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APPROXIMATION OF AIR POLLUTION IN CENTRAL AREA OF BRASOV

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Abstract:
Cities are a source of air pollution, but in reality air pollution is the result of a combination of factors. It is the sum of these factors that gives air pollution particular characteristics in a given city. Fuel use is a prime source of air pollution in contemporary cities although there are cities where wind-blown dusts or the long range transport of pollutants, produced at great distance, are dominant sources. The relative contribution of different combustion sources is a function of economic, social and technological factors, but all mixtures contain nitrogen oxides (NO_x), sulphur oxides (SO_x), volatile organic compounds (VOC), carbon monoxide (CO) and ozone (O_3). 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. In order to realize an approximation 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 an approximation model for urban air pollutants.

1. INTRODUCTION

The big development of the industry in the last years has extended and develops the transportation from the all world. Very populated urban and rural areas are directly affected by the mobility increase and by the intense merchandises and population circulation. Road transportation represents the general vehicles and pedestrians movement, concentrated on the land meant on this porpoise (roads). The road traffic phenomenon its manifest in large territories, but also in small areas.

This situation, collaborated with an important fleet grown at international level, it lead at attain the saturation of the motor vehicles rate in metropolitan areas around the world. In 2008, in Europe exist over 300 millions vehicles, and the grown rate over 2007 was 2.8 [%]. In this case the principal problems that appear were the road transportation pollution. The road transportation with internal combustion engines vehicles has an important impact on air pollution, affecting all ecosystems [1].

The combustion process results in emissions of VOC, NO_x, PM, and CO, which are released from the tailpipe while a vehicle is operating. VOC also escape into the air through fuel evaporation. Despite evaporative emissions controls, evaporative losses can still account, on hot days, for a majority of the total VOC pollution from current model cars. VOC and CO emissions rates typically drop as speed increases. NO_x emissions rates turn up at higher speeds. Emissions rates at all speeds have been falling over time as newer, more controlled vehicles enter the fleet. Emissions rates are higher during stop-and-go, congested traffic conditions than free flow conditions operating at the same average speed [3].

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.

The polluted environment impact on human health is very varied and complex. This can manifest through small inconveniences in human activity (discomfort), or through strong health disturbances. The most severe damaging effects related to pollution from traffic are found in urban areas. It is here that the traffic density is largest and concentrations of car exhaust gases are often orders of magnitude higher than in rural areas. Urban areas can still not be considered as homogeneous entities; the largest pollution levels occur in street canyons where dilution of car exhaust gases is significantly limited by the presence of buildings flanking the street.

The approximation of chemical pollutants can by made using linear, exponential or polynomial regressions, Gaussian models, Lagrangian model, etc. The Romanian, US, European and Asian studies shown that this pollutants can by approximated in function of different parameters using mathematical models [5].

2. CHARACTERISTICS OF STUDIED AREA

In the metropolitan areas the most sensitive places are the residential areas, commercial areas, historical zone of the city and the main institutions. In this case the selected route is the one that cross through historical center of the city and make the connection to the residential areas. In this study, for the Brasov city was selected the town's historical center area. The analyzed route was: Iuliu Maniu Street, Nicolae Iorga Street, Lunga Street, Nicolae Balcescu Street, 15 Noiembrie Street, Castanilor Street. The six analyzed 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 - Lunga Street + Eroilor Boulevard + Muresenilor Street; Intersection 5 - Eroilor Boulevard + Vlad Tepes Street + Nicolae Balcescu Street + 15 Noiembrie Boulevard; Intersection 6 - 15 Noiembrie Boulevard + Castanilor Street.

