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ANALYSIS OF PARTICULATE MATTER COMPOSITION

According to current research, particulate matter (PM) has a negative impact on citizens in particular (respiratory and cardiovascular diseases). Based on EU studies, deaths of 347,900 Europeans are attributable to air pollution. Formation of particulate matter from road transport has been a concern for big cities in particular.

For long time monitoring PM we choosed the sections of roads located both within urban areas and rural areas were selected for long-term monitoring, differing in particular by the surface of the roadway – either with asphalt concrete paving (AC) or with stone mastic asphalt (SMA) paving, an asphalt compound with disintegrated stone grade and a higher percentage of asphalt binder.

We were executed the Air Samples with using medium-volume LECKEL MVS6 sampling pump.

Keywords: traffic, emissions, environment, monitoring, PM10

Introduction

Considering the predominant use of combustion engines, exhaust gases contain high amount of both gaseous and solid contaminants. They include high quantities of the finest fractions that can stay in the air for a long time; they can easily enter the respiratory tract and be harmful to human health.

The Faculty of Civil Engineering of the University of Zilina, Department of Highway Engineering has participated in the international project "SPENS Sustainable Pavements for European New Member States" [3] aimed at sustainable transport and focusing on evaluation of effects of different types of roadways on generation of particulates caused by transport. The Department continues this focus also in research activities of the Centre of Excellence for Systems and Services of Intelligent Transport.

The aim of this part of the work to be presented is to compare development of particulate matter and its composition along roads depending on surface type of the road.

1. Particulate Matter Monitoring

Sites representing both non-urban and urban roads with various traffic volumes and various surface types were selected to monitor concentrations of specific fractions of the particulate matter at locations with different traffic volume.

Air samples were taken using medium-volume LECKEL MVS6 sampling pumps. The devices are intended for outdoor use at high or low temperatures. The flow of the air to be taken is controlled and basic physical parameters are maintained by means of a ther-

Fig. 1 Automatic system for traffic intensiveness monitoring (SIERZEGA SR4)

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Fig. 2 Filter weighing by means of analytical scales (left); measuring position by the D1 highway (right)

mally compensated slot. PM capturing filters are inserted between Teflon holders into a sampling head forming an integral part of the device. Filters from nitrocellulose fibres were used to capture PM (Fig. 2).

Measurements were taken in compliance with the European standards EN 12341 [8] and EN14907 [9] where this methodology is used as a reference method.

- Particle concentrations were determined gravimetrically from every exposed filter. Traffic volume was recorded continuously using an automatic traffic intensiveness detector SIERZEGA SR4. Detector – the microwave radar Works at the base of dopplers principle (Fig. 1).

Multiple measurements were taken at four sites between 2007 and 2009. Most measurements focused on PM10 monitoring. Representation of different particles was monitored at two sites in July and October 2008, taking samples to monitor chemical composition of PM.

The positions were selected as follows (Fig. 3):

1. D1 highway, Predmier – four-lane road, surface – stone mastic asphalt (SMA);
2. II/507 Bytca, bypass road – two-lane road, surface – stone mastic asphalt (SMA);
3. I/18 Zilina, city through road – four-lane road, surface – asphalt concrete (AC);

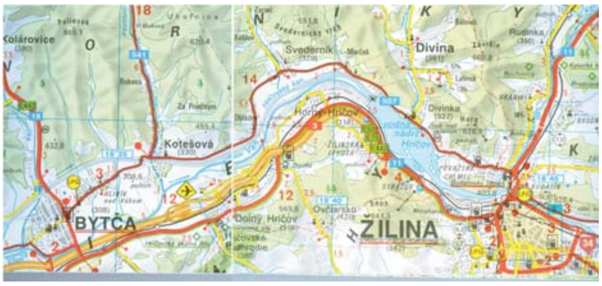

Fig. 3 Scheme showing localisation of measuring positions around the city of Zilina

4. I/18 Dolny Hricov – two-lane road, surface – asphalt concrete (AC).

Dependency between temperature and particulates concentration was shown at the monitored positions (Figs. 4 to 7), but no dependency between average values of particulates formed and total traffic volume was proven. This can be proven, for example, by the monitored section No. 4 in Dolny Hricov with the D1 highway opened early in 2008, so traffic volume at the I/18 road significantly decreased, but with no effect on PM10 particulate concentration (Fig 7).

