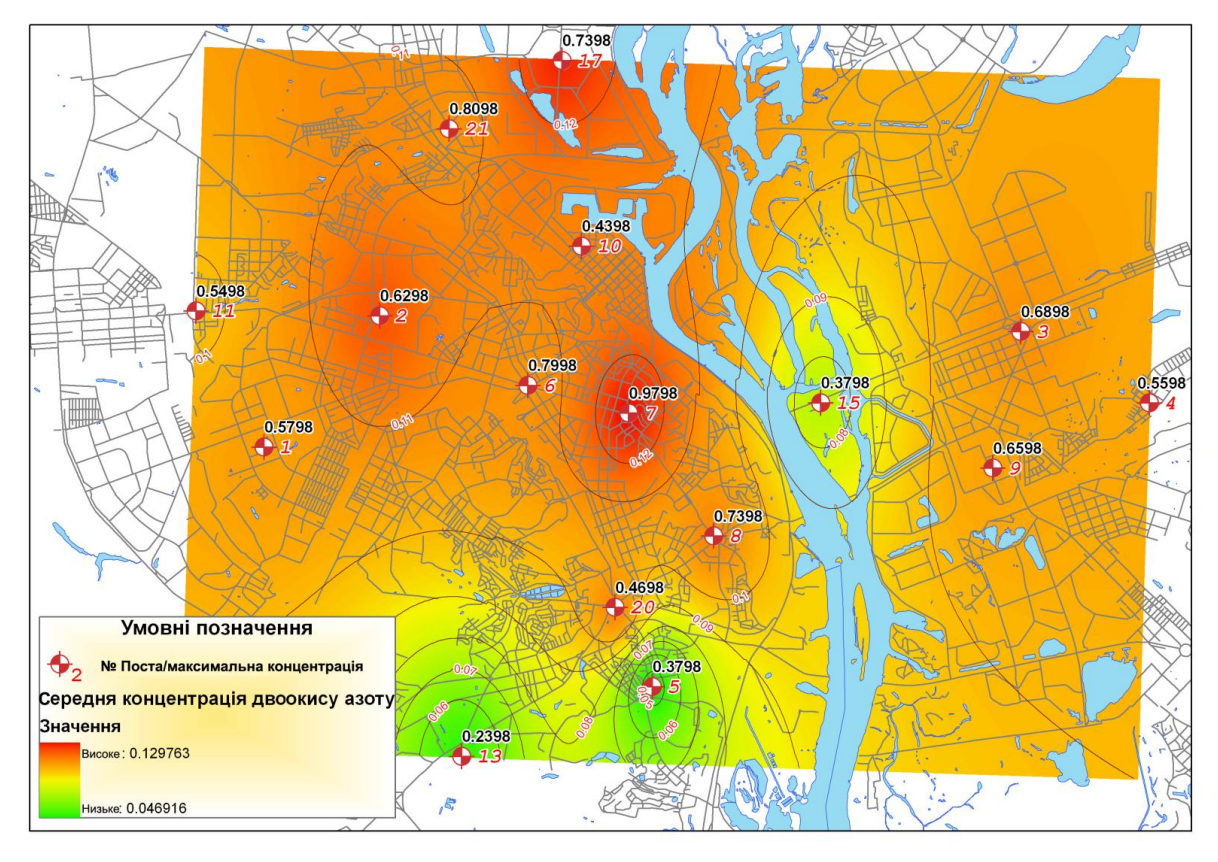


Three stations are on the left bank of the Dnipro river (monitoring station 3, 4 and 9), station 15 is situated on the Venetian island of Dnipro river and **12 stations** are situated on the right bank of the Dnipro and represents air quality in the central part of the city.

Measurement of basic air pollutants makes 4 times per day (at 01, 07, 13, 19 hours).