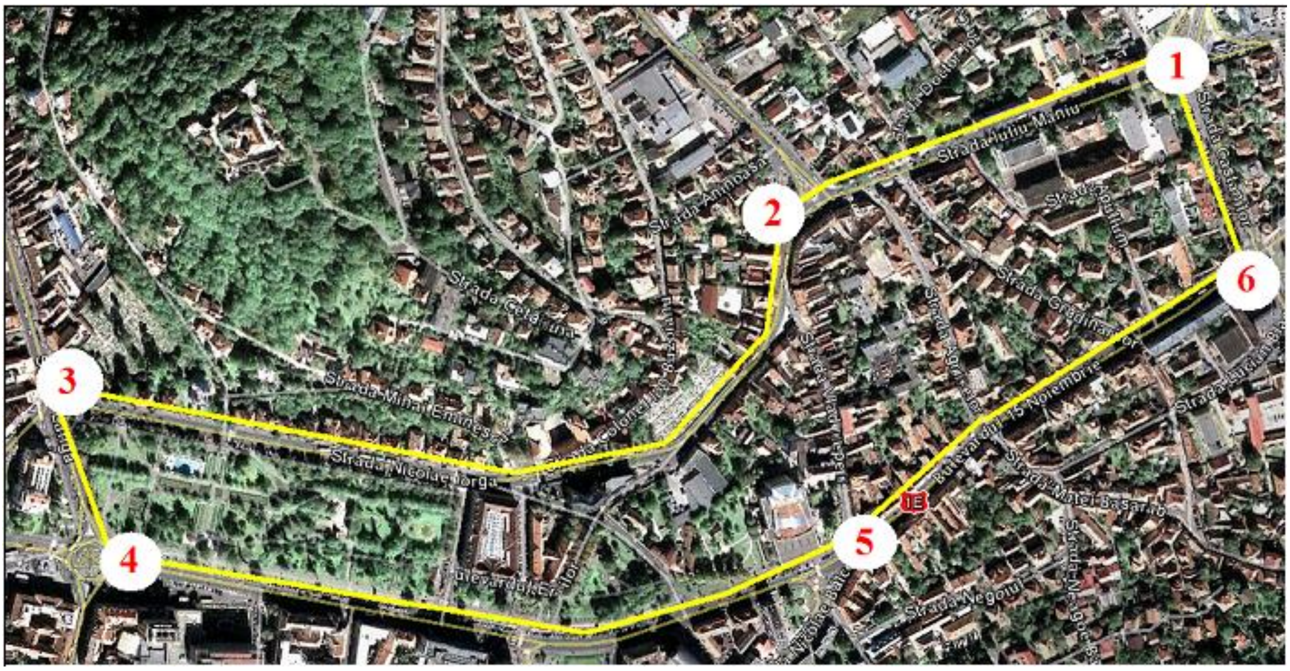

Fig. 1. The studied route from Brasov city.

3. TRAFFIC FLOWS 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. 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. For the chemical measurements was used the MultiRae IR gas monitor. 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 [2,3].