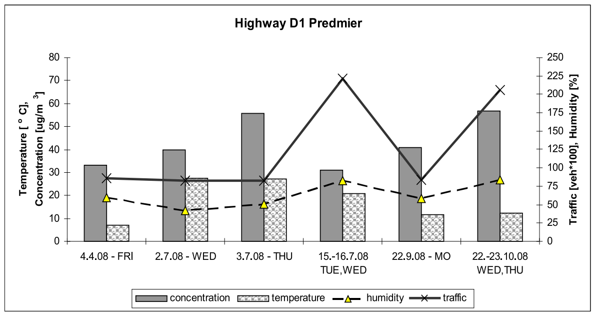

Fig. 4 Long-term observation at the measuring position 1, D1 highway, Predmier

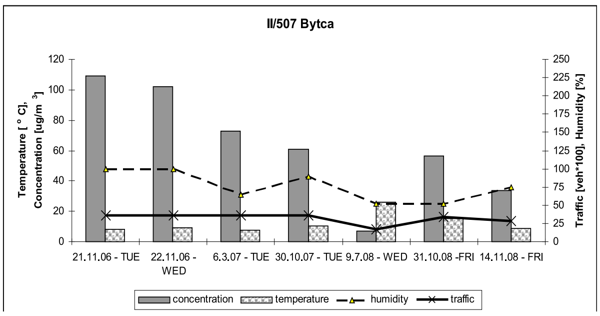

Fig. 5 Long-term observation at the measuring position 2, II/507 road, Bytca bypass

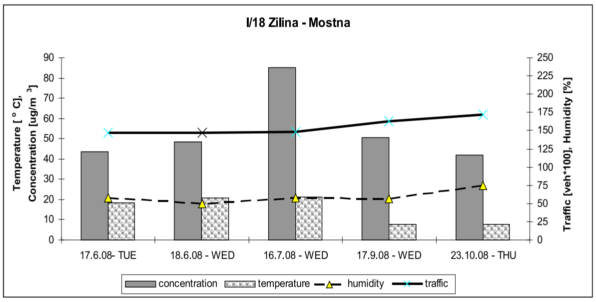

Fig. 6 Long-term observation at the measuring position 3, I/18 Zilina city through road

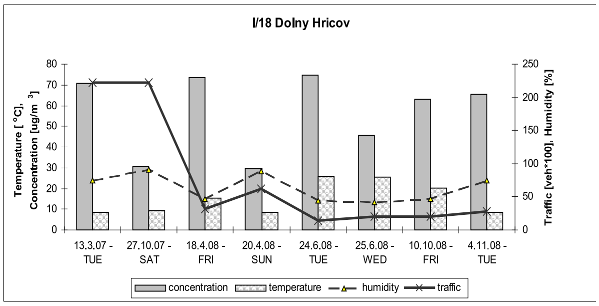

Fig. 7 Long-term observation at the measuring position 4, I/18 road Dolny Hricov

Fig. 8 Measurement at the roadway position 4 Dolny Hricov (on the left)

Roadway surface, asphalt concrete ACo roadway surface 11 - 15 years old (on the right)

Continuous control measurements were made using mobile monitoring equipment in cooperation with ENVItech, s.r.o. Trencin (Figs. 8 to 9). However, traffic count was done only manually during the continuous measurement. This partial measurement, on the contrary, indicates an interim dependency between the currently increasing traffic volume and the amount of PM concentration.

2. Comparison of Surfaces on the Basis of their Qualitative Parameters

Measurements of roadway surface roughness and analysis of surface pavement compound were done on measuring positions 2 and 4. The measurements support results presented on monitoring

Fig. 9 Measuring at position 4 after laying down the new surface (2 weeks old); Mobile monitoring equipment by ENVItech Trencin on the right

of particulate matter composition depending on surface pavement type.

Average results for roughness from two repeated measurements taken by Profilograph GE representing thickness of macrotexture surface are as follows:

- Mastic asphalt surface (SMA) was found to be MPD = 0.95... i.e. the surface is visually rougher, its grain size is larger;
- Asphalt concrete (AC) was found to be MPD = 0.42... i.e. the surface is visually smoother with fine grain size.

This corresponds also to composition of the asphalt compounds: SMA – 20% share of fine fraction up to 2 mm; AC – 50% share of fraction up to 2 mm.

Roughness measurements by the profilograph were taken also at position 4, observing differences between the original roadway surface and the newly laid pavement surface (made from asphalt concrete again).

