Urban air pollution: input from car parking places

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Abstract

In the urban environment the car parking places are built in components. From the standpoint of air pollution view they can be treated as square pollution sources up to a point, because pollution is formed by mobile sources – vehicles. Pollution is emitted from cars coming into and leaving parking places, as well as during warming which is especially important in winter. Cold starts are the main constitution of all emissions emitted from parking places. Nevertheless, parked cars with hot engines also emit oil evaporations, especially if the cars are older then 10-12 years (84-88% of all vehicles in Riga belong to this group). In typical emission inventories the parking place and a collective garage are both included among the small sources of pollutants. A collective garage with the air-conditioning is really a small source. Pollutants are emitted over the roof into the free atmosphere with good dispersion conditions. The impact of such a pollutant source on the quality of the surface layer of the atmosphere is small. Nevertheless, the parking places on the sides of streets and in close vicinity to the street give high pollution. It is therefore important to determine the pollutant emission of the parking place. The emission of pollutants is calculated as an average of the emission during the idle and slow speed regime of a car engine running. Emissions from car parking in a city make up a noticeable part from all the pollution caused by vehicles, especially when cold starts are taken into account. Our calculations show that all people living beside the street where cars are parked during day/night time suffer from higher concentrations of carbon oxides and volatile organic compounds (benzene)

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1 Introduction

About one-third of all the vehicles driving around every day in Latvia are to be found in the capital, Riga. The city centre is located in the Old City and has many architectural monuments, narrow streets, classical urban street canyons, parks etc. There are also Parliament, Government, different governmental and business institutions, markets, entertainment places etc. Taking all this into account, the city centre attracts thousands of vehicles every day. Most of the parking places in the centre of Riga are opened and located on the sides of streets, partly sharing pedestrian sidewalks, but mostly making streets narrow. Reduced permeability of streets is the main reason for very low average vehicle speeds in the centre (8-13 km/h), especially during the morning-evening rush hours.

It is not practicable or cost effective to monitor pollution in all locations. The purpose of dispersion modelling is to assess pollution concentrations in locations where monitoring has not been undertaken and to allow predictions to be made for the future based on changing circumstances. Modelling is also useful to assess "what if" scenarios and to carry out "source apportionment" to identify the most significant contributors e.g. road traffic or industry, to pollution in a particular location.

The Framework Directive on Ambient Quality Assessment and Management emphasises air quality modelling as a priority technique for assessing ambient air in combination with air quality measurements. References modelling techniques and required spatial resolution are not specified at present but the first Daughter Directive indicates data quality objectives for models, in terms of accuracy. However, due to very different air quality modelling methodologies used in the Member States it is most likely that no unique modelling technique will be prescribed. It is important that the models utilised are appropriate to local conditions, sources and topography, as well as being selected for compatibility with available emission and meteorological datasets.

Detailed urban air pollution studies are continuously carried out in the largest Latvian city: Riga by two institutions: Riga City Council and Latvian Hydrometeorological Agency. For the urban air pollution assessment both measurement and modelling approaches are applied. Riga's air quality assessment is performed by the joint work of specialists from Environmental Department of Riga City Council and technicians from Latvian Hydrometeorological Agency [1-3].

In an urban environment the car parking places are built in components. From the standpoint of air pollution they can be treated as square pollution sources up to a point, because pollution is formed from mobile sources – vehicles. Pollution is emitted from cars coming into and leaving parking places, as well as during warming up the engine, which is especially important in winter. Cold starts are the main constitution of fall emissions emitted from parking places. Nevertheless, parked cars with hot engines also emit oil evaporations, especially, if cars are older then 10-12 years (84-88% of all vehicles in Riga belong to this group). Survey data shows that the Old City (about 1 km^2) has parking places for

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300-400 vehicles, but during the daytime their number reaches 2500. Cars are parked directly on streets because the pavements in Old City are very narrow. There are also 5 multi-storey car parks around the Old City with a total capacity of 1250 places. We described car parking places with specific NO_2 emission coefficients characteristic for point (closed underground parking place), linear (cars parked directly on street sides) and square (open-air parking places) sources. Total emissions are calculated and compared with emissions from stationary sources, accounted by the Latvian Environmental Agency in database "2Gaiss". Nitrogen dioxide values measured directly by street monitoring stations (DOAS open light beam and conventional types) characterize traffic emissions, while benzene concentrations can be directly connected with emissions from cold starts (two DOAS air monitoring stations are located directly in car parking places).

