Evaluation of Air Pollution Measurements in Urban Environment Considering Traffic Intensity

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Abstract: **This paper presents the analysis of air pollution monitoring and evaluation results in the center of Riga City. The air quality reports have pointed out that road traffic and road infrastructure are the main issues of air pollution in the center of Riga. However, none of the reports validated this assumption considering actual traffic flow data. In the present article, the air pollution data have been collected and analyzed in the context with traffic flow. The statistical analysis of both the air pollution and traffic flow data was performed and the correlation between them was established and evaluated. Finally, the conclusions and recommendations for further improvements of the methodology of measurements necessary for successful air quality assessment in the urban areas and particularly in Riga city are given.**

Keywords: **air pollution, air quality monitoring, traffic intensity.**

I. INTRODUCTION

Increasing road traffic during the last decade has adversely affected environmental quality. This trend has also been identified in the notifications of the European Commission, where Riga, which concentrates most of Latvia's traffic, has been mentioned as having poor air quality (1). The authorities have to deal with the unsatisfactory air quality indicators more and more frequently, which raises alarming concerns with regard to the worsening of the environmental situation in Riga. Currently transport is considered as the main pollution source in Riga City, but no researches have been found where this impact, its mechanisms and variables affecting the scale and content of degrading air quality are analyzed. This, therefore, calls for an in-depth situation analysis and this particular research is considered as such.

This study is focused on the road traffic input to the overall pollution content. Pollution evaluation methods are analyzed on the basis of real traffic measurements in context with air quality monitoring data of Riga city. Measurements were performed in a three-month period and resolution of data covers bits of information on one-day scale. The main goal of this research is to determine to what extent the pollution measurements are affected by the changes in the traffic volume.

Emissions of various compounds originating from road transport contribute to the following: greenhouse gases in the atmosphere (CO_2, CH_4, and N_2O), acidifying compounds (NOx and SO_2), gases causing photochemical smog (NOx, VOCs, CH_4 and CO) and local air pollutants (CO, VOCs, SO_2, NO_2, lead compounds and particulate matter – especially PM_{10}) (11). Main components of air pollution caused by road traffic are CO_2, NO, SO_2 and PM_{10}. In several earlier research

efforts quantified proportions of these pollutants have been reported in comparison to other air pollution sources (2,3), thus associating air pollution with the impact of the traffic. This research, however, is conducted to directly quantify correlation between road traffic and air pollution parameters.

Two frequently made statements are questioned in this study, namely: a) road traffic is the main source of air pollution and b) the level of air contamination is proportional to the road traffic intensity. Considering the aforementioned statements has also enhanced the knowledge base regarding how to evaluate infrastructure planning in relation to the expected air quality as well as possible measures in certain situations where improvement is necessary. Such aim of the research has been set because the assumption that traffic induced pollution makes a significant contribution to the general air pollution scene was often made in the previous reports. However, none of them questioned this assumption using traffic flow data.

II. REVIEW OF AVAILABLE RESEARCH REPORTS

State Meteorology Centre reported on the increase of PM_{10} pollution during and after salt-sand mixture usage in winter maintenance, which in 15 % – 20 % of cases exceeds daily norm of 50 $\mu g/m^3$ (3). As follows from the article (3), there is a clear trend for the increase of the amount of this pollutant in winter and spring periods, when relatively low humidity and precipitation are observed. However, similar trend has been identified in the period from October to December, which could not be associated with dry periods. According to these findings, one may conclude that road traffic and salt-sand usage in winter maintenance activities are not the main contributors to PM_{10} pollution. Even further, (3) does not bring the evidence that road traffic or salt-sand mixture have to be considered as PM_{10} pollution sources.

Air quality improvement program for Riga City contains the analysis and evaluation of the air pollution (4), which designates the road traffic as a main air pollution source with the contribution of 14 % of emissions and 47 % of immissions. Besides, according to this program in Riga city center light traffic vehicles are those generally responsible for the pollution. However, these statements are not confirmed by documented facts or traceable pollution research analysis. Here road traffic has also been recognized as playing the leading role in NO_2 emissions, i.e. 69 % from the total NO_2 emissions. As mentioned above, the same criticism for the lack of factual background applies here. As an argument to stress the role of road traffic pollution on the one hand the authors of (4) have mentioned the presence of CO. On the

other hand, they contradictorily point out that CO is a by-product of all combustion processes, especially wood heating, which is increasingly used in Riga among some others. All these research gaps leave questions regarding the objectivity of CO pollution association with the road transport emissions and calls for a more detailed research in order to characterize the situation with air pollution in Riga.

