ROAD TRAFFIC CHEMICAL POLLUTION MODELING SYSTEM

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ABSTRACT - Traffic chemical pollution is probably the most serious and pervasive type of pollution from the urban areas. The problem has been compounded by increases in traffic volumes far beyond the expectations of our early urban planners. For the realized study it was choose a route from the historical centre of the Brasov city. The route contains six intersections. The data regarding the traffic flow were collected during the chemical level measurements. The points of the measurements were chosen in function of the intersection's geometry and of the buildings' placement from this area. In order to realize a modeling system for the main air pollutants, it is necessary to analyze all the intersections from this area. In this study is presented the methodology for a chemical pollutants approximation model.

For intersection's analysis there were collected data about the road traffic and data about the chemical pollution in the neighborhood of the road. The volume of the traffic flow was determined by counting the total number of the vehicles, which passed through the intersection during one hour (8.00-9.00 or 15.00-16.00) in all ways. For each intersection ware selected several measurement points for the chemical pollutants monitoring. For measuring the concentration of the chemical pollutants from the studied area it will be used a team of two persons. In order to realize this data base, all the traffic flows data and chemical pollution data registered for the studied intersections, ware collected in work sheets, using Microsoft Excel software. Using the measured data from the intersections, an average pollution level for each of these ones can be established. For model verification, in one of the route intersections ware made chemical pollution measurements.

MAIN SECTION - Automotive Vehicles and Environment

1. INTRODUCTION

Cars, buses and trucks are a source of air pollution. When their engines burn fuels (gasoline or diesel), they produce large amounts of chemicals that are emitted in engine exhaust. In addition, some of the gasoline used by engines vaporizes into the air without having burned, and this also creates pollution. Stringent regulations on engine performance and fuel formulation have brought about a decline in the amount of air pollution produced by individual vehicles. Because we locate in Brasov's Center, we can say that we have a traffic flow close to the saturation limit of the access way. This fact is obvious in the intersections of the studied route. In the central area of the Brasov City can be found the biggest concentration of the carbon monoxide, where the majority in traffic is composed by the vehicles equipped with gasoline engines, where the traffic conditions are admitting their functioning frequently at uneconomical regimes, with partial loads, low engine speeds and uncompleted burnings of the fuel. The nitrogen oxides, the ozone and the VOC are usually specific to the peripheral urban areas, where it can be noticed a high volume of heavy vehicles, which have diesel engines.

2. THE STUDIED AREA

For the pollution level measurement it was chosen the Brasov's historical center area. In this area there are many commercial, cultural and touring objectives: institutions (City Hall, Prefecture, University's buildings, high schools and schools), shops, hotels, churches, museums, theatres, monuments and parks. These objectives bring on each day a high number of pedestrians which are exposed to the pollution caused by road traffic from this area. The analyzed route was: Lunga Street, Eroilor Boulevard, 15 Noiembrie Street, Castanilor Street, Iuliu Maniu Street, Nicolae Iorga Street.