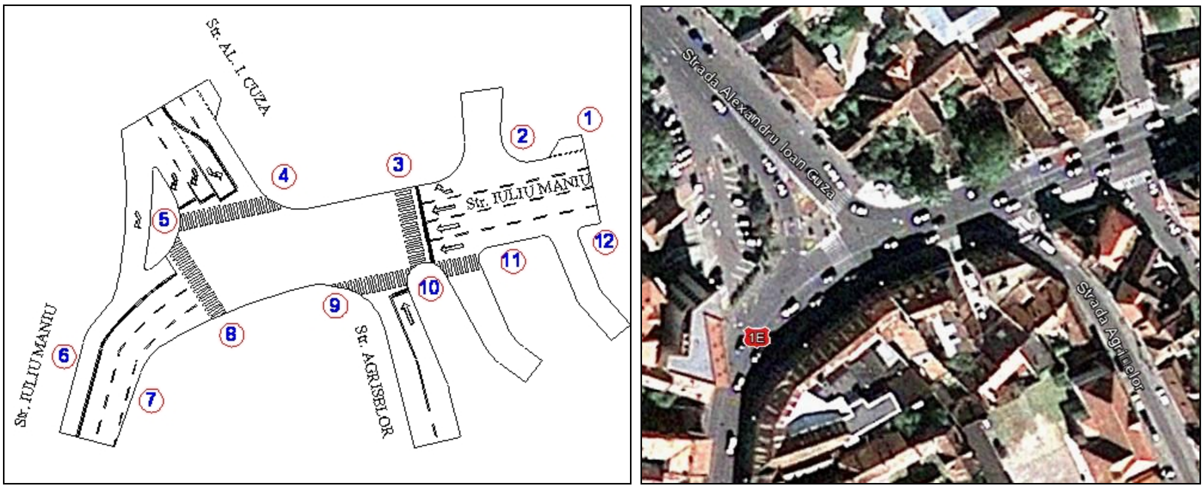

Fig. 2. The points where the measurements were done for one intersection (2).

4. ACCOMPLISHMENT OF THE APPROXIMATION MODEL

In order to accomplish a chemical pollution approximation model in function of traffic flow, will be used several variable functions. The approximation model will be decided in function of studied area geometrical and meteorological parameters. This model can use for chemical pollutants approximations, linear, exponential, polynomial regressions or Gaussian / Lagrangiane models.

Establishment of the chemical pollution prediction mathematical model in function of traffic flow steps are: accomplishment of a data base for traffic and chemical pollution values; pollutants analyses; establishment of the pollutants concentration approximation method; obtaining the mathematical model of chemical pollutants variation in function of the traffic flow; using the mathematical model for chemical pollution prediction in similar areas (urban areas) [1].

In order to realize the 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. For chemical pollution analyses will be established worksheets that contain measured values and graphic representations for each studied route, in function of season and hour interval. The concentration variation of three chemical pollutants (CO [ppm], VOC [ppm], O_3 [ppm]), specific to the areas near the road' infrastructure for the two analyzed time intervals is presented in the next graphics (for one intersection):

