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IDENTIFICATION OF THE EXPLOATATION DUST IN ROAD DUST

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Preliminary Note – Prethodno priopćenje

The aim of this publication is to determine models of explore dust from vehicle brake systems and the presentation of measurement results of the exploitation dust, which is separate from road dust. The following methods and measuring devices were used: T-01M device, screen analysis, analysis of chemical composition with the use of a scanning microscope with Energy Dispersive x-ray Spectroscopy (EDS) analyser. The measurements for identifying this type of dust were conducted on marked sections of roads: motorway, city road and mountain road. The explored dust was distinguished in the following car systems: brakes, clutch plates, tyres and catalytic converters.

Key words: models of explore, car dust, road dust, air pollution

Identifikacija i iskorištavanje cestovne prašine. Cilj ove publikacije je utvrditi modele upotrebe prašine, koja je odvojena od cestovne prašine. Za ispitivanje su korištene sljedeće metode i mjerni uređaji: T-01M uređaj, granulometrijska analiza i upotreba pretražnog elektronskog mikroskopa s energetsko disperzijskim spektrometrom. Za mjerenja su uzeti uzroci prašine na različititim dijelovima ceste: autoceste, gradske i planinske ceste. Istraživana prašina potječe od sljedećih dijelova automobila, kočnice, spojke, gume i katalizatora.

Ključne riječi: modeli upotrebe, automobilska prašina, cestovna prašina, onečišćenje zraka

INTRODUCTION

The chemical composition of the dust formed during the movement of the cars is difficult to determine interchangeably, because of the diversity of factors, both in terms of quality and quantity. General information concerning this issue is available in publications [1,2].

The diverse selection of materials makes the identification of the emitted dust complicated, both in reference to its size as well as to its chemical composition. Main places, where dust is formed from vehicles are: the brake system, the contact of the tyre with the road surface and the clutch plate [3]. Although it is possible to find in literature some data concerning dust concentration, there are no quality analyses or analyses of the size of the dust particles, coming from vehicles depending on their speed, force of brake and driving dynamics.

In the publication models for exploring dust from brake systems are presented (size of dust particles, rough chemical composition in reference to the amount of heavy metal elements included in it) as well as the results of measurements of dust coming from the road.

METHODOLOGY

In order to determine the influence of the factors on the level of dust pollution level, it was necessary to isolate it from the road dust. In order to do it, reference samples for exploring dust are needed to be created. During laboratory tests, with the application of Tester T-01M using frictional materials of the inner parts of vehicles, which were brakes and clutch plates, dust particles were collected for the purpose of the research with the use of specially adjusted car vacuum cleaner. Paper filter was fitted instead of a traditional filter, and it allowed for keeping the particles with the grain size of up to 4 µm. The particles were gathered during the test with the use of tester device T-01M of mandrel-disk type. During the test with the use of this tester 10 braking systems were tested [4].

The next stage of the test was to discriminate vehicle dust from road dust. The dust collected during laboratory tests from the inner parts of the vehicle, mentioned in the paragraph above, were dried in the first stage for 45 minutes in temperature of 50 ^{o}C ± 1 ^{o}C. During that time it was in polyethylene containers. Next, the whole amount of dust was weighed with precision to two decimal places. In the next stage, the dust was poured into a pile of screens with clearance of eyelets of 250 µm, 90 µm, 56 µm, 20 µm and placed in shaker. Before each use of screens they were placed in an ultrasonic cleaner filled with redistilled water.

Shaking out the dust was conducted each time for 45 minutes. After that each dust fraction was poured to a separate polyethylene container and was weighed with accuracy to two decimal places. The tests were conducted in such conditions, in which there was no difference between the weight of the whole dust amount and the

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weight of dust after sieve analysis. Permissible aberration was within the error boundary which is less than 1 % of the loss.Bigger error would mean untight screen pile and the achieved result would be adulterated. During the tests the highest error level was 0,63 %, so it should be assumed that the analysis was conducted properly. The results achieved for each fraction type were placed on a graph and the granulometric curve was created in that way.