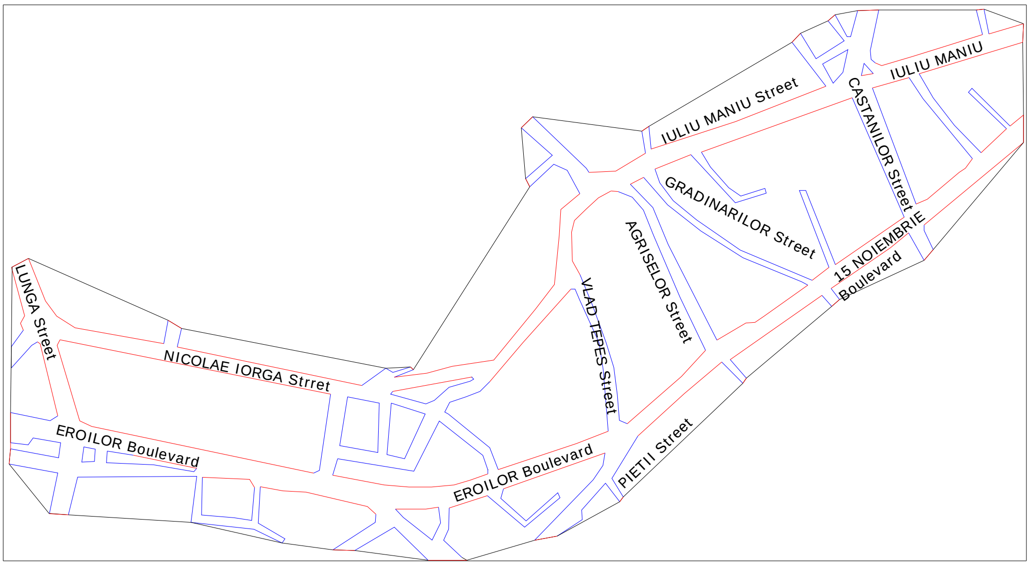


Figure 1. The studied area of Brasov city (the historical centre)

The route includes six intersections, from which four are with traffic lights and two are marked with traffic signs. The six intersections are: Intersection 1 - Castanilor Street + Iuliu Maniu Street; Intersection 2 - Alexandru Ioan Cuza Street + Agrişelor Street + Iuliu Maniu Street; Intersection 3 - Nicolae Iorga Street + Lungă Street; Intersection 4 - Lungă Street + Eroilor Boulevard + Mureşenilor Street; Intersection 5 - Eroilor Boulevard + Vlad Ţepeş Street + Nicolae Bălcescu Street + 15 Noiembrie Boulevard; Intersection 6 - 15 Noiembrie Boulevard + Castanilor Street.

3. ROAD TRAFFIC AND CHEMICAL POLLUTION DATA MEASUREMENT METHODOLOGY

For intersection's analysis there were collected data about the road traffic and data about the chemical pollution in the neighborhood of the road (the values of some pollutants resulted from the fuel combustion). The most common and handy method is the manual collecting of the road traffic data, with the help of an observer team, each member of this team writing down a specific element of the road traffic. For a certain input with variable time signals it is established the following data measurement in order to analyze the intersection: traffic volume, number of vehicles which are passing the stop line, for each traffic direction (forward, left, right), for each vehicle category. In the figure above it is presented a regular intersection with four phases, with observers placed so that to obtain a minimum number of them. In this case, with special turning moves there are necessary more persons, the maximum number being of 5: one for each entrance and the 5th one to measure the time interval [4], [5]. The volume of the traffic flow was determined by counting the total number of the vehicles, which passed through the intersection during one hour (8.00-9.00 or 15.00-16.00) in all ways. For measuring the concentration of the chemical pollutants from the studied area it will be used a team of two persons. The two persons will use the necessary equipment (portable gas analyzer) and will write the specific values of the measurement points [7]. For the chemical measurements was used the MultiRae IR gas monitor. The MultiRae IR combines a PID and carbon dioxide sensor with O_2, LEL and 1 specific toxic gas sensor in one compact monitor with sampling pump. With this gas analyzer can be determined the concentration of the following pollutants: CO, NO, NO_2, H_2S, VOC, O_3, SO_2. The measurements were made for each of the 6 intersections of the route. Simultaneously there were taken the values of traffic flow. The four distinct situations, in function of season and time interval in which the measurement was made are: cold season, morning rush hour (8.00-9.00); cold season, evening rush hour (15.00-16.00); warm season, morning rush hour (8.00-9.00); warm season, evening rush hour (15.00-16.00). Next is presented as an example the scheme of an intersection, with the chosen measurement points in order to make the measurements.