Experience of other European countries, for instance, of Austria (5), shows that NO_2 and PM_{10} spread is mainly governed by horizontal/vertical movements of air masses and their corresponding speed and direction. These conclusions are drawn from the direct measurements of each pollution type in relation to traffic intensity data on an hourly basis.

In other research (6) pollution measurements were collected for modeling purposes, which would simulate interaction between different pollution sources environment characteristics. Situations were isolated to these where wind has only a minor effect. Even if CO emissions were calculated based on traffic intensity data, the authors claim that association between these two parameters is weak because of the influence of other CO sources present as well as because CO emission amount is strongly dependent on the driving regime. As a result, one may consider involving other traffic variables for building a really functional model of this kind.

Another study on air pollution caused by road traffic in different wind conditions has been carried out in Bucharest (7). Here mathematical correlation between traffic intensity and NO and NO_2 has been established, which in this case proves road traffic to be the main NOx pollution source. Different situation is observed with SO_2 pollutant – the observed correlation is low and therefore road traffic contribution to this pollutant group is less distinguishable. The fact that air pollution is lesser when traffic flow is continuous is another important conclusion of this study. This knowledge is valuable when setting a list of possible air quality improvement measures.

In two hypotheses (8) put forward by Stockholm researchers, the main PM_{10} pollution sources are:
a) road pavement particles ripped away from the surface by studded tires, which then are brought up in the air during the dry periods;
b) road pavement deterioration products accompanied by sand particles from the winter maintenance period deposits. However, none of both hypotheses have been confidently proven. Nevertheless, correlation between the proportion of the studded tires in the traffic and PM_{10} pollution level was clarified, but it was not useful in the explanation of pollution variations during one day or even one month periods.

Etyemeziana et al. in (9) point out that traffic intensity alone does not characterize pollution levels – the speed of the traffic flow is also an important factor. For instance, PM_{10} pollution increases with the increasing speed of road traffic flow. In addition, these authors formulated the hypothesis that only regular street cleaning activities improve PM_{10} pollutant levels.

III. DATA ACQUISITION AND ANALYSIS

The main purpose of this research is to acknowledge the degree of dependence between such parameters as road traffic intensity and different air pollution compounds. Geographical boundaries covered by the research are Riga City; the data were collected from June to September of 2011 by one hour interval measurements. This measurement period was chosen in order to minimize the impact of air pollution caused by heating.

Air pollution parameters considered in this study include:

Particulates	PM_{10}
Sulfur dioxide	SO_2
Nitrogen dioxide	NO_2
Carbon monoxide	CO
Benzene	C_6H_6

The data for each of the air pollutant parameters were obtained using air pollution monitoring stations of the Housing and Environmental Department in Brīvības Street between Ģertrūdes and Bruņinieku Streets and Kr. Valdemāra Street between Dzirnavu and Lāčplēša Streets.

Traffic data used for survey were acquired from JSC "Latvian State Roads" traffic measuring stations located on the main Riga's arterial roads (see Fig. 1)

Fig. 1. Location of traffic measuring stations on the Riga's arterial roads.

At the same time, the traffic flow parameters were recorded on Brīvības Street along the air quality monitoring point to assess the correlation and get associative link to traffic estimation and associate it with the traffic on the city approach roads.

Based on the traffic flow data, the correlation between traffic flow on the Riga approach roads A1 and A2 and thus on arterial streets in the city center has been determined. As shown in Fig. 2, the intensities of both flows are in sufficiently strong correlation: $K = 0.92$ and $R^2 = 0.85$. On the basis of the results obtained, it can be concluded that the correlation of traffic data for Riga's approach roads is reasonably associative with the traffic flow data of city centre streets and can be used for the following traffic induced air pollution analysis.

Using the relationship described above, the traffic volume for the 24-hour period (daily) was acquired and correlation between the traffic flow and air pollution parameters at air quality monitoring points was then determined. The correlations

in focus for each type of pollution are: at the monitoring point in Kr. Valdemāra Str. for: CO, NO_2, C_6H_6, PM_{10}; and at monitoring point in Brīvības Str. for: SO_2, NO_2, C_6H_6.

Along with the pollution and traffic data, the meteorological data, such as precipitation (raining or dry), and wind strength in three levels: 0–5 m/s, 5–10 m/s, and > 10 m/s were recorded with the purpose to further use them for data filtering and measurement factor analysis.