After the collection of the dust and the conduction of the granulometric analysis the sample was also analysed chemically. For the use in this paper the scanning microscope with an EDX analyser was used. The abrasive material used in the construction of clutch plates, brake blocks or brake lining varies in terms of used material. That is why the chemical composition of dust formed as a result of brake friction is much differentiated in terms of chemical elements. Brakes include metals and metal salts, non-organic compounds which are infusible and a certain amount of polymers and organic compounds. After the chemical analysis of dust and on the basis of relevant literature analysis [4 - 6] the elements of heavy metals for the same type of dust were selected and they were titanium, strontium, copper, zinc, barium, nickel and lead. In case of three-function catalytic reactor of the car no dust particles were collected due to their too small diameter (Table 1). Only tests with the use of scanning microscope with analyser EDX were conducted.

Table 1 **Comparative samples of dust**

Place of dust formulation	Metallic elements characteristic for a given dust	Granulometric distribution
Brakes	Sb, Ti, Sr Zn, Ba, Cr, K	below 20 μm – 12 % 20 – 56 μm – 79 % 56 – 90 μm – 7 % 90 – 250 μm – 2 %
Clutch plates	Sb, Ti, Sr, Zn, Ba, Cr, K	below 20 μm – 22 % 20 – 56 μm – 73 % 56 – 90 μm – 4 % 90 – 250 μm – 1 % 250 μm above. – 0 %
Catalyser	Rh, Pd, Pt, Cs	below 20 μm – 93 % 20 – 56 μm – 7 % 56 – 90 μm – 0 % 90 – 250 μm – 0 % 250 μm above. – 0 %

RESULTS ON THE SIZE OF THE DUST PARCICLES

The first stage of the analysis concerned the measurement of the dust particles. On the basis of the reference model (Table 1) the following fractions were set: below 20 μm, 20 – 56 μm , 56 – 90 μm and 90 – 250 μm (Table 2). The dust particle size above 250 μm was not included in the tests due to almost zero or very low number of occurrences in exploitation dust.

In fraction range below 20 μm it was concluded that the presence of that fraction in car dust is 17 %, on the contrary to dust gathered on road sections, city sections, motorway and mountain road where the dust particles with such diameter are only 0,5 % of the whole. In case of mountain road during the tests no dust with particle diameter of less than 20 μm was found. In the tested motorway section the amount of dust particles with diameter below 20 μm is four times bigger than in the case of city section. On the motorway section the mean value is 0,46 % and in the city 0,097 %. Such significant participation of dust particles with diameter below 20 μm in car dust suggests that the particles present in road dust should be looked for in this fraction. It implies that the use of vehicles on a motorway causes bigger dust pollution of sizes below 20 μm in comparison to that in city conditions.

Table 2 **Results of statistic analysis**

Research place	Dust fraction μm	$\bar{X}$	Me	Min.	Max.
Motorway	> 20	0,46	0,47	0,32	0,58
	20 – 56	1,36	1,31	0,75	1,79
	56 – 90	2,23	2,36	1,02	2,89
	90–250	28,74	28,43	26,35	31,12
Traffic	> 20	0,09	0,09	0,02	0,15
	20 – 56	3,61	3,60	2,08	4,79
	56 – 90	4,92	5,05	4,04	6,05
	90–250	28,97	28,91	27,01	30,84
Mountain road	> 20	0	0	0	0
	20 – 56	0,67	0,67	0,59	0,74
	56 – 90	0,92	0,90	0,76	1,15
	90–250	33,56	33,81	32,59	34,11
Exploitation dust	> 20	17,04	16,86	14,91	19,64
	20 – 56	71,28	71,03	69,26	74,27
	56 – 90	8,56	8,85	7,12	9,59
	90–250	3,12	2,90	2,07	4,68

In the analysis of the fraction ranging from 20 – 56 μm it was stated that this is the biggest group in the whole dust size range – 71,2 %. Therefore, particles with such diameter are formed in biggest numbers from vehicles. After the analysis of the test results it was calculated that dust particles from that range constituted 66,6 % less than in the reference dust analysis. In the city section the average result was 3,6 % from the total road dust in that area that is three times more than on the motorway where the average result was 1,3 %. In the case of the mountain road the particles from that size range constituted 0,6 % of the total. This value was the lowest from all the tested road sections.