Residential areas of Riga cover about one-half of the city (144 km^2), and car parking places are arranged very close to houses or directly between them. In the morning the residential areas are the most polluted places in the city because most of the cold starts arise directly here. During the daytime and especially in the evening hours the industrial and City Centre areas, where business activities are located, are the most polluted places.

We described car parking places with specific NO_2 emission coefficients characteristic for point (closed underground parking place), linear (cars parked directly on street sides) and square (open-air parking places) sources.

To decrease pollution from parked cars in the City Centre it is important to state priority zones in the centre – for pedestrians only in the Old City, for public traffic (mostly electric – trams and trolleys) – in the City Centre. Also implementing a "park and ride" system in Riga could decrease the number of parked cars in the City Centre noticeably.

2 Methodology

Car parking places in the city were described with specific NO2 emission coefficient characteristic for point (closed underground parking place), linear (cars parked directly on the side of streets) and square (open-air parking places) sources, using COPERT III methodology [4]. To calculate we used the EnviMan software (OPSIS AB, Sweden) [5]. The Dispersion Module in this software contains the Gauss Plume Model which is sufficient for small scale urban applications and is simple and fast to use for car parking places. Meteorological data was used from the Riga City Council meteorological station at Riga Airport taking into account 1 hour average values for temperatures at two levels (2 and 10 meters), wind vector, solar radiation and precipitation for the period 1993-2002.

2.1 Classification of traffic

The main object of this study is parking places in the city centre used mostly by passenger cars. There is a limited number of bus parking places in the centre –

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International Buss Station, a parking place for public traffic buses and three parking places for tourist buses, which could be the topic of separate research. Basic classification was supported by the fact that in 2002 about 86% of cars used by Riga's inhabitants were older then 10-12 years [6].

Old and used passenger cars correspond to ECE 15/04 EC standard (cars with 1.4-2.0 carburettor engines). The remaining 14% corresponds to the Euro I standard. It was assumed that all classified vehicles are light passenger cars (class M1 accordingly COPERT and ECE classification).

2.2 Polluting substances

Exhaust emissions included in the COPERT III methodology accounts for carbon oxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOC), methane (CH_4), carbon dioxide (CO_2), nitrous oxide (N_2O), ammonia (NH_3), sulphur oxides (SO_x), particulate matter (PM), PAHs and POPs, dioxides, furans and heavy metals (Pb, Cd, Cu, Cr, Ni, Se, Zn).

Fuel type and constitution determine the amount of emissions. There is no official information available about the composition of fuels distributed in fuel refilling station in Riga. Therefore calculations of emissions and emission factors for CO, NO_x and VOCs (especially benzene) only were made in our work.

2.3 Calculation methodology

Emissions produced by cars in parking places are divided into three main groups:
- emissions from hot engine (cars travelling in a parking area to find empty places and having just parked after driving;
- cold start emissions;
- evaporation emissions from hot engines.

More attention was paid to cold start emissions. Cold start emissions depend on the outside temperature and are much higher in winter, but evaporative emissions which also depend on outside temperatures, are much higher in summer. Another parameter is the time spent for car heating in a parking place – typically some minutes in winter and less than a minute in summer, and fuel consumed which is higher during cold start. Cold start emissions for the Euro I class are also higher because catalysts only work properly at high temperatures, when the engine is hot. Also the number of starting operations in a particular place or zone concerning cold start emissions is unknown. To establish this we can make the restrictive assumption that each trip leaving a zone is considered as a start. Further information has been requested from mobility model developers concerning parking duration distribution before the trip.

Up to now, neither mobility models nor emission models consider this aspect. New developments in cold start emission modelling [Sérié et Joumard, 1997] consider the driving pattern at the beginning of the trip using average speed, average fuel consumption and average mobility pattern as additional data. Those parameters are available from the mobility models [7-14], and for Riga we choose next: the average driving speed in the city - 5-10 km/h, the average fuel consumption: 3 9.5 (Euro I) – 14.7 (Pre Euro) liters per 100 km, and the average annual driving pattern - 20 402 km [15].

