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Prognostication of Ozone Concentration in the Air

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Summary: The relation between the ozone concentration and the meteorological parameters is investigated using a real data. A maximal hourly concentration for a day prognostication method is proposed. An initial prognosis is made by the use of regression methods which apply only the meteorological parameters. The prognosis is updated on every hour and here besides the meteorological parameters the last measured ozone concentration is used.

Keywords: Ozone, Prognostication, Regression Model.

1. INTRODUCTION

Ozone is one of the main air polluters with harmful influence over human health. Standards which guarantee the human health protection are defined. They are as follows: health protection level 110 μg/m^3 eight hours mean concentration; informing the public level 180 μg/m^3 one hour mean concentration; warning the public level - 360 μg/m^3 one hour mean concentration.

The aim of the current research is to develop a maximal hourly concentration prognostication model for a twenty-four-hours period in all cases of high health risk.

2. METHOD

2.1 Relation between the ozone concentration and the meteorological parameters

It is well known that the ozone in the atmosphere is formed as a result of photochemical reaction between nitrogen oxides and volatile organic aggregates. In most cases a high ozone concentrations in the air are measured during the summer months. Obviously the meteorological parameters during that time are helping the ozone formation.

Used data
A data for the period 2000-2004, collected in the region of Hasen, Germany is used. All ozone measurement stations also detect the following meteorological parameters: temperature of the air, relative air humidity, wind speed and direction. Some stations measure the sun radiation and/or air pressure in addition. The performed station analysis show that the ozone concentration do not depend on the air pressure and the wind speed. That is why the relation between the ozone and the other three parameters (temperature of the air, relative air humidity and sun radiation) is examined in detail. These three parameters are measured in six stations: Bad Arolsen, Linden, Michelstadt, Nidda, Riedstadt, Wetzlar.

Initial data processing
Days with full set of data for all parameters in all six stations are selected. The total number of these days is 1149. The average values for the parameters in the six stations are calculated, i.e. the relation between the mean ozone concentration in the air for the examined region and the average temperature of the air, the average relative air humidity and the average sun radiation is searched.

Correlation between the ozone and the temperature, the sun radiation and the relative humidity
We found that:

- The correlation between the ozone and the air temperature is high (Fig. 1). The value of R^2 is 0.6995. The relation is non-linear.
- The correlation between the ozone and the sun radiation is smaller (Fig. 2). The value of R^2 is 0.6566.
- The correlation between the ozone and the relative air humidity is the weakest one (Fig. 3) but it is from the same order - the value of R^2 is 0.6424. The relation is non-linear.

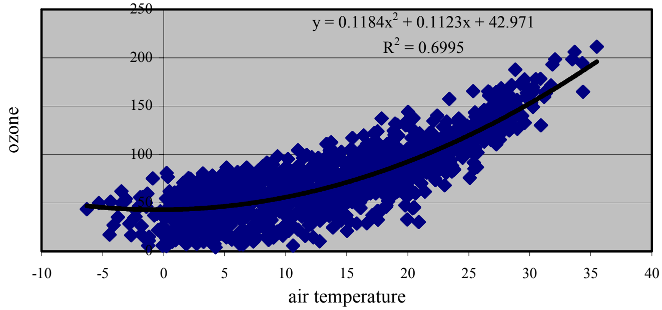

Fig. 1. Correlation between the ozone and the air temperature

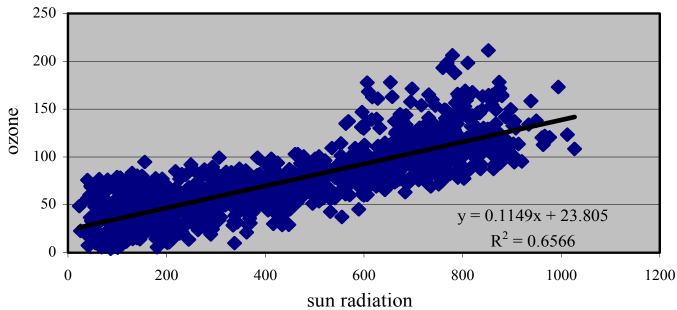

Fig. 2. Correlation between the ozone and the sun radiation

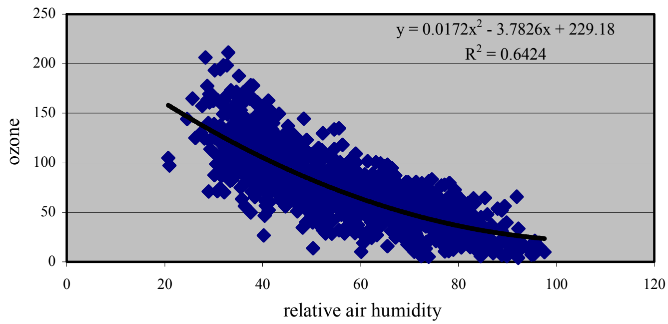

Fig. 3 Correlation between the ozone and the relative air humidity

Correlation between the meteorological parameters

If we want to prognosticate the ozone concentrations, using meteorological parameters, we have to find out how strongly they are mutually related.

We found that:

- The correlation between the sun radiation and the relative air humidity is very strong. The value of R^2 is 0.759.
- The correlation between the sun radiation and the air temperature is smaller. The value of R^2 is 0.623.
- The correlation between the temperature and the relative air humidity is the weakest one. The value of R^2 is 0.4252.

Conclusion

The most suitable meteorological parameters for the ozone concentration prognostication are the temperature and the relative air humidity.

2.2. Regression model

In accordance with the above conclusion, the temperature and the relative air humidity are the two parameters, which have to be used in the model development. The non-linear relation (Fig. 1 and Fig. 3) is a difficulty.