The granulometric analysis conducted in reference to particles with a diameter of 56 – 90 μm showed that they are above 8 % of the total dust. This fact shows a small participation of such particles in the reference ones with smaller diameter. It may be assumed that the use of vehicles will not influence significantly the level of particles emission with a diameter in the range 56 – 90 μm for the road dust. On the city section the fraction of such dust was 4,9 % of the total. This was the highest value from all tested road sections. On the mountain road the particles from this range made up 0,9 % whereas on the motorway 2,2 %. The achieved results may show that use factors occurring on the city road cause bigger pollution with dust than in the case of factors occurring on the motorway. On the mountain road with much smaller traffic volume and almost no traffic of transport vehicles the use of vehicles has practically no influence on the level of dust pollution.

Fourth group of granulometric analyses comprised dust coming from abrasive parts of vehicles, such as brakes or clutch plates. Dust from clutch plates with particle diameters in the range of 90 – 250 μm was present in the whole dust at only 3,1 %. This may imply that only a small part of particles with such diameter, formed as a result of the use of abrasive parts in vehicles, will be included in road dust. On city sections of the road the participation of this fraction in the whole dust was at the level of 28 %. On the mountain road, where the traffic is smaller than on the motorway or in the city the presence of particles with diameters of 90 – 250 μm was about 33 % of the total dust. It is a value which is higher than in the city and motorway. The lack of difference in the percentage participation of that fraction of dust between the motorway section and city section leads to a conclusion that the vehicle traffic does not significantly influence the emission of particles with diameters of 90 – 250 μm.

RESULTS ON THE CHEMICAL ANALYSIS OF DUST

The chemical composition of the samples was fixed with the use of scanning microscope (SEM) S4200 (HITACHI) in extreme conditions: electron energy of the primary beam 15 keV, cold cathode with field emission, absorption current intensity $1*10^{-10}$ A. In order to take a microphotography of dust a signal of secondary electrons (SEM) was used. Magnifications from 50 to 8000 times were used. In the chemical composition analysis of dust an X-ray energy dispersive spectrometer (EDS) VOYAGER (NORAN, detector Si-Li, thin polymer window) co-operating with the microscope was used. The duration of the chemical composition analysis equalled 100 s. Identification of the chemical elements was conducted by comparison of the spectral lines (on an energy scale) on the graph with of the lines of particular chemical elements. A spectral series K was applied. Because dust has very low density both the base on which the samples were placed (copper stands) and the microscope table (brass MC70) were stirred up.

That is why the K lines of copper and zinc appear in the spectra, although such chemical elements do not always exist in the tested dust. For the purpose of this analysis a scanning microscope with chemical analyser was used. Material for tests was gathered in the form of 12 dust samples with segregated granulation. Dust samples were put on copper stands.

On the basis of the achieved samples, an analysis of the dust from each dust particle from brake system and from clutch plate was conducted. In Figure 1 a microphotography of surface dust is presented, which comes from brake with size of 20 – 56 μm with X-ray spectrum. On the particle surface there are chemical elements characteristic for vehicle use such as manganese, copper, chromium, iron, zinc and tin. It confirms the correctness of the assumed hypothesis that the particles of dust are present in fractions of below 56 μm.

In the analysis of dust particles coming from car clutches a similar group of chemical elements was observed and such group was equal to theoretical knowledge [6]. In Figure 2 a surface sample of dust in fraction of below 20 μm is presented, which comes from clutch plates. On the surface such chemical elements as barium, chromium and zinc were present. Copper was not considered a characteristic chemical element here because the washer for testing of the dust samples was made of copper.

The same analysis technique was applied for the rest of samples of road dust gathered on particular sections of the road. In tests of road dust the characteristic chemical elements from vehicles were found in fractions up to 56 μm. In Figure 3 a fragment of road dust particle is

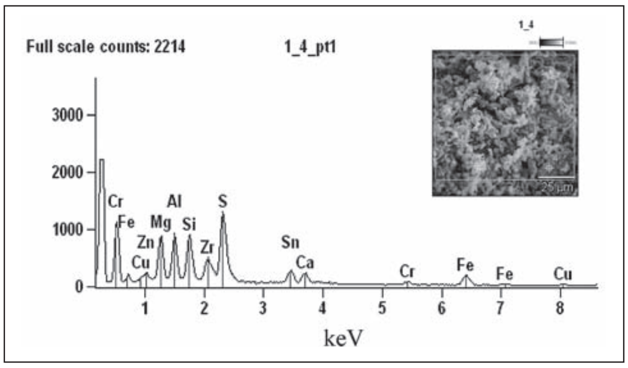

Figure 1 Exploitation dust coming from the brake, (SEM) magnification 1000 x (EDS)