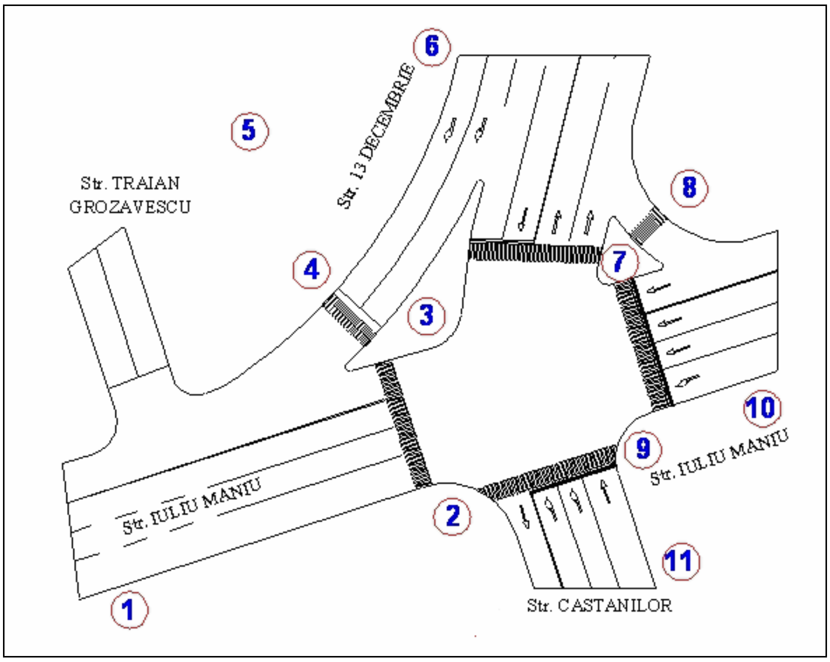


Figure 3. Example: the points where the measurements were done for one intersection

4. ACCOMPLISHMENT OF THE MATHEMATIC MODEL FROM THIS STUDY

Using the measured data from the intersections, it can be established an average pollution level for each of these ones. For each intersection it will be analyzed only the points which are near the road, excluding the points which are far from the road or placed after green areas or other objectives. For each pollutant it will be established an average value, expressed in the corresponding measuring unit. The average will be a rounded arithmetical mean, which will contain all the values obtained in the measurement points, but without the maximum and the minimum value.

$$X_{average} = \frac{\sum_{i=1}^{n} p_i - \min(p_i) - \max(p_i)}{n-2} \qquad (1)$$

where: $X_{average}$ = the average value of the analyzed pollutant; p_i = the value of the pollutant in each of the analyzed points; n = the number of analyzed points for each intersection.

In order to realize the model there were made tables with the traffic values and the values of the three pollutants, in function of the intersections of the analyzed route. For calculus were used the equations corresponding to the determined polynomial curves, for each pollutant, using the values obtained experimentally. The working page of the mathematical model was made grouping the four analyzed situations, for each of the analyzed route. For each of these situations, in each of the two routes, the intersections were sorted increasingly by the number of etalon vehicles.

For each of the studied pollutants there were determined their variations in function of the etalon vehicles number. From the six pollutants that were measured, there were analyzed only three of them: carbon monoxide (CO), volatile organic compounds (VOC) and ozone (O_3). The rest of pollutants weren't analyzed for the following reasons: Nitrogen oxide (NO) – the values of the NO concentration are minimal for most of the intersections (1 [ppm]), abstractions making only some intersections. Sulphuretted hydrogen (H_2S) – the values of H2S concentration varies very little from one season to another or from one time interval to another. Nitrogen dioxide (NO_2) – for the values of NO_2 couldn't be established a dependency in function of the etalon vehicles number.

Table 1 - Winter, 8.00-9.00

Intersection number	Etalon vehicles	CO average [ppm]	VOC average [ppm]	O3 average [ppm]
4	2969	4,1250	2,7500	–
8	3245	4,1670	4,3333	–
9	3657	4,3333	4,8333	–
3	4678	4,7143	5,1429	–
2	4905	4,8000	6,1000	–
1	5451	5,4286	6,2857	–

Table 2 - Winter, 15.00-16.00

Intersection number	Etalon vehicles	CO average [ppm]	VOC average [ppm]	O3 average [ppm]
9	3464	4,5000	3,3333	–
8	3479	4,6667	3,5000	–
2	3869	4,9000	3,5000	–
4	3915	5,1250	4,1250	–
3	4852	5,0000	4,5714	–
1	5289	5,1429	4,7143	–