2.4 Calculation of emission factors

Cold start emissions were calculated using the equation:

$$E_{cold} = \beta \times e_{hot} \times \left(\frac{e^{cold}}{e^{hot}} - 1 \right), \text{ where}$$

E_{cold} - emission factors for a cold engine, g/km;

β - cold engine driving fraction;

$\frac{e^{cold}}{e^{hot}}$ - ratio between emissions from a cold and hot engine.

Parameter β is expressed by the formula:

$$\beta = 0.6474 - 0.02545 \times l_{trip} - (0.00974 - 0.000385 \times l_{trip}) \times t_a, \text{ where}$$

l_{trip} – average driving distance with a cold engine -15 km [16}:

t_a – annual average temperature: +6.2 ºC (results from the last 30 years),

average winter temperature: –0.4 ºC;

Emissions for a hot engine were calculated as:

$$e_{hot} = \int [e(V) \times f(V)] dV, \text{ where}$$

V – average speed (km/h).

Calculated emission factors are collected in table 1:

Table 1: Emission factors calculated for ECE 15/04 and Euro I cars in the case of hot and cold engines.

	e_{hot} *(ECE 15/04)*	e_{hot} *(EURO I)*
CO	60	8
NO_x	1.6	0.5
VOC	6.3	0.4
	e_{cold}/e_{hot} *(ECE 15/04)*	e_{cold}/e_{hot} *(EURO I)*
CO	4.1	5.1
NO_x	1.2	1.1
VOC	3.1	8.8
	E_{cold} *(ECE 15/04)*	E_{cold} *(EURO I)*
CO	50.3	9.1
NO_x	0.07	0.01
VOC -benzene including	3.5 0.2	0.8 0.06

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Emissions from parking places are next:

CO: (50.3 * 86 % + 9.1 * 14 %) * cur number * 6 km * 182.5;
NO_x: (0.07 * 86 % + 0.01 * 14 %) * car number * 6 km * 182.5;
Benzene: (0.2 * 86 % + 0.06 * 14 %) * car number * 6 km * 182.5;

Next approximations and averages were used to calculate emission values above:
6 km – average diurnal mileage in parking place;
365/2 = 182.5 – number of cold car days;
Number of cars –function from dimensions of parking place and car turnover.

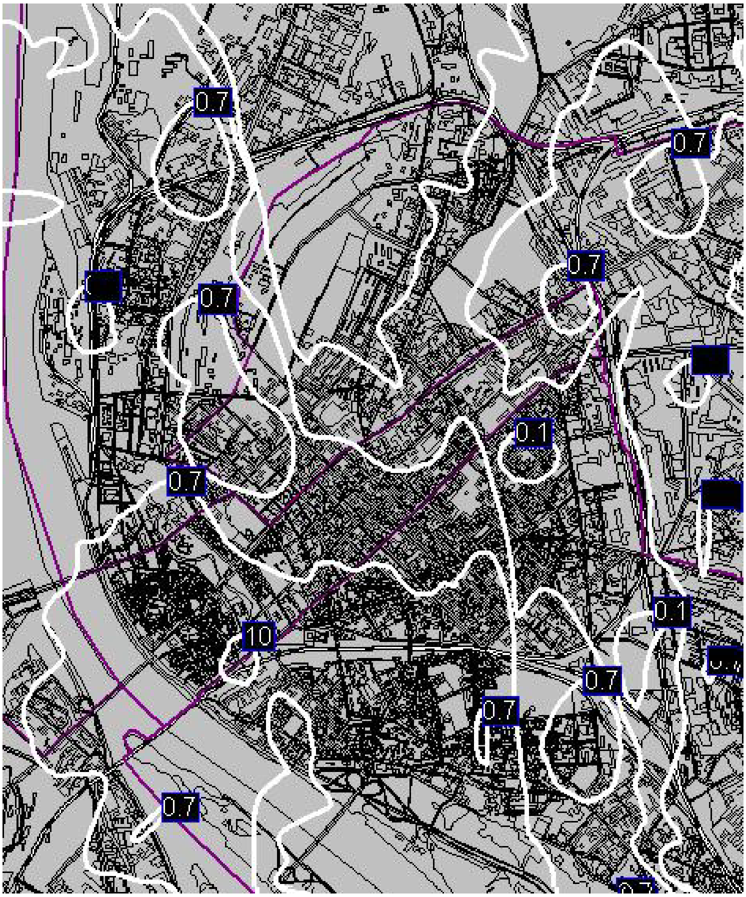

Figure 1: Nitrogen dioxide emissions (maximal 1-hour values) only from car parking places in the central part of the city.