Average results for roughness from two repeated measurements taken in August 2008 show that the new surface is better in terms of quality and rougher:

- the newly laid asphalt surface (AC/new) was found to be MPD = 0.80;
- the original asphalt surface (AC/old) was found to be MPD = = 0.38.

When the new pavement surface was laid down, formation of particulate matter was reduced, probably due to a better bond between the fine aggregate and the binding material (Fig. 10).

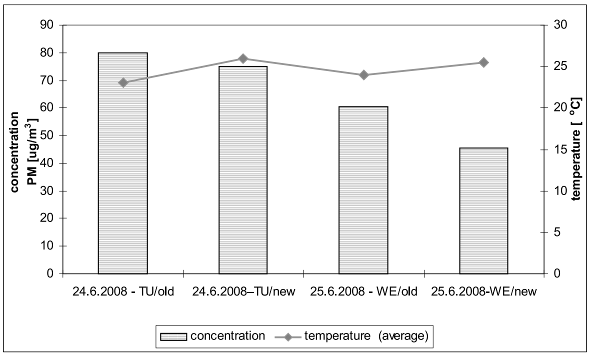

Fig. 10 Comparison of measurements of particulate matter concentrations on the original asphalt surface and the newly laid one at the Dolny Hricov position

3. Chemical Analysis of Samples

Chemical analyses of samples taken at position 1 were done to determine content of selected metals (ICP/MS, Agilent 7500ce). The aim was to identify differences in PM composition resulting from operation of vehicles on roads with different surfaces. To evaluate metal content in PM10 fraction we cooperated with Centrum dopravniho vyzkumu Brno *(Brno Transport Research Centre).*

It is assumed that inorganic particles are formed only by abrasion of cement-concrete pavements. These particles therefore represent 90% of the particles resulting from abrasion of asphalt-concrete pavements [4] and they consist mostly of coarse fraction PM.

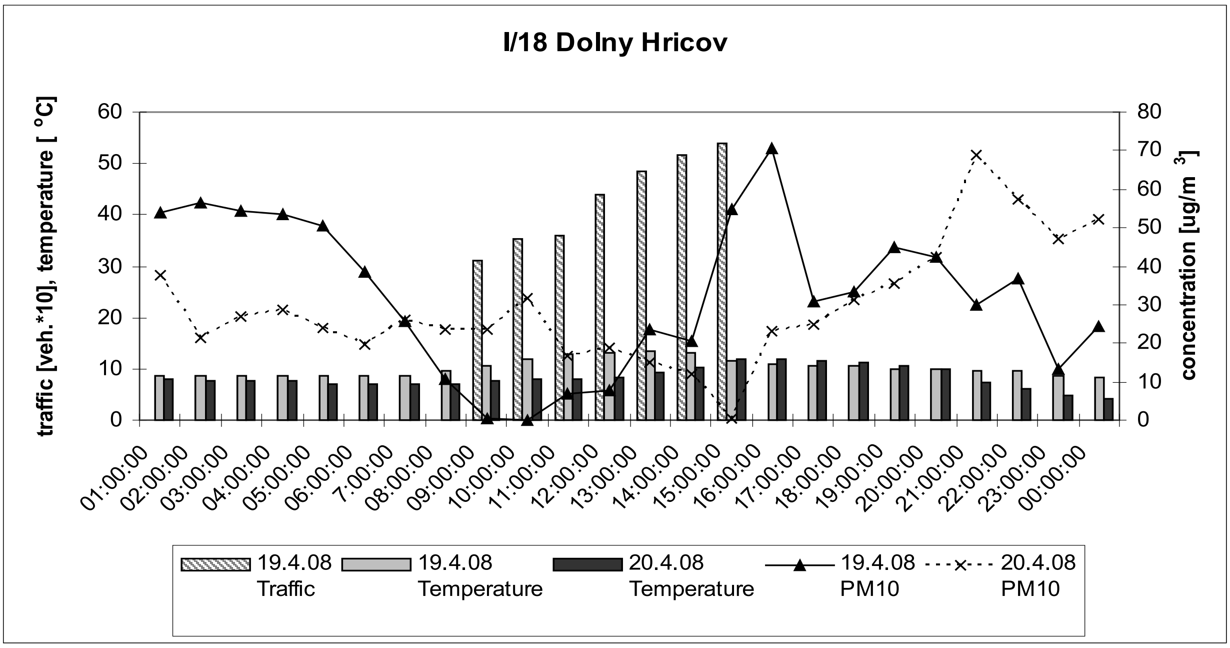

Fig. 11 Course of dependency between particulate matter PM10 formation and air temperature (position 4 – Dolny Hricov)