Resulting correlations from these measurements are presented in graphs in Fig. 3 and Fig. 4.
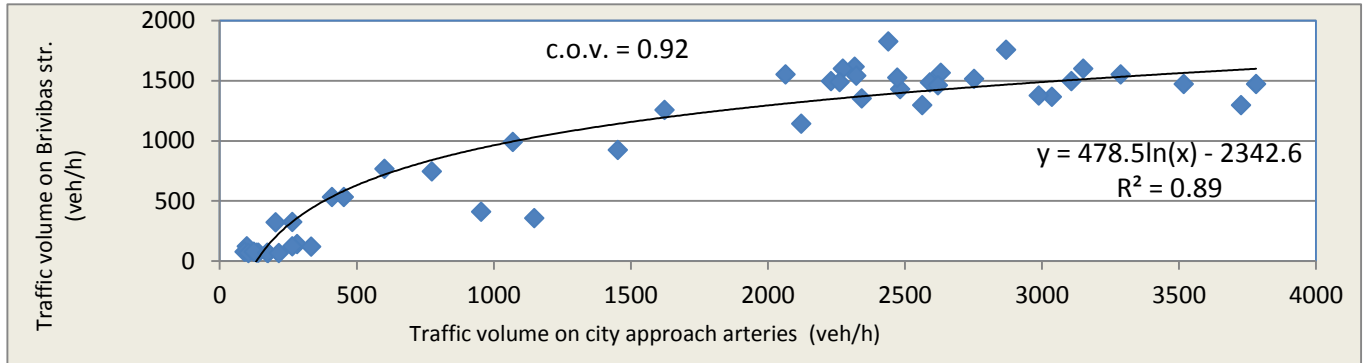

Fig. 2. Correlation between traffic flow on the Riga approach roads A1 and A2, and on the arterial streets in the city center.
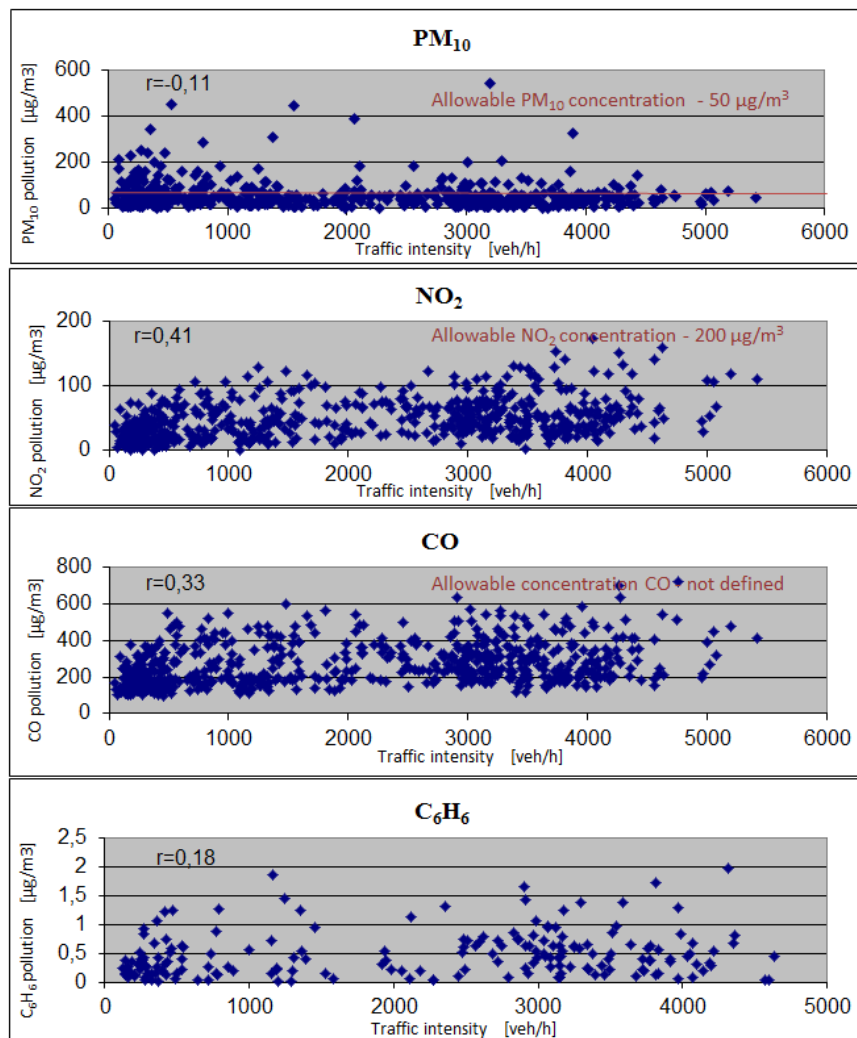