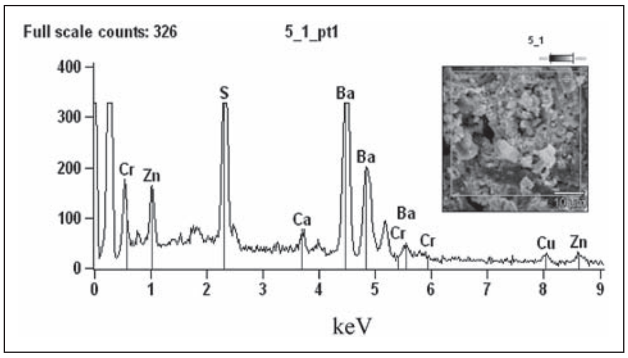

Figure 2 Exploitation dust coming from clutch, fraction below 20 μm. (SEM) magnification 2000 x, (EDS)

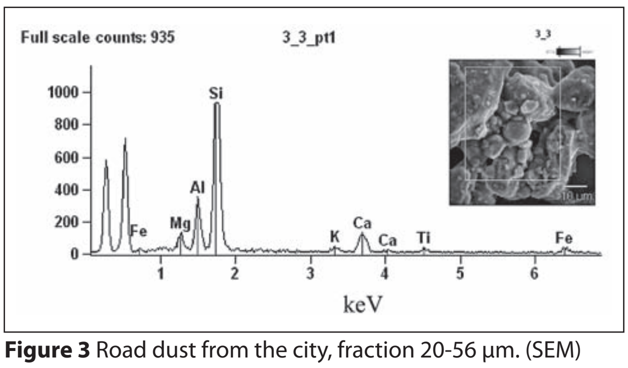

Figure 3 Road dust from the city, fraction 20-56 μm. (SEM) magnification 2000 x, (EDS)

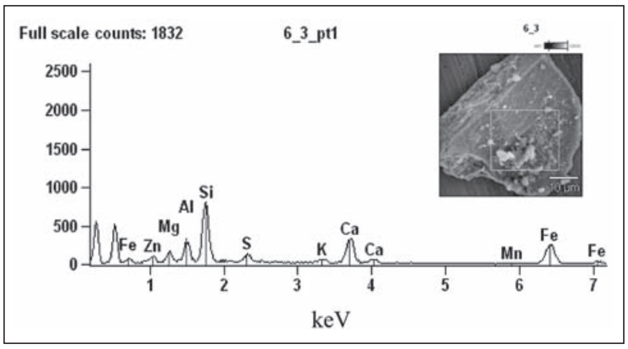

Figure 4 Road dust from a mountain road, fraction 20-56 µm. (SEM), magnification 1000 x, (EDS).

shown coming from the city section. A presence of such chemical elements as magnesium, titanium, iron and silicon, calcium and potassium was confirmed (the last three show other background than use). Similar results were obtained in surface analysis of the dust coming from mountain road and motorway section (Figure 4).

SUMMARY

On the basis of the conducted measurements it was established that:

- the recognition of the size of dust coming from cars needs a separation of fraction up to 56 µm from the whole road dust (test results confirmed that in such dust fractions the characteristic chemical elements "from use" appear, which are zinc, manganese, iron and titanium),
- during the measurements it was established, that the biggest amount of dust up to 56 µm was present on the city roads, that was 3.6 % of the total tested dust,
- no dust particles coming from use were found during tests in fractions above 56 µm,
- in the process of separation of fraction of dust the assumed criterion of fraction size should not be generalised, because of specific spatial, economic and road conditions which should be taken into account (on roads surrounding certain industry enterprises such as steel plant or cement plant the results may be higher in reference to the contents of the tested dust),
- the biggest amount of particles of fraction below 20 µm appeared on the motorway – about 0.5 % of the total. On mountain road such fraction was not present due to small car traffic.

The authors would like to mention the fact that realised measurements and tests of dust structure did not include the quantity comparisons.

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