Stations 6,7

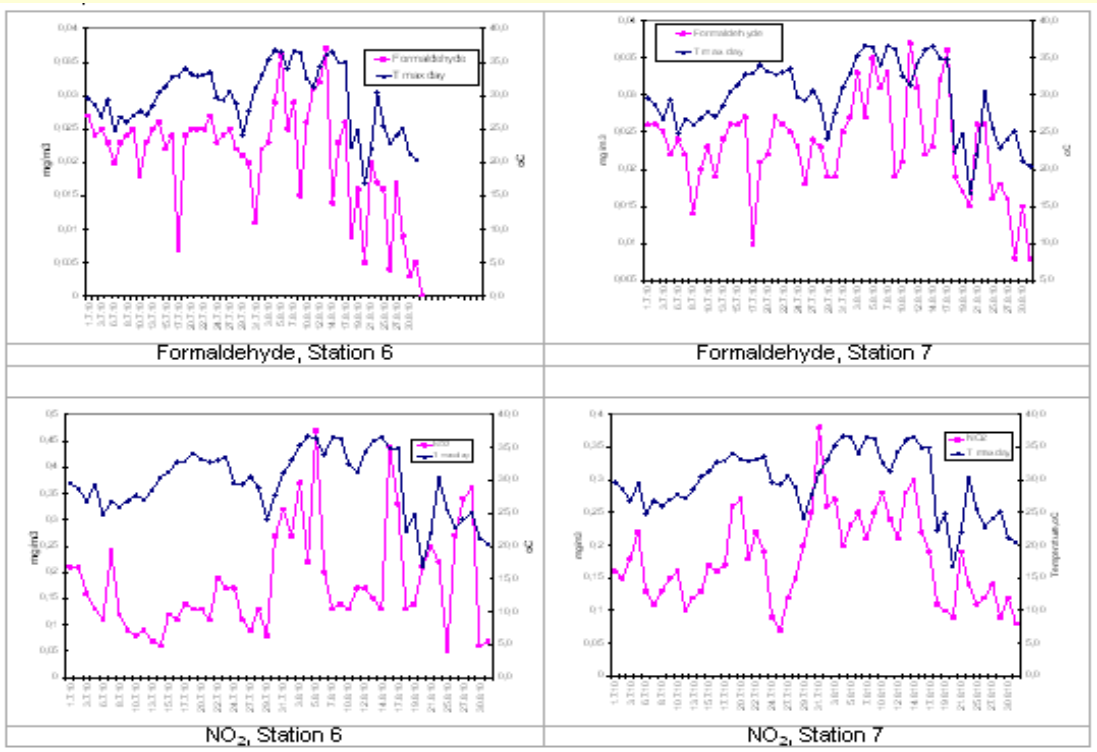
Main precursor of ground-level ozone - NO_2 : spatial distribution of mean annual concentrations in air of the city Kiev, Ukraine



Source: Snizhko S., Shevchenko O. (2011)

0,085 mg/m3 - 0,20 mg/м3

Interactions between meteorology and chemistry during heat waves episode in July-August 2010



All plots shows sufficient increasing both substances during period of HW. Contentration of formaldehyde increases with increasing temperature and reaches a maximum in the hottest days of this period.

Content of NO2 raised at the beginning of the HW and then slightly decreases.