Fig. 3. Correlation data of air pollutants with traffic intensity in Kr. Valdemāra str.
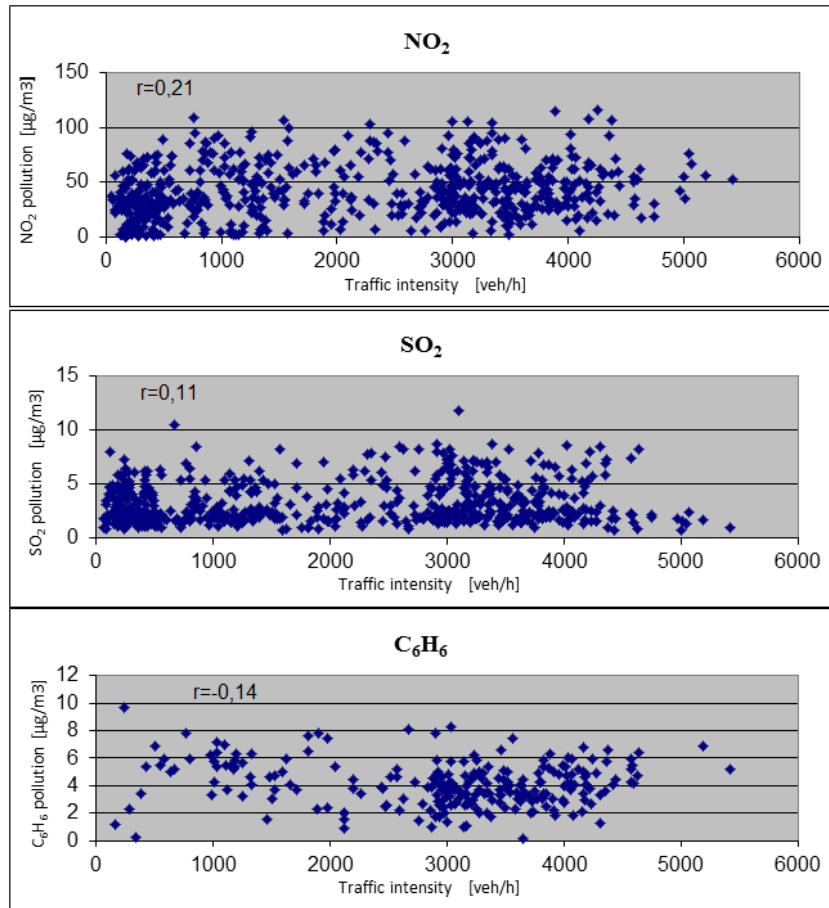
Fig. 4. Correlation data of air pollutants with traffic intensity in Brīvības str.

TABLE I

SUMMARY OF CORRELATION COEFFICIENTS

Sampling point	CO	SO$_2$	NO$_2$	C$_6$H$_6$	PM$_{10}$
Kr. Valdemāra Str.	0.33	–	0.41	0.18	−0.11
Kr. Valdemāra str. – raining			0.59		0.13
Kr. Valdemāra str. – still			0.39		0.12
Kr. Valdemāra str. 0:00 am – 6:00 am					0.01
Brīvības str.	–	0.11	0.21	−0.14	–
Brīvības str. – raining			0.49		
Brīvības str. – rain and wind			0.31		
Brīvības str. – still			0.29		

IV. RESULTS AND DISCUSSION

Assessment of the results shows that none of the measured air pollution parameters demonstrates a strong correlation with the traffic intensity. The highest correlation indicators established are from CO and NO$_2$ pollution, which are known as significant pollutants produced by internal combustion engines.

Nevertheless, the obtained results show (see Table I) that all of the observed forms of air pollution have only weak and very weak correlations with road traffic intensity. This can possibly be due to the unsuccessful location of the air quality monitoring stations, considering pollution induced by traffic and due to the fact that during congestion and low traffic volume (completely opposite circumstances) traffic intensity [vehicles/hour] is similar – in both cases low. The measured parameter and the changes of air pollution are closely linked with the nature and patterns of the air flow. Therefore, if the goal is to obtain a critical value of traffic induced pollution, in accordance with the procedure laid down defined in the EU directive (10), the location of the sampling sites must comply with the following:

"..–the areas within zones and agglomerations where the highest concentrations occur to which the population is likely to be directly or indirectly exposed for a period which is

significant in relation to the averaging period of the limit value(s)..",

– situated so as to avoid measuring very small micro-environments in their immediate vicinity, which means that a sampling point must be sited in such a way that the air sampled is representative of air quality for a street segment not less than 100 m length at traffic-orientated sites.

