Analysis of elemental and mineralogical composition of car brake pads

Kubılė L.[1], Ragelıenė L.[1], Dıkšaıtytė A.[1], Tučkutė S.[2], Mıškınytė A.[1]

[1]Vytautas Magnus University, Vileikos str. 8, Kaunas, Lithuania

[2]Lithuanian Energy Institute, Breslaujos str. 3, Kaunas, Lithuania

*corresponding author: Kubilė L.

e-mail: lina.kubile@vdu.lt

Abstract

The car traffic is an important source of particle emission. The inevitable process of car stopping is related with the particles emission because of break pad waning. High temperature, pressure and friction induces chemical or morphological changes of the initial composition of brake pads. Brake pads are mainly combined of different materials: carbon, silicates and iron oxides. This study presents a summary of elemental and mineralogical composition of different brake pads commonly used in Lithuania. The mineralogical composition of brake pad samples were identified by XRD (X-Ray Diffraction Spectrometry), while the elemental composition was determined by XRF (X-Ray Fluorescence Spectrometry) and EDS (Energy Dispersive Spectroscopy). The texture and morphology was determined with SEM-EDX (Scanning Electron Microscopy). Various particles of heavy elements - Ba, Zn, Co, Ni, Cr, Al, Sb, V, Y, Pb have significant impact on health and environment.

Keywords: heavy metals, particles, brake pads, toxicity, environment.

1. Introduction

The particle emission caused by motor vehicle braking system has a negative effect on the environment and human health. Particulate matter are the main cause of environmental effects such as reduced visibility, acid deposition and ozone. The most polluted areas include largely urban zones where heavy traffic, power industry and other industrial facilities induce dust emission (Chłopek *et al*. 2016). Traffic-related sources have been recognized as a significant contributor of particulate matter particularly within major cities. Brake wear is a non-exhaust source which can be a significant particle emission contributor, especially within areas with high traffic density and braking frequency (Grigoratos and Martini, 2015). According to studies, in urban zones brake wear can contribute up to 55 % by mass to total non-exhaust traffic-related particle matter 10μm emissions and up to 21 % by mass to total traffic-related particle matter 10μm emissions, while in freeways, this contribution is lower due to lower braking frequency (Grigoratos and Martini, 2015). Particulate matter pollution is very harmful for human health, it was designated a Group I carcinogen by the International Agency for Research on Cancer (IARC) (Hamra *et al*., 2014).

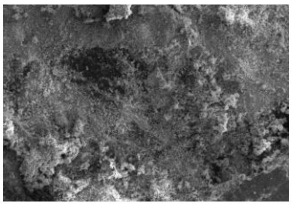
The materials of automotive brake pads are composites of many substances. Additives, such as abrasives, friction modifiers, fillers and reinforcements, binder materials are used in brake pad material to enhance proper funcions of braking system. Some additives are potentially toxic. After the ban of asbestos fibers for brakes manufacturing in mid-90s, composition of brake linings has rapidly changed but there is still a number of possible toxics used (heavy metals, their sulphides, PAHs etc.) (Kukutschová *et al*., 2011; Afiqah *et al*., 2015). Detailed information on materials used for creating brake pads is not provided by manufacturers. The main components of particulate matter are transition metals, organic compounds, minerals, biological origin substances and other materials.

Toxicological research studies have demonstrated that particulate matter causes oxidative stress in cells, generates oxygen-free radicals, stimulates proinflammatory factors and causes mutations (Valavanidis *et al*., 2008). Cytotoxic and carcinogenic mechanisms of particulate matter depend on chemical composition and size of particles.

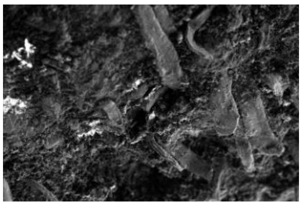
The aim of this study was to investigate elemental and mineral composition of different brake pads including most popular in the country. The information acquired through research is important for emission inventories and toxicological studies.

Table 1. The comparative elemental analysis of the powder of two different brake pads (S1 and S2) performed with XRF and EDS

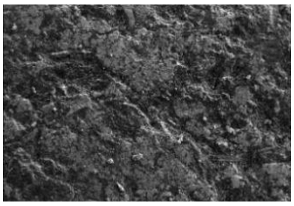
Sample	Concentration of elements, % (wt)							
	Ca	**Fe**	**Mg**	**Zn**	**S**	**Ba**	**Cl**	**Cu**
S1 (XRF)	1.68	16.00	0.88	2.43	1.15	4.53	0.15	3.97
S1 (EDS)	2.05	18.17	0.77	1.06	1.39	9.55	0.19	0.83
S2 (XRF)	3.35	19.00	-	1.81	0.43	1.14	1.69	1.31
S2 (EDS)	4.46	33.05	0.52	2.17	0.50	2.02	3.07	1.88



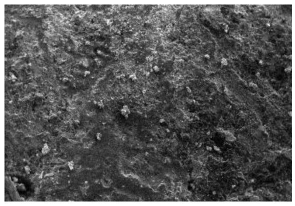
A – surface of the left side



B – The deeper layer of left side



C – the surface of central area



D – the surface of right side

Figure 1. Break pad areas and SEM images of coresponding parts. A – surface of the left side; B – the deeper layer of left side; C – the surface of central area; D – the surface of right side.