Table 3 - Sumer, 8.00-9.00

Intersection number	Etalon vehicles	CO average [ppm]	VOC average [ppm]	O3 average [ppm]
3	2248	2,8571	3,5714	0,0100
8	2281	3,1667	6,0000	0,0100
4	3157	3,7500	6,6250	0,0113
9	3158	3,6667	6,3333	0,0117
1	3985	4,0000	7,4286	0,0129
2	4945	5,2000	9,1000	0,0170

Table 4 - Sumer, 15.00-16.00

Intersection number	Etalon vehicles	CO average [ppm]	VOC average [ppm]	O3 average [ppm]
8	2535	2,3333	5,0000	0,0150
9	3064	3,0000	4,8333	0,0133
4	3272	3,2500	6,0000	0,0188
1	3984	4,2857	6,0000	0,0243
2	4083	4,0000	6,1000	0,0290
3	4824	4,8571	6,5714	0,0286

The taken values vary randomly in function of weight of the different vehicles' categories from the road traffic, but also in function of the geometrical parameters of each intersection. For each of the four situations, the intersections were arranged increasingly after the number of etalon vehicles. Next to each intersection there were written the average values of the two pollutants, to represent in a chart the dependence between these two and the number of etalon vehicles. The obtained curves were calculated for each representation of the experimental values (obtained from measurements), obtaining a theoretical curve given by a regression equation. It was whished to obtain a theoretical curve very closed to the curves obtained with the experimental values. For each situation, the resulted theoretical curves will be described through regression equations. Next it will be presented the resulted curves and equations from the analysis, for VOC, for a single situation (cold season, morning rush hour, 8.00-9.00). Simulations were used regression equations for simulations, as follows: linear regression, polynomial regression of second degree, polynomial regression of third degree and exponential regression. These are presented below in graphical representation and the equations.

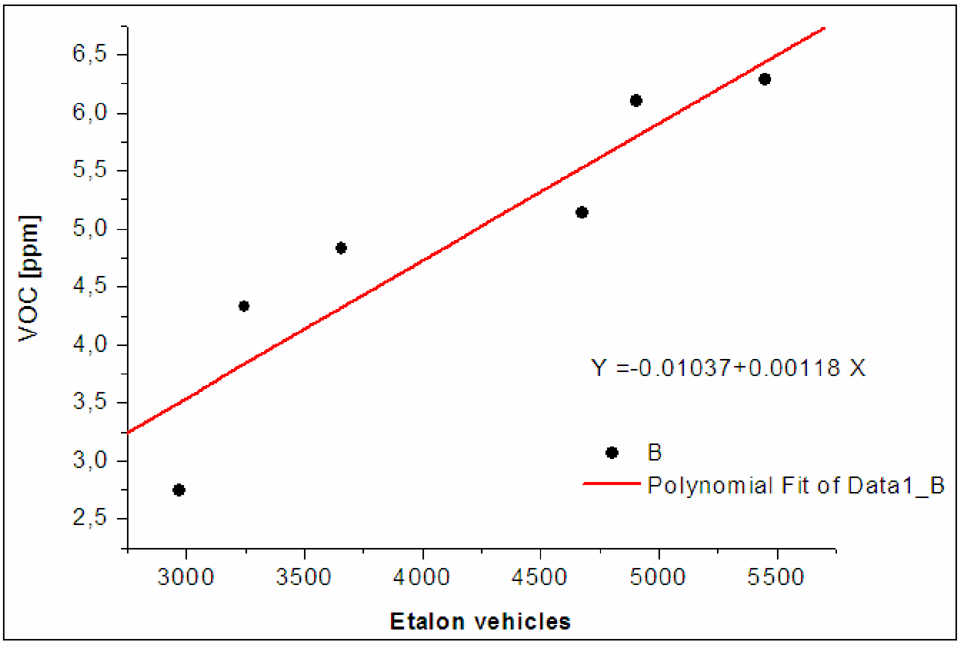


Figure 4. Linear regression and the representative equation

The equation is: $VOC_{theoretical} = -0.01037 + 0{,}00118 \cdot V_E$ *(2)*

Where: $VOC_{theoretical}$ = the theoretical values of the VOC concentrations which describes the variations of the mathematical model curves; VE = the number of etalon vehicles.