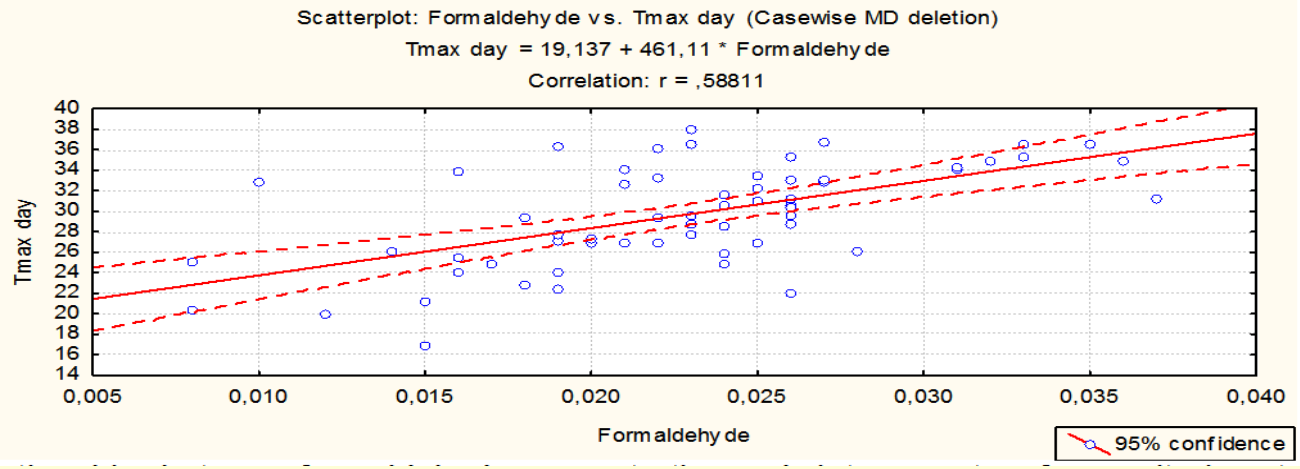
This behavior of NO2 may be connected with his participation in photochemical processes.

Statistical estimation of the impact of HW on air pollution

To estimate the impact of HW on air pollution we have performed a comprehensive analysis of climatic characteristics and some air pollutants, in particular NO_2, formaldehyde.

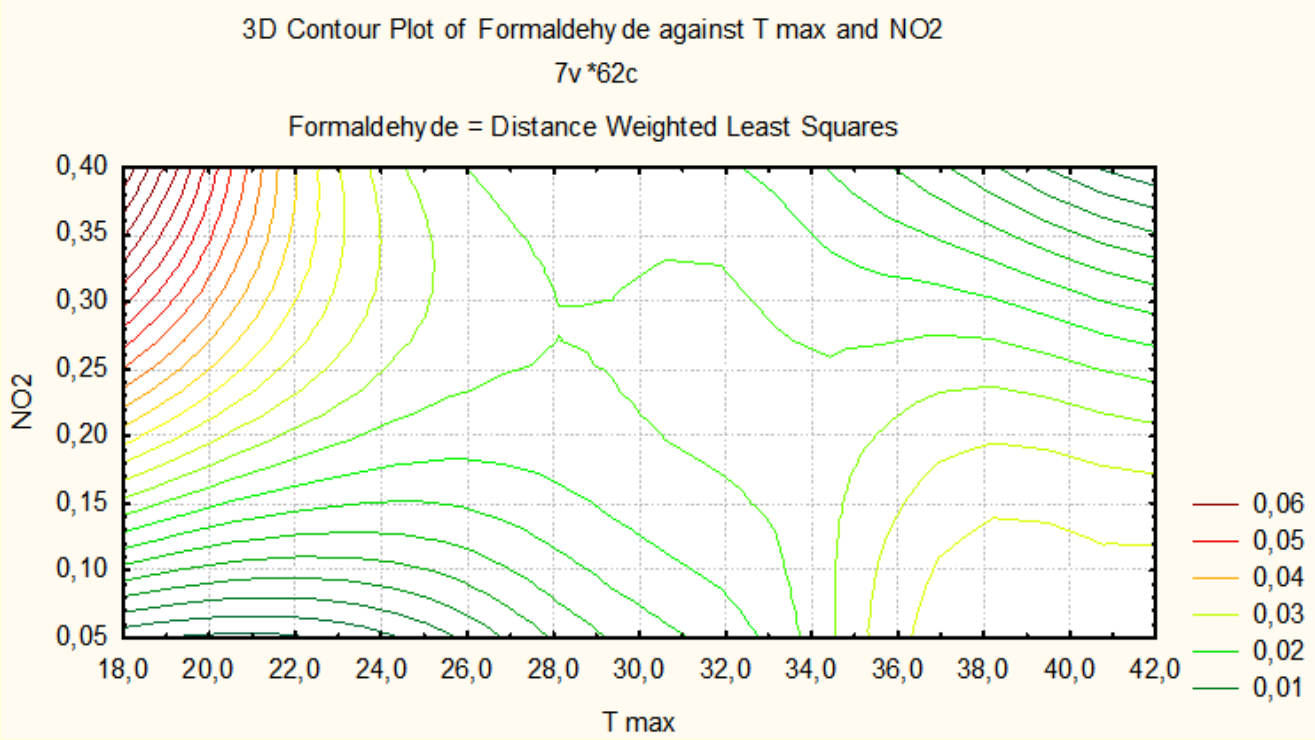
Statistical analysis shoved high positive correlation between temperature indexes and concentrations of pollutants. This can means that oscillation of both substances in the time determined by the same dominant meteorological factor.