Table 2. The elemental analysis of solid break pad A, B, C, D areas.

Element	Concentration, % (wt)			
	A	**B**	**C**	**D**
C	9.02	18.57	28.23	14.61
O	23.09	4.66	19.38	27.61
Fe	62.23	64.04	44.61	40.36
Ca	1.83	-	-	4.09
Ba	1.07	5.50	2.87	1.07
Mg	-	4.17	2.81	3.81
Zn	-	-	-	2.53
S	-	1.15	-	-

* The data of EDS analysis presented only of the elements which concentration was higher than 1.

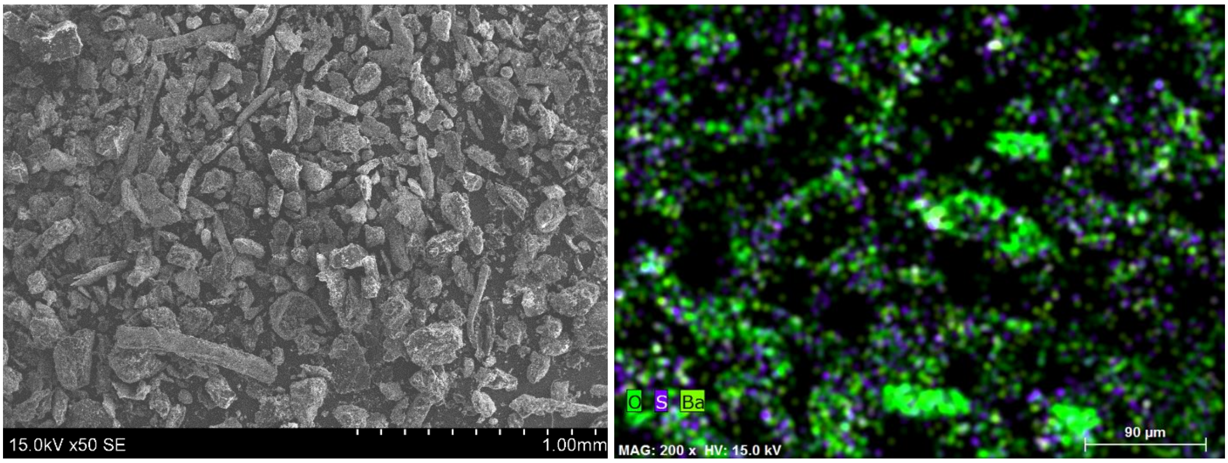


Figure 2. S2 brake pad surface (1 mm, 50x) by SEM (left) and SEM mapping photograph of Ba, S and O (right).

2. Materials and Methods

The elemental composition of brake pads was studied using X-ray Fluorescence spectrometry (XRF), Scanning Electron Microscope (SEM) (HITACH S-3400N) and Energy Dispersive Spectroscopy (EDS) (BRUKER Quantax). While X-Ray Diffraction spectrometry (XRD) (Bruker D8 Discover) was used for the identification of mineral composition.

For this research, both solid brake pads and samples of powder produced by rubbing same brake pads were used. All present data was calculated by three independent experiments.

3. Results and Discussion

The elemental composition of brake pads is given in Table 1. The comparative analysis data (gained by XRF and EDS) confirmed that the brake pads are heterogeneous due to their nature. Therefore, the quantitative analysis data are highly dependent on the area from which the sample of powder was prepared. Hence, the elemental analysis of different areas of solid brake pad was done using EDS. The picture of brake pads is given in Figure 1. The elemental analysis of solid break pad different areas are given in Table 2. The data presented in this table revealed that the composition of deeper layer of left side differs from the other investigated parts of brake pads with the highest amount of Fe, Mg, Ba and S. Mapping photograph (Figure 2) confirms the close distribution of Ba, S and O, which is the identification of existing $BaSO_4$ in the brake pad.

4. Conclusion

It was determined that the main elements of investigated break pad are: C, O, Fe, Ca, Ba, Mg, S, Al. Barite, calcite, mullite are the main components of mineral composition (and small amounts of CuO, Fe_2O_3, ZnO, TiO_2).

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