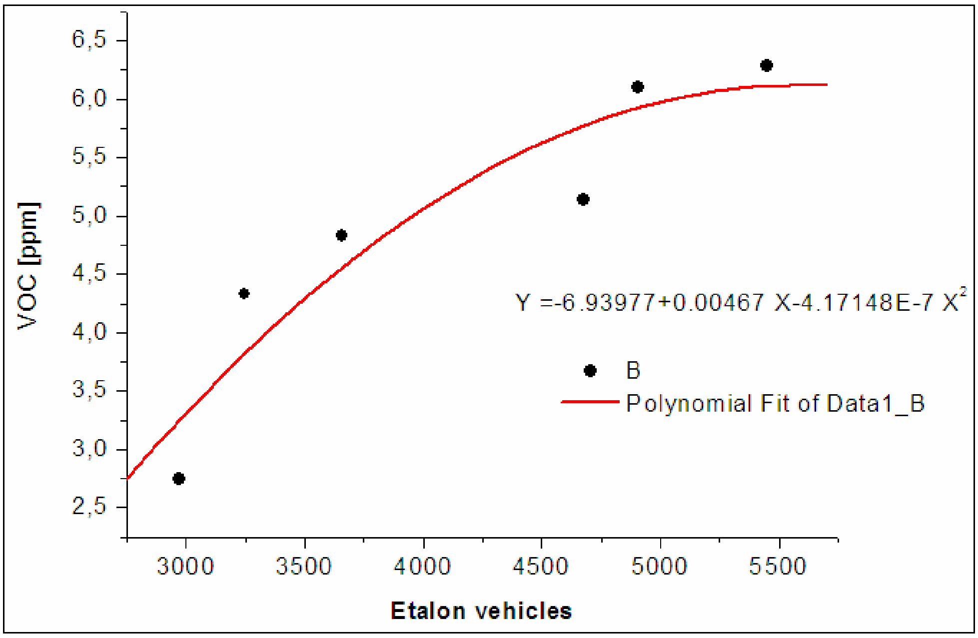


Figure 4. Polynomial regression of second degree and the representative equation

The equation is: $VOC_{\text{theoretical}} = -6.93977 + 0{,}00467 \cdot V_E - 4.17148 \cdot 10^{-7} \cdot V_E^{\,2}$ *(3)*

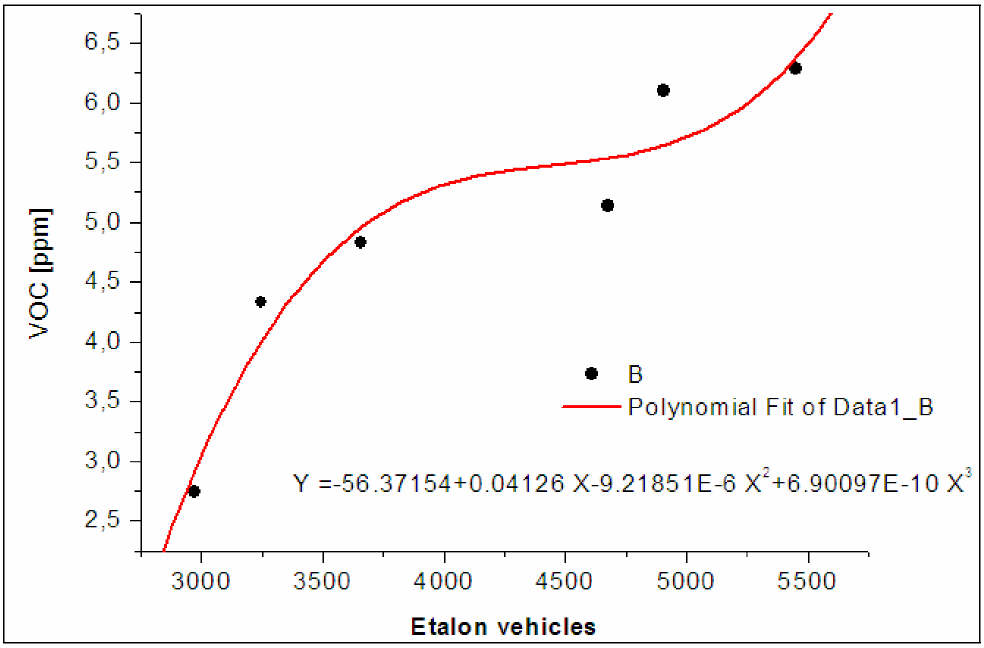


Figure 4. Polynomial regression of third degree and the representative equation

The equation for polynomial regression of third degree is:

$$VOC_{\text{theoretical}} = -56.37154 + 0{,}04126 \cdot V_E - 9.21851 \cdot 10^{-6} \cdot V_E^{\,2} + 6.9009 \cdot 10^{-10} \cdot V_E^{\,3} \quad (4)$$

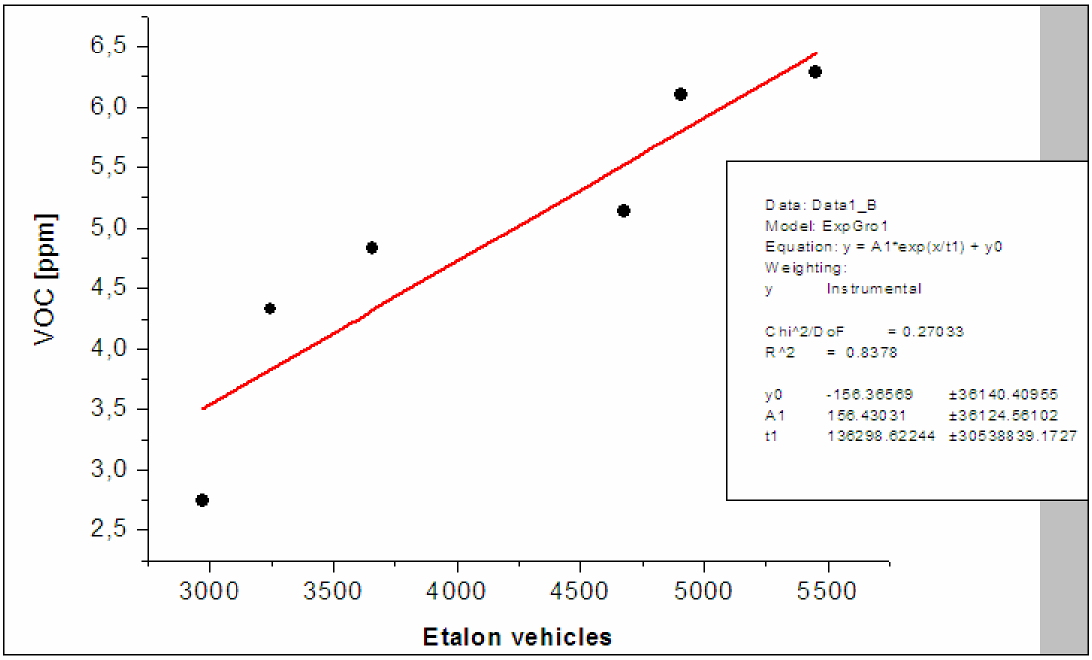
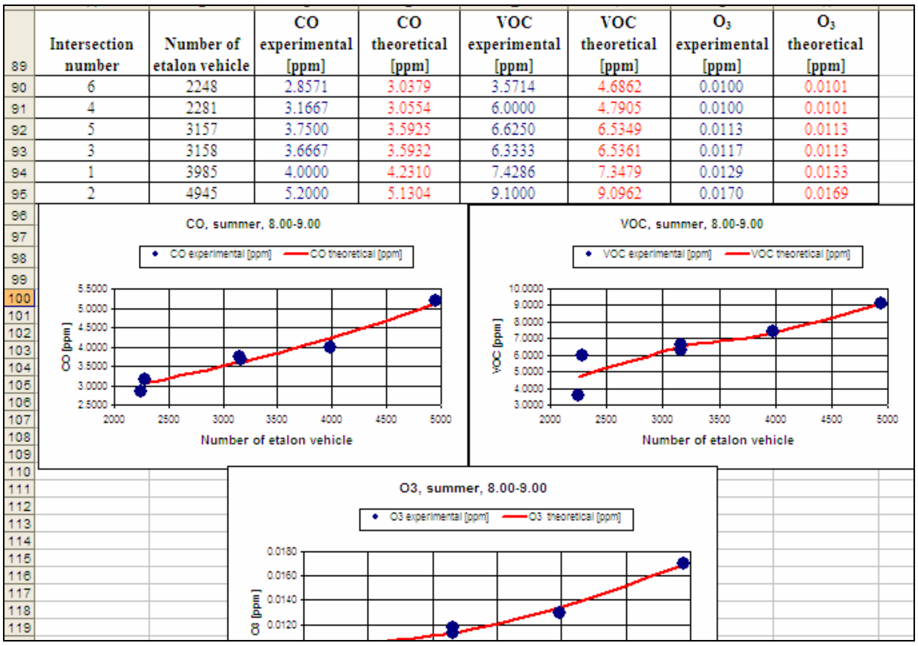