Index of T max daily may be a good descriptor of coupled impact of meteorological factor on ozone formation processes in the ground level layer of air.



The impact of temperature on formaldehyde formation confirms a significant value coefficients of correlations between Tmax day and formaldehyde concentration (r=0,588). This relationship was approximated by linear regression equation.

Graphical approximation of relationship between formaldehyde, NO_2 and air temperature



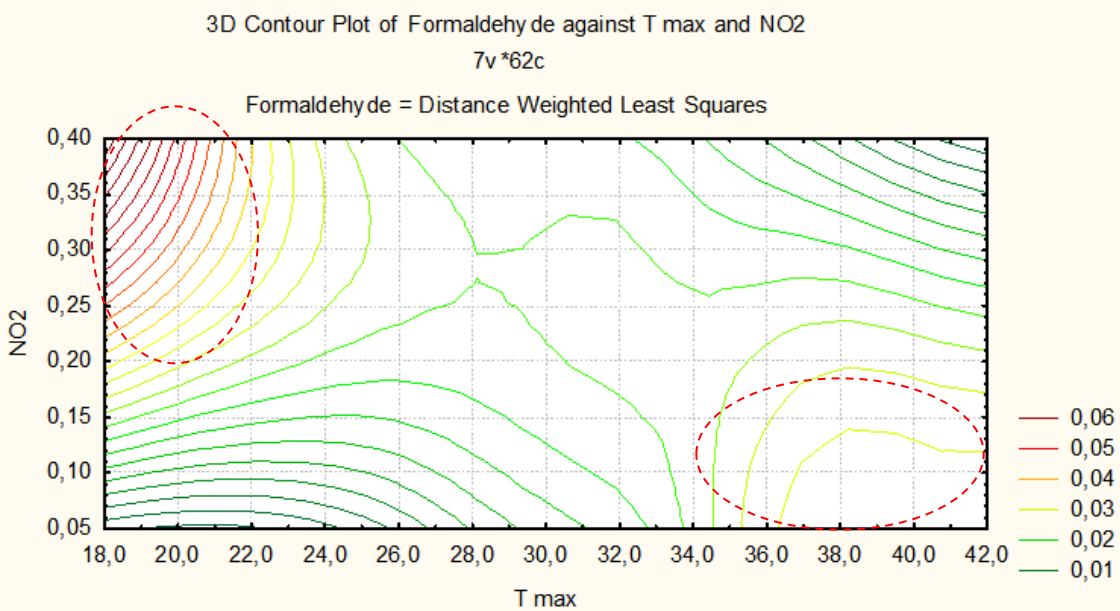
The above data indicate that concentration of formaldehyde depend on temperature and concentration of NO_2. Using the PC-Program “Statistica” we have calculated the relationship between formaldehyde accumulation and leading ozone precursor NO_2 and air temperature and have got relative good approximation of this relationship in form of 3D Contour Plot

Two combination of temperature and NO_2 concentrations tend to formation of highest concentrations of formaldehyde

3D contour plot presents distribution of probably formaldehyde concentration in bright range of air temperature (T max daily) from 18,0 to 42,0ºC and NO_2 concentration from 0,05 to 0,40 mg/m_3. Probability of formation highest concentrations of formaldehyde is possible in two cases:

- highest concentrations of NO2 in range 0,20-0,40 mg/m³ and relatively low for summer HW episode temperature in range from 18,0 to 23,0°C;

- relatively low concentrations of NO_2 in range 0,05-0,20 mg/m³ and very height temperature – 35,0–42,0ºC.