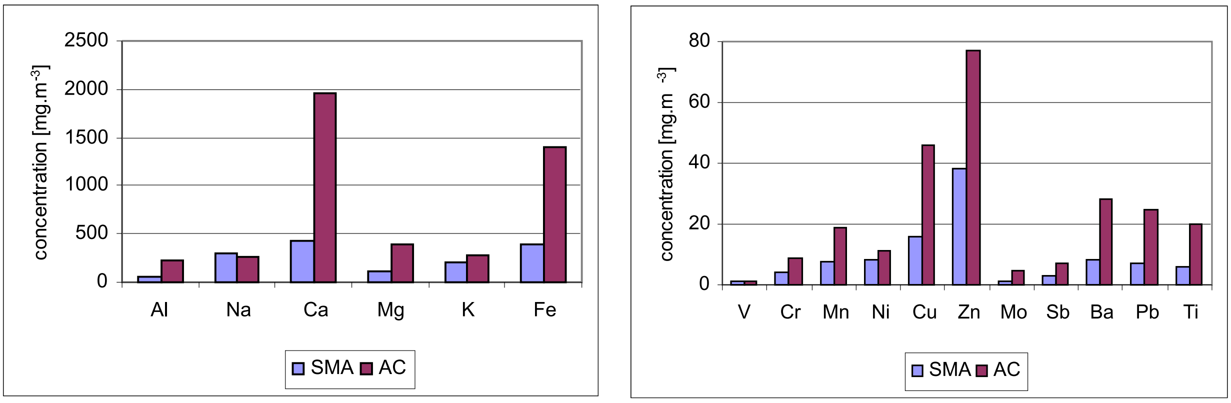

Fig. 12 Content of selected substances in PM10 fraction - position 1 - I/18 Zilina through road [1]

Contents of selected metals, representing sources related to mechanical abrasion of particles, such as Zn, Sb, Cu, Ba and other, were identified in both fine and coarse PM fractions. Contents of selected metals in both PM fractions were higher at sites with asphalt-concrete pavement at both collection campaigns, except K and Pb in the second collection campaign in the autumn (Fig. 12).

4. Discussion about Results

According to foreign studies, abrasion of tyres, brake shoe lining and roadway contributes significantly to non-combusted traffic emissions. For example [6] or [7] suggest that the share of non-combusted PM10 emissions in total traffic pollution is 50% at present and 50% comes from combustion processes. Considering the renewal of vehicle fleets and use of new fuel types it is likely that the share of non-combustion emissions will become higher.

Analysis of principal components (PCA) for emission source quantification in transport was done by [5]. A component analysis transforms initial variables into orthogonal quantities summarising variances of the initial variables. However, it is up to interpretation whether these new components represent artificial characteristics or whether they reflect real factors.

Thurston [5] specifies the substances that achieve the highest component values. For tyre and brake shoe lining abrasion, these are benzothiazole, zinc (Zn), copper (Cu), antimony (Sb), titanium (Ti), nickel (Ni); for roadway abrasion, these are nickel (Ni) and vanadium (V); and calcium (Ca), aluminium (Al) a barium (Ba) in case of resuspendation.

Based on the chemical analysis done at measuring stations (Fig. 12) it can be assumed that the data obtained on higher Ca, Zn, and Cu values among the chemical substances monitored show that the particulates captured in flow pump filters can originate from tyre and brake shoe lining abrasion and resuspendation. The share of road surface abrasion is negligible. Comparison of effects of roadway surface clearly shows that abrasion of components was higher on a roadways made from asphalt concrete than on roadways made with mastic asphalt surface.

These are just partial results of our research work. The monitoring should be complemented by other measurements to have sufficient number of samples for a relevant statistical evaluation. This research work is under way.

Acknowledgement:

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Share of specific transport sources to PM10 based on evaluation by Principal Component Analysis (PCA) (Thurston, 1983) Table 1

Share	Unidentified source	Diesel combustion	Petrol combustion	Re-suspension	Abrasion of tyres and brakes	Abrasion of roadway
%	7.9	25.0	21.6	10.7	22.6	12.2

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