Analyzing the location of particular sampling points, it can be remarked that Brīvības Str. station avoids the canyon effect because in one direction a part of the street closer to the sampling point ends in an open area. Therefore, aeration there can be considered better that in the adjacent streets, and can significantly reduce the anticipated pollution level. Thus pollution parameters observed at this point cannot be considered as suitable for evaluation of traffic induced pollution in the Riga city center.

Referring to the sampling point on Kr. Valdemāra Str., this is a much narrower street canyon and the traffic there is denser. However, this site is characterized by regular congestions in the rush hours, which results in a small flow rate, as well as in the limited capacity. This means that the peak capacity is limited and traffic speeds in this time are very slow, consequently, less PM_{10} pollutants are brought up. This circumstance could be considered as a reason for the relatively small correlation for PM_{10} with traffic flow. The street canyon of this sampling point consists of 2 to 6 floor buildings, which therefore do not represent the worst conditions of air pollution in the Riga center (as for example: Marijas Str.)

The measurements from both stations were filtered for the purpose to eliminate possible distorting factors and establish pollution formation patterns. Thus, in case of Kr. Valdemāra Str. NO_2 and PM_{10} were analyzed, and in Brīvības Str. station – NO_2. Findings of the evaluation of the correlations obtained in calm weather conditions show that on Brīvības Str. correlation increases, which can be explained by the loss of the natural ventilation, but on Kr. Valdemāra Str. correlation even decreases, which can be explained by the character of the canyon, which is too narrow for the wind to be able to efficiently aerate. Here it should be noted that the amount of data to be analyzed was significantly less than in other weather conditions.

A significant correlation increase is shown with regard to NO_2 pollution measured in rain conditions at both stations. In this case the correlation coefficients (0.49 and 0.59) are getting closer to the medium level. This can be explained by the fact that rain delays dispersion of NO_2 pollution and it concentrates in the sources nearby. In addition, NO_2 comparatively does not dissolve too well in the water. Here, more conclusive indications regarding the impact of traffic on pollution levels can be seen. But, as already mentioned, the correlation is still only close to a medium level. This indicates that traffic forms a relatively small portion of the total pollution.

Separate correlation data from the night hours from 0:00 a.m. to 6:00 a.m. with characteristic low traffic volume were selected. Testing the hypothesis that transport is the main source of NO_2 contamination, at this time low pollution levels

would have been expected. However, it appears that the correlation is even lower as compared to other time periods and is actually close to zero. So the proposed hypothesis cannot be validated as true.

V. CONCLUSIONS

The analysis of the described data shows that there is no strong correlation between traffic intensity and corresponding air pollutant variables. The highest correlation coefficients obtained are for CO and NO_2. Nevertheless, the obtained results show that all of the observed forms of air pollution have only weak and very weak correlations with road traffic intensity. Therefore, air pollution characteristics at sampling points in the period considered is not functionally dependent on the traffic, and road traffic cannot be identified as the main or the greatest air pollution source.

The practical gain of the research lies in the quantitative definition of the correlation, which associates traffic intensity parameters between traffic arteries near the air quality monitoring stations in the city center with the traffic on Riga's approach roads, which are equipped with traffic flow counters.

If road traffic is considered to be one of the sources of pollution, then it is necessary to consider the correlation between the level of pollution and traffic intensity. To prove and establish the true impact of traffic on the overall structure of air pollution, it is necessary to create new or modify the existing monitoring stations or their locations according to the objectives and principles fixed in Directive 2008/50/EC of the European Parliament (10). On the other hand, in-depth analysis must be carried out to determine how different traffic conditions (congestion or free flow) affect pollution, as well as which of the traffic flow parameters correlate with pollution. Graphs (Fig. 3 and Fig. 4) show that during high and low traffic volume, the amount of pollution is almost equal. This phenomenon leads to the hypothesis that traffic flow characteristics, surroundings and environmental conditions noticeably influence the pollution measurements. In addition, technical functionalities of the monitoring stations should include traffic intensity and speed measurement capability in order get direct data on the specific factors.

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