Figure 4. Exponential regression and the representative equation

The equation for exponential regression: $VOC_{theoretical} = 156.43031 \cdot e^{\frac{V_e}{136298.62244}} - 156.36669$ (5)

The most representative solution for each situation can be applied. In most cases were used linear and exponential regression because of their simplicity and smallest errors. For this analyzed chemical compounds, in order to realize a unitary mathematical model, it can be written equations of pollution concentration variation depending on etalon vehicles number measured in one hour time interval.



Intersection number	Number of etalon vehicle	CO experimental [ppm]	CO theoretical [ppm]	VOC experimental [ppm]	VOC theoretical [ppm]	O_3 experimental [ppm]	O_3 theoretical [ppm]
6	2248	2.8571	3.0379	3.5714	4.6862	0.0100	0.0101
4	2281	3.1667	3.0554	6.0000	4.7905	0.0100	0.0101
5	3157	3.7500	3.5925	6.6250	6.5349	0.0113	0.0113
3	3158	3.6667	3.5932	6.3333	6.5361	0.0117	0.0113
1	3985	4.0000	4.2310	7.4286	7.3479	0.0129	0.0133
2	4945	5.2000	5.1304	9.1000	9.0962	0.0170	0.0169

Figure 5. Presentation of mathematical model results for one of the four situations, for the analyzed route

. After the introduction of the formulas and the graphical representation of the three pollutants, result the theoretical curves corresponding to the used equations. In figure 5 are presented the table and the corresponding diagrams for this route, in the warm season and the evening rush hour (15.00-16.00). In the table are presented: the corresponding number for each intersection, the traffic values (etalon vehicles), the average values for the chemical pollutants concentration (determined using the data obtained experimentally) and the pollutants' values obtained through calculus, using the equation of each pollutant compound.

5. CONCLUSION

The prediction model can be used to approximate the air pollution level in urban areas. It can be determined the values of CO, VOC and O_3 concentrations regarding to the number of etalon vehicles in one hour interval (for morning or evening rush hour). The mathematical model can be used for different routes and situations and introducing a number of etalon vehicles for an intersection can be estimated the pollution level for three chemical pollutants. From this study which as realized on the base of the data obtained experimentally can be observed some characteristics of the pollution made by traffic flow: substantial increments of the chemical compounds concentrations resulted from the fossil fuels burning are in the case of transitory functioning of internal combustion engines; the time interval and the season influence visibly the chemical pollutant compounds; the meteorological conditions (temperature, wind's speed and direction, humidity, air pressure) influence the pollutants' values; the traffic's flow composition (cars, trucks, buses, trolleybuses) but also the traffic volume values (expressed by the Traffic capacity = etalon vehicles \ hour) have a determinant role over the city's pollution level; intersection's and main street's geometry on which is developing the city's transitory traffic influences significantly the pollution level; the biggest impact over the air quality, from the areas designated to pedestrians, is given by the traffic road, the pollutant emissions from the vehicles being maximal near the roads, at the height of the human respiratory organs.

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