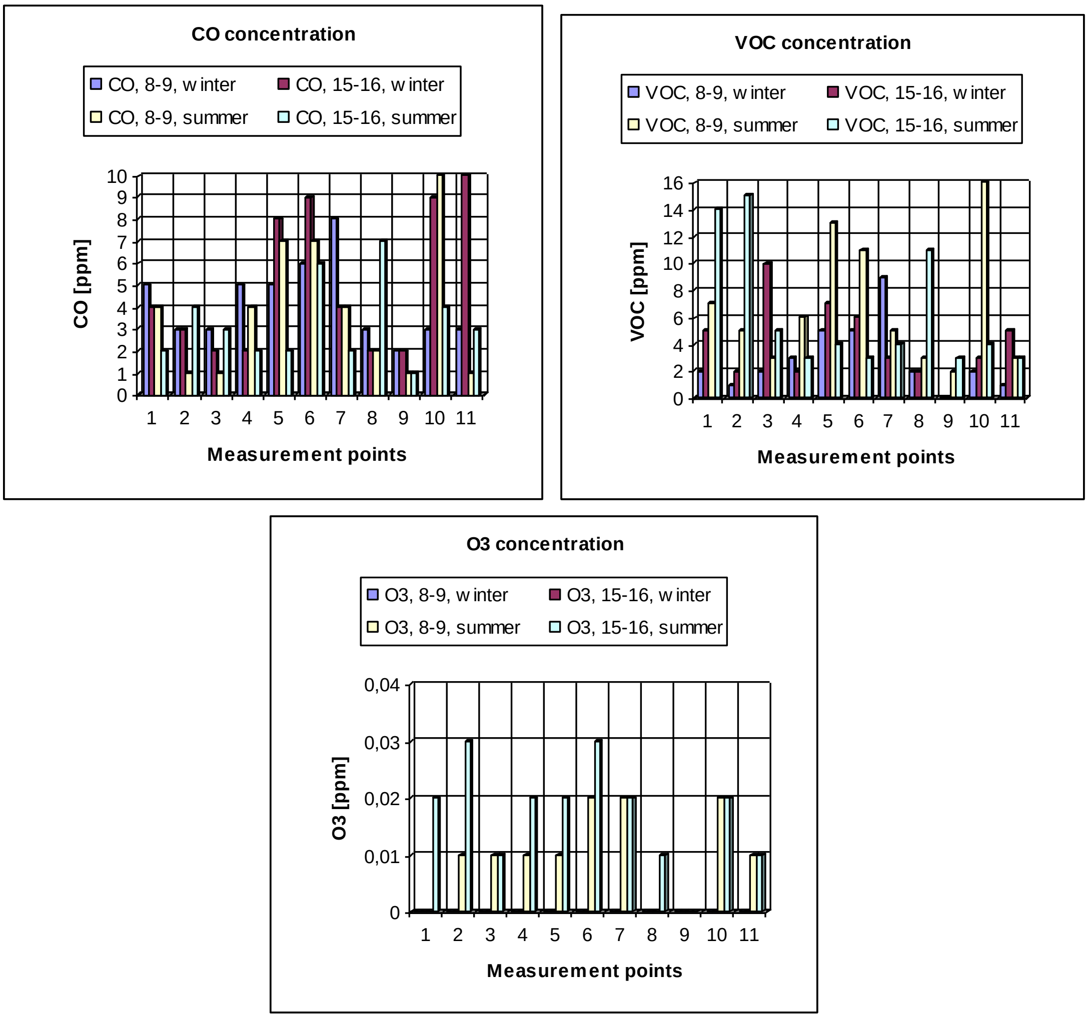

Fig. 3. The concentration variation of CO, VOC and O3 [ppm] for Intersection 4 - Eroilor Boulevard + Vlad Tepes Street + Nicolae Balcescu Street + 15 Noiembrie Boulevard.

From the six pollutants for which were made measurements, there were analyzed only three and these are: carbon monoxide (CO), volatile organic compounds (VOC) and ozone (O_3). The rest of the pollutants were not analyzed for the following reasons: nitrogen monoxide (NO) – the values of the NO concentration are for most of the intersections minimum (1 [ppm]); suppurated hydrogen (H_2S) – the values of the H_2S concentration varies very little from one season to another, and is not specific to vehicles; nitrogen dioxide (NO_2) – the values of the NO_2 concentration varies depending on the season and on the time interval when the measurements were made. The values are between 0.1 and 0.2 [ppm] for most of the cases. Though, it could not be established a dependency of the NO_2 concentration in function of the etalon vehicle number. The values measured vary randomly in function of the weight of different categories of vehicles from the road traffic, but also in function of geometrical parameters of each intersection.

Will be used the one variable function numerical approximation models. The approximation model choosing it will be decided in function of studied area geometrical and meteorological parameters. This model can use for chemical pollutants approximations, linear, exponential, polynomial regressions or Gaussian / Lagrangiane models. To obtain the pollutant concentration variation curves and to establish the mathematical equation for each curve, it can be used ORIGIN Pro software.