We found that if the ratio between the temperature and the relative air humidity is used, a very simple and good model can be developed. The model can be presented with the following regression equation:

$$y = a_0 + a_1 * (x_1 / x_2)$$

where: y is the maximal daily ozone concentration; x_1 is the maximal daily air temperature; x_2 is the minimal daily relative humidity.

The model was developed with the use of data from the following stations: Bad Arolsen, Linden, Michelstadt, Nidda, Riedstadt, Wetzlar. The ozone concentration, the temperature and the relative air humidity in the model equation are the average values from the six stations. We accept that these are the average values for the whole region.

The obtained value of R^2 is 0.7708.

2.3. Daily cycle of the hourly ozone concentrations

In the previous our research [1] we proved that ozone concentration has a strong daily cycle. Fig.4 shows the daily cycle of the relative hourly ozone concentrations. The cycle was estimated by the average concentrations for the six stations. Only days in which the maximal hourly concentration of 110 μg/m³ is exceeded are included. The relative concentrations are minimal at 5h-6h and after 7h the concentration is growing fast, i.e. the formation and collection of ozone in the air starts after 7h. The maximal relative concentration is reached at 15h and the value of this maximum is 0.95. This means, that the concentration of ozone at 15h is always the maximal daily value or is very close to the maximal value.

Conclusion
If we are able to prognosticate correctly the ozone concentration at 15h, we will be able to prognosticate the maximal hourly concentration for the day in all cases of high health risk.

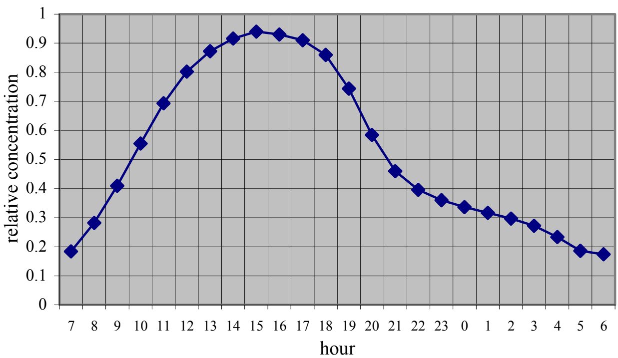

Fig. 4. The daily cycle of the relative hourly ozone concentrations

2.4. Ozone concentration prognostication procedure

The maximal ozone concentration prediction model, which uses the meteorological parameters is further developed and the following procedure is proposed.

Initial prognostication is made by the model

$y = a_0 + a_1 * (x_1 / x_2)$

where: y is the maximal daily ozone concentration; x_1 is the maximal daily air temperature; x_2 is the minimal daily relative humidity.

The prognostication is **updated** at 9h, 10h, ..., 14h according the model:

$$y = a_0 + a_1 * (x_1 / x_2) + a_2 * x_3$$

where: y is the ozone concentration at 15h; x_1 is the air temperature at 15h; x_2 is the relative air humidity at 15h; x_3 is the ozone concentration at the hour of update.

The procedure can be used for a single station or for a whole region. If the procedure is applied for a region, than the ozone concentration, the air temperature and the relative humidity are the average values calculated from the data for all stations located in the region.

3. RESULTS AND DISCUSSION

Education with a set of 938 days (for the period 2000 - 2003) and testing with a set of 280 days (2004) were performed. The average ozone concentration, air temperature and relative humidity for the six stations are used for the purpose.

The obtained results are illustrated in the following tables:

Table 1. R^2 education values

Initial prognosis	9h prognosis	10h prognosis	11h prognosis
0.768	0.850	0.882	0.917
	12h prognosis	13h prognosis	14h prognosis
	0.947	0.973	0.991

Table 2. Average absolute testing error, μg/m^3

Initial prognosis	9h prognosis	10h prognosis	11h prognosis
14.2	11.5	9.9	8.3
	12h prognosis	13h prognosis	14h prognosis
	6.2	4.4	2.5

Table 3. Average relative testing error, %
(for concentrations which exceed 100 μg/m^3)

Initial prognosis	9h prognosis	10h prognosis	11h prognosis
11.6	11.3	10.1	8.9
	12h prognosis	13h prognosis	14h prognosis
	6.4	3.9	1.9

The model performance is illustrated at Fig. 5.

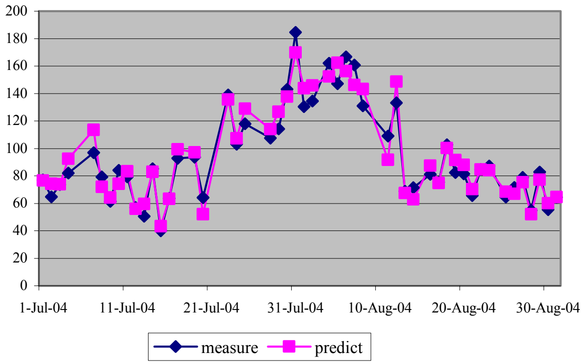

Fig. 5. Average ozone concentrations for the region, measured at 15h and predicted at 12h.

4. CONCLUSION

A maximal hourly concentration for a day prognostication method is proposed. An initial prognosis is made by the use of regression methods which apply only the meteorological parameters. The prognosis is updated on every hour and here besides the meteorological parameters the last measured ozone concentration is used.

The obtained results prove that the prognosis is enough accurate and can be used for public warning in cases of high health risk.

The specified models are valid only for the examined region.

The proposed procedure can be applied for other regions when:

- The initial prognostication uses other meteorological parameters;
- The hourly updating of the prognosis can use besides the ozone and the concentrations of other measured air polluters like nitrogen oxides and volatile organic aggregates.

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