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3 Results

Two different situations were analyzed. In the first, all car parking places accounted in Riga 70 (only 5 – closed and/or multi-storey) were included in the calculations. Results are shown as NO_2 concentrations in μg/m^3 (maximal 1 hour) for the City Centre (Figure 1).

As it is seen from Figure 1, higher NO_2 are from bus parking places (in the city centre – International Buss Station – is given above 10 μg/m^3 as 1 h maximal value).

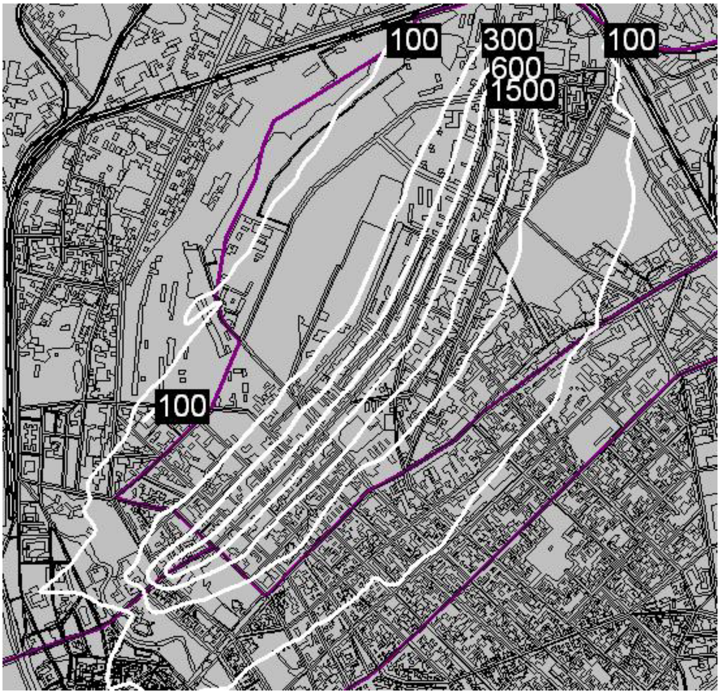

Figure 2: Carbon oxide (98% from 8 hour averages) emissions.

The second example was taken as a typical canyon-type street in the central part of the city - Kr. Valdemara Street. In this street the houses on both sides of street are partly business and shop location, and partly – dwelling houses (a typical situation in the central part of city, with houses from the 1930^s – first stage is shop or business office, next 4 stages – flats). There are 6 lanes on the street (3 in each direction) and 4 lines are used for driving (annual average daily traffic is 23100) units) and 1 line in each direction – for car parking. Calculations were made for different substances: carbon oxide concentration in mg/m^3 (98% from 8 hour averages), nitrogen dioxide concentration in μg/m^3 (maximal 1 hour concentration and annual average concentration) and benzene concentrations

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in μg/m^3 (annual average concentration). Different scenarios with only hot, mixed hot/cold and only cold starts were analysed. Interesting results were obtained with cold starts on all traffic in the street. With cold starts the carbon oxide emissions increased by approximately 35% (presented in Figure 2). It was noticed also, that nitrogen dioxide emissions increased only by 2%, when cold starts are included. A relevant increase in volatile organic carbons (benzene) emissions was noticed (25%) when cold starts are accounted for.

4 Conclusions

Emissions from car parking in the city formed a noticeable part of all pollution caused by vehicles, especially when cold starts are taken into account. Our calculations showed that all people living beside the street where cars are parked during day/night time suffer from higher concentrations of carbon oxide and volatile organic compounds (benzene):

1. With cold starts the carbon oxide emissions increased by approximately 35%.
2. Nitrogen oxide emissions increased by only 2%, when cold starts are included.
3. An important increase in volatile organic carbons (benzene) emissions is noticed when cold starts are accounted for.

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