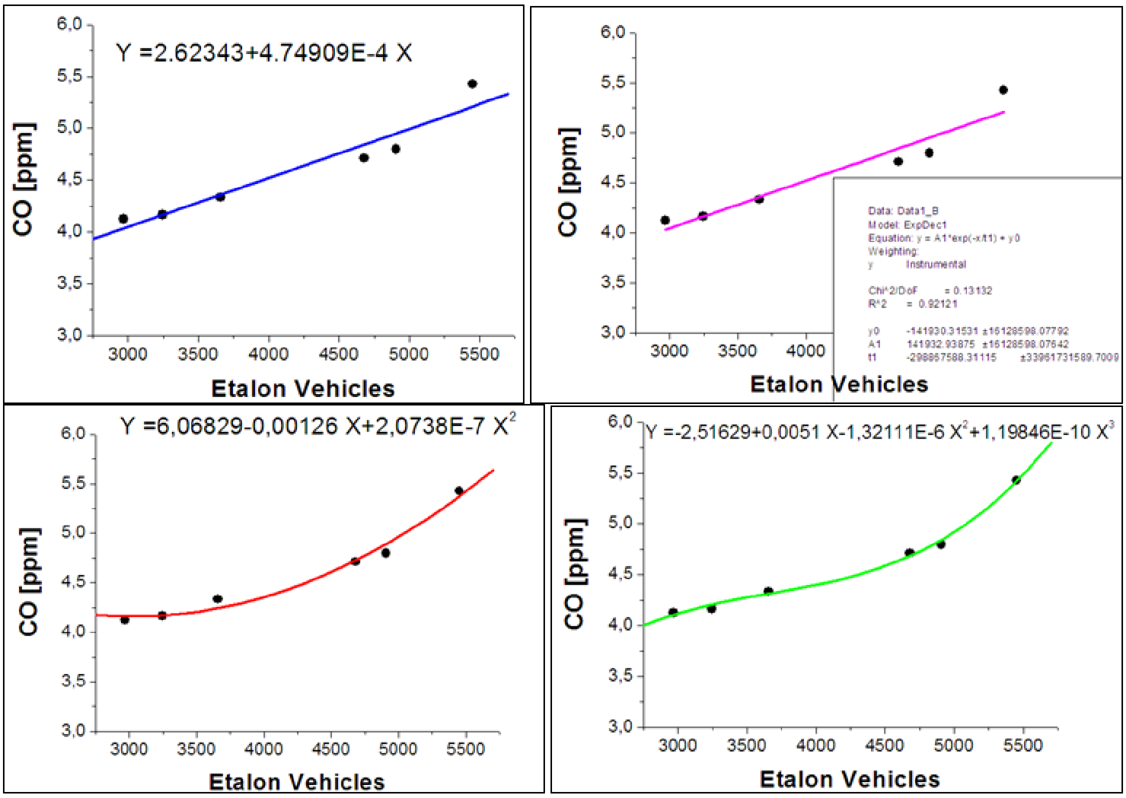

Fig. 4. The linear, exponential, polynomial (second and third degree) regressions used for CO level.

In order to realize the model, tables with the traffic values and the values of the studied pollutants were made, depending on the intersections of the analyzed route. That will result chemical pollution worksheets. Every worksheet will be composed from tables that contain: intersection number; etalon vehicles / hour number; experimental values for each pollutant; values resulted after mathematical modeling.

Using the measured data from the intersections, an average pollution level for each of these ones can be established. For each intersection, only the points which are near the road were analyzed, excluding the points far from the road or placed after green areas or other objectives. For each pollutant an average value, was established expressed in the corresponding measuring unit. The average was a rounded arithmetical mean, which contained 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 exponential regression curves, for each pollutant, using the values obtained experimentally. The working page of the mathematical model was made grouping the four analyzed situations, for the analyzed route. For each of these situations, 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. 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.