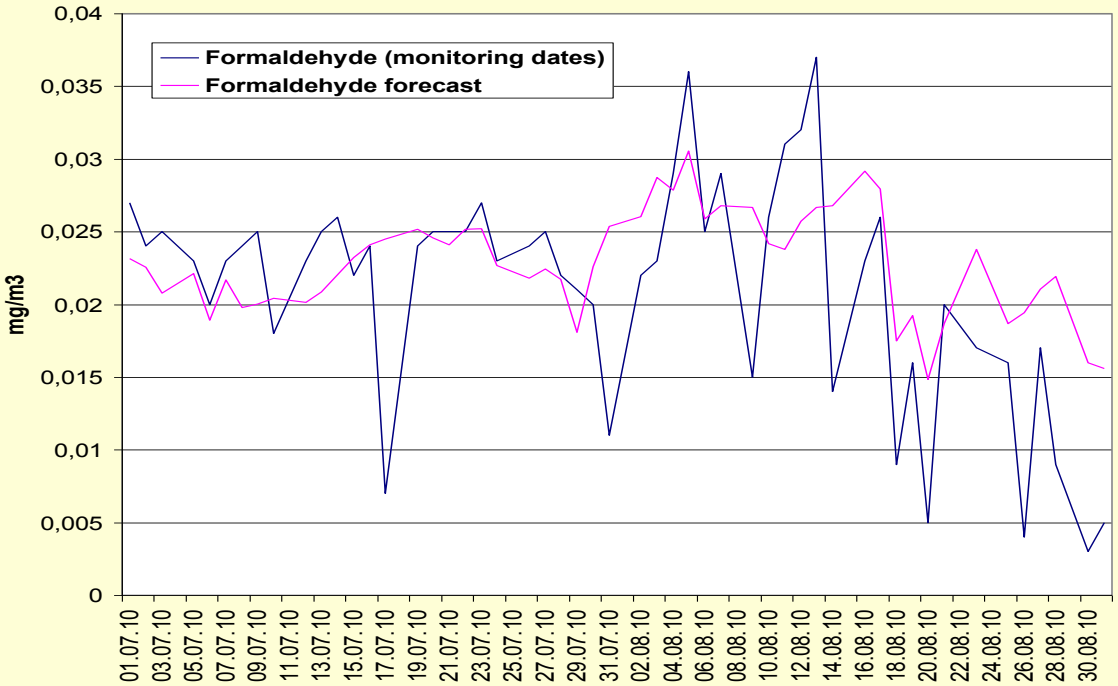


Statistical model of temporal dynamics of formaldehyde during HW

For approximation relationship between formaldehyde, NO_2 and air temperature we have calculated an equation of multiple linear regression:

Formaldehyde (mg/m³) = 0,001577+0,011329 NO_2 (mg/m³)+0,000648 T max day (°C).

Results of retrospective forecast calculation using this this equation and monitoring dates from station 6 shows satisfactory results.



Conclusions

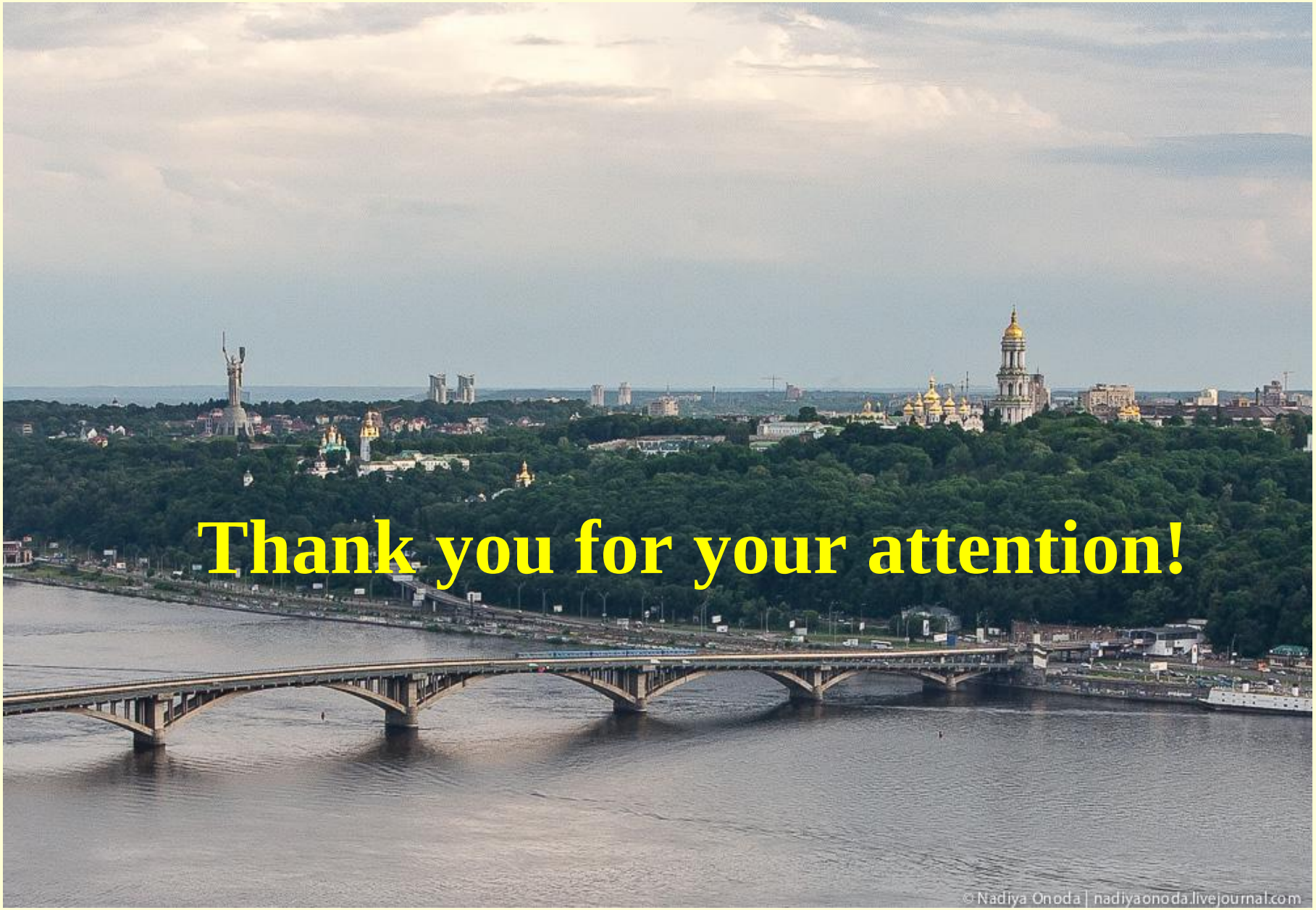
1. In Kiev have been detected a significant increasing of the concentration of some pollutants, especially NO2 (by 50%) and formaldehyde (by 200%) due to the increasing number of road transport in the city.

2. Have been detected sufficient increasing NO2 and formaldehyde during period of HW. Concentration of formaldehyde increases with increasing temperature and reaches a maximum in the hottest days of this period. Concentration of NO2 raised at the beginning of the HW and then slightly decreases.

3. The impact of temperature on formaldehyde formation confirms a significant value coefficients of correlations between Tmax daily and formaldehyde concentration (r=0,588).

4. Was developed statistical model of temporal dynamics of formaldehyde during HW.

This model can use as statistical model for short-time expert assessment of formaldehyde accumulation in urban air during HW cases if not available a more modern numerical forecast models.


Thank you for your attention!
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