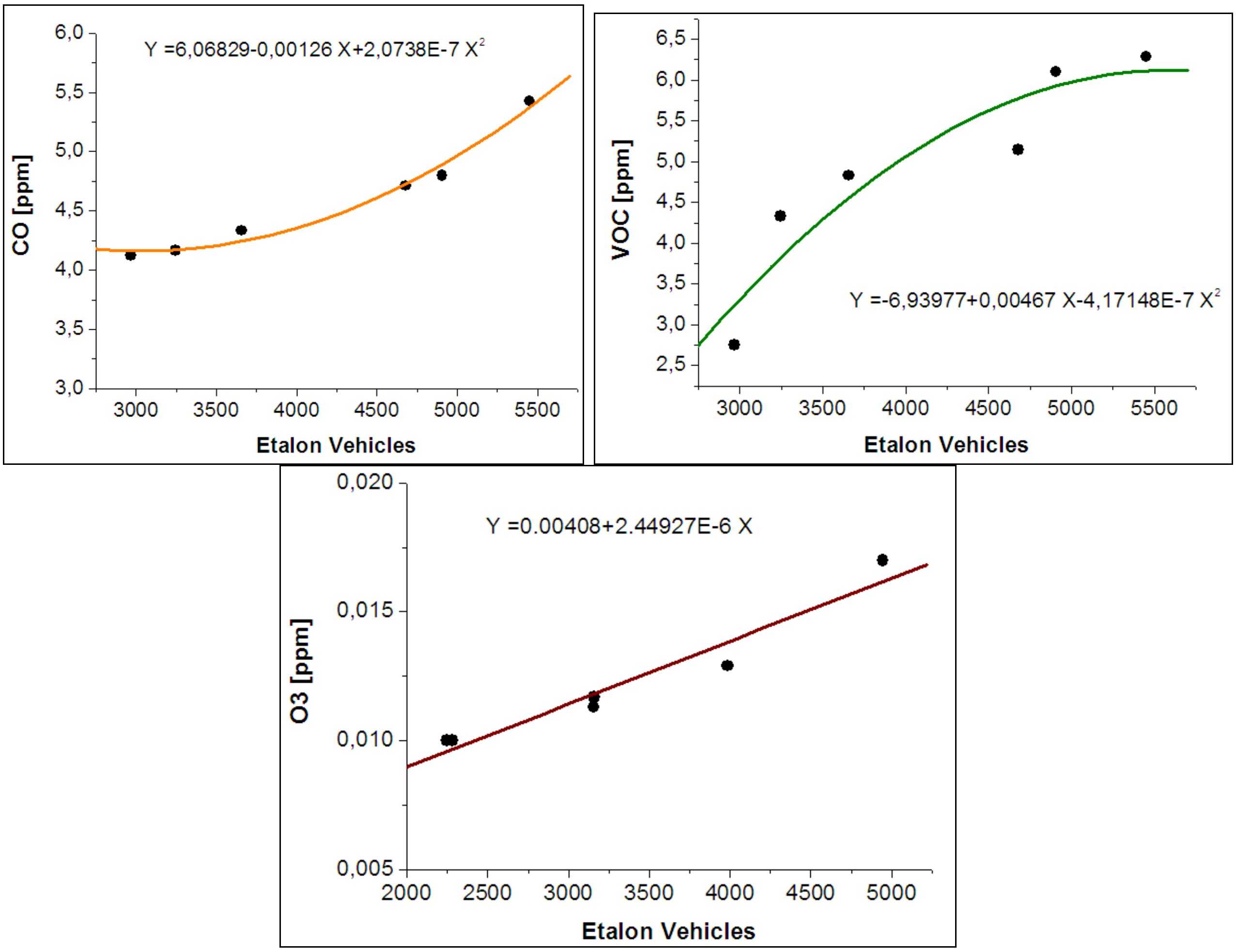

Fig. 5. The variation of the CO, VOC and O_3 concentration in function of the etalon vehicles number.

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 three pollutants, to represent in a chart the dependence between these three 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 exponential regression equations.

Next it will be presented the resulted curves and equations from the analysis, for each of the three studied pollutants, for a single situation.

For exemplification, are presented the CO, VOC and O_3 variations for warm season, at the morning rush hour (figure 5).

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.

$$CO_{theoretical} = 6{,}06829 - 0{,}00126 \cdot V_e + 2{,}0738 \cdot 10^{-7} \cdot V_e^2 \quad (2)$$

$$VOC_{theoretical} = -6{,}93977 + 0{,}00467 \cdot V_e - 4{,}17148 \cdot 10^{-7} \cdot V_e^2 \quad (3)$$

$$O_{3theoretical} = 0{,}00408 + 2{,}44927 \cdot 10^{-6} \cdot V_e \quad (4)$$

Where: $CO_{theoretical}$, $VOC_{theoretical}$ and $O_{3theoretical}$ = the theoretical values of the CO, VOC and O_3 concentrations which describes the variations of the mathematical model curves; V_e = the number of etalon vehicles.

After the introduction of the formulas and the graphical representation of the three pollutants, result the theoretical curves corresponding to the used equations.

Intersection	Etalon Vehicles	CO experimental [ppm]	CO theoretical [ppm]	VOC experimental [ppm]	VOC theoretical [ppm]	O_3 experimental [ppm]	O_3 theoretical [ppm]		
3	2248	2,8571	2,9716	3,5714	4,8467	0,0100	0,0096		
8	2281	3,1667	2,9969	6,0000	4,8991	0,0100	0,0097		
4	3157	3,7500	3,6673	6,6250	6,2896	0,0113	0,0118		
9	3158	3,6667	3,6681	6,3333	6,2912	0,0117	0,0118		
1	3985	4,0000	4,3010	7,4286	7,6039	0,0129	0,0138		
2	4945	5,2000	5,0357	9,1000	9,1278	0,0170	0,0162		

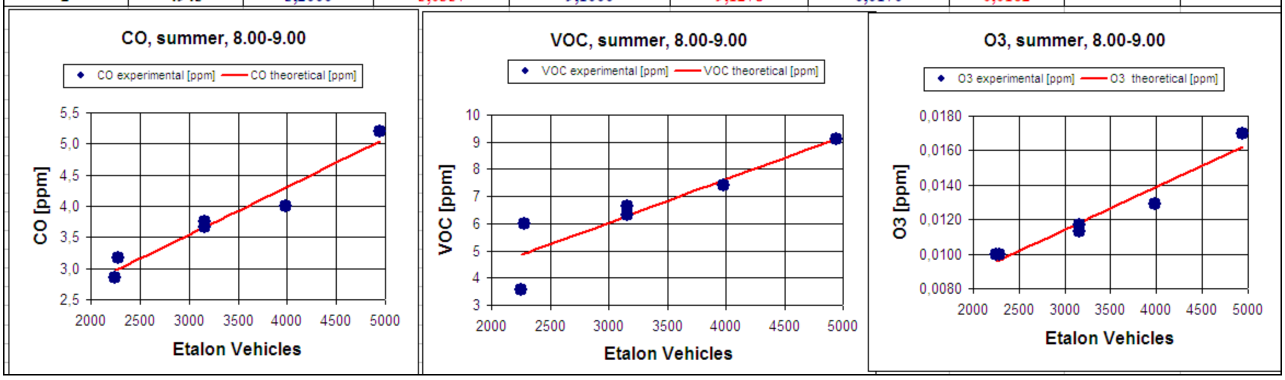

Fig. 6. Presentation of mathematical model results for one of the four situations, for the analyzed route

In figure 6 are presented the table and the corresponding diagrams for the analyzed route, in the warm season and the morning rush hour (8.00-9.00). 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. The three diagrams represent the variation of the three pollutants in function of the measured traffic volumes in the route's intersections. The blue spots represents the values determined experimentally, from the measurements and corresponds to the values from the table (written also in blue), from columns C, E and G. The red curves represent the pollutants variations with the etalon vehicle number, using the values obtained mathematically using the equations corresponding to each pollutant. These values are written in red and they are situated in columns D, F and H of the table. The pollutant approximation can be used for different routes and situations and introducing a number of etalon vehicles for several intersections, it can be estimated the pollution level for three chemical pollutants.

5. CONCLUSIONS

The approximation 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). 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.

The resulted levels of air pollutant concentrations are relatively high for the analyzed area. To reduce the pollution in the historical centre of Brasov city, we propose several measures: road traffic limitation in the historical centre of the city; optimization of road traffic in the entire city; accomplishment of a data base that would include traffic volumes and air pollutant concentrations, for all crowded areas in the city; traffic flows analysis and prediction using simulation and modeling software; fleet modernization for all vehicle categories from Brasov city; reparation and modernization of roads and common transportation lines; accomplishment of bicycle lanes and modern bicycle transportation systems; accomplishment of pollution maps for Brasov City.

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