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POLLUTANTS IN RAIL BED MATERIAL

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Abstract: The following concentrations NEL, PAU, Cu, Ni, Zn, As, Cr, Cd, Pb and Hg are presented in this paper which were measured in five selected samples of rail bed materials from region of the city Košice, Slovak Republic. The experimental part of the paper highlights the effect of the size of rail bed particles on the concentration of different pollutants in both aqueous solutions and dry matters. Due to these results it can be clearly stated that decreasing the particles brings about the concentration increase of all observed elements in both aqueous solutions and dry matters. Concerning the five analyzed samples only one of them, taken from the rail switch, (particle size from 0 to 63 mm) is ecologically insufficient as in this given sample the concentration of Cr exceeded the limit by 5.312 mg/kg of dry matter. The measured value of Cr concentration was 255.312 mg/kg of dry matter and the threshold limit value according to the Methodical Instruction No.18/99 of the Ministry of Transport, Post and Telecommunication of Slovak Republic is 250 mg/kg of dry matter.
Keywords: pollutants, rail bed, ecological assessment

1. INTRODUCTION

The rail bed is part of the roadster which transfers load onto the railway roadbed construction. It supports the elasticity (flexibility) of the roadster, ensures the required stability of the rails and enables adjustment of the rail position. The rail bed material has to meet different quality requirements. The following materials can be used new natural gravel e.g. granite, greystone, andesite or recycled ones. The size of rail bed granula has to be in the range of 32 mm to 63 mm. The material quality of rail bed during its period of service is assessed due to qualitative comparison of analyzed samples due to different assessment parameters of rail bed material in laboratory conditions with threshold limits [1, 2]. The permanent monitoring of dangerous heavy metals (Hg, Cd, As, Cr, Pb, Ni, etc.) in various parts of environment leads to improvement of human health protection [3, 4].

To diagnose the parameters of ecological quality of rail bed material there were applied the methods of laboratory analyses of chemical material properties.

The diagnosed parameters of initial diagnosis can be divided into the following ones:

- Technical parameter – includes simple petrography containing limestones and dolomite [5];
- Ecological parameter – according to technical specification for chemical analyses of material:
    1. in modified aqueous solution within six hours leaching period,
    2. in the dry matter.

In carrying out an initial diagnosis of rail bed construction parameters exclusively the methods of soil and sedimentary mechanics are applied [6].

The rail bed material has to resist not only the operational stress but also climatic effects (water, snow, snow with ice, wind) and all these factors demote its technical quality.

The aim of this paper is to identify and assess the pollutants in five selected samples and due to the results of ecological analysis on monitored size fraction to decide whether the material meets or does not meet the ecological requirements on assessed rail bed material in aqueous solution and in dry matter according to Methodical Instruction No. 18/99 of the Ministry of Transport, Post and Telecommunication of Slovak Republic.

2. EXPERIMENTAL

The analyzed samples come from the region of the city Košice (SR) and namely from the sleepers of various quality classes: divide station rails, station rails and rail switches. The concentration of pollutants NEL (nonpolar substances–oil substances), PAU (polyaromatic hydrocarbons), Cu, Ni, Zn, As, Cr, Cd, Pb, Hg in sample materials were identified during the experiment:

a) In modified standard solution
b) In the dry matter

The samples with 1 kg weight were provided for the accredited laboratory. The modified standard solution was prepared due to weight ratio i.e. sample: water = 1:10. The total weight of the dry matter was determined for the laboratory sample at the temperature 105°C. Then the amount of original sample was weighed which was equal to 100 g±0.1 g of the dry matter on 1 litre of distilled water. The weighed sample was qualitatively transferred into a suitable non–reactive box and 1000 ml of distilled water was added on each 100 g of weighed sample [7]. The box was locked up and the sample with water was intensively being shaked. The intensity of shaking on the shaking machine with horizontally vibrating working floor was 100 vibrations / min (the sample was permanently floating). Next the solid phase was separated from the liquid one by filtration.

Further experimental conditions were as follows:

- Temperature of leaching was 20±3°C
- Contact period between solid and liquid phases was 6 hours (3 hours shaking, 3 hours resting phase)

Cu, Ni, Zn, Cr, Cd, Pb concentrations in the leaching solutions were analyzed by AES–ICP (Varian LIBERTY 200) and Hg by AAS–AMA (AMA 254) methods.

Arsenic was analyzed by hydride generation method i.e. HG–AAS (Varian SpectrAA 220, VGA–76) in the leaching solutions and in the dry matter.

Cu, Ni, Cd and Pb concentrations in the dry matter were analyzed by FAAS (Varian Spectr AA 220) method and Zn and Cr concentrations by AES–ICP method. The Hg concentrations were analyzed by AAS–AMA (AMA 254) method. Cu, Ni, Cd, and Pb concentrations in the dry matter were analyzed by FAAS (Varian Spectr AA 220), Zn and Cr by AES–ICP method.

PAU concentrations in the dry matter were analyzed by HPLC/FD method (VARIAN STAR).

Labeling of rail bed material samples:

- samples 1 and 4 come from station rails
- samples 2 and 5 are from divide station rails
- sample 3 is from rail switch.

During experiment the samples 1 to 5 were applied with particle size from 0 mm to 63 mm. The concentration of pollutants was identified also in samples with particle size from 0 mm to 8 mm and from 0 mm to 32 mm.

The granulometry of rail bed material samples 1 to 5 are presented in Table 1. In sample 1 there was identified 6.1% fraction of particles +63 mm and in sample 2 this fraction was 9.97 %.

Table 1. Granulometry of samples No. 1 – 5

Sample number	Fraction due to granular material classes /%			
	0–8 mm	8–16 mm	16–32 mm	32–63 mm
1	17.86	6.32	21.57	48.15
2	19.93	13.62	24.25	32.23
3	30.95	6.23	26.56	36.26
4	22.22	8.71	18.92	50.15
5	12.33	6.17	24.40	57.10

3. RESULTS

The experimentally determined concentrations of pollutants in different samples in aqueous solutions are shown in Table 2. In the last column there are presented the threshold limit values of concentration according to Methodical Instruction No.18/99 on ecological assessment of analyzed material obtained from the rail sleepers [7]. The particle size of analyzed samples of rail bed material was from 0 mm to 63 mm.

Table 2. Measured concentrations of pollutants in aqueous solution (particle size 0 – 63 mm) and the threshold limit value of concentrations.

Pollutant	Concentration / mg l^{-1}					
	1	2	3	4	5	Treshold [7]
NEL	0.0054	0.002	0.0062	0.0089	0.0012	0.1
Cu	0.0093	0.0096	0.0136	0.0242	0.0075	0.1
Ni	0.0018	0.004	0.0031	0.0044	0.0025	0.1
Zn	0.0027	0.0084	0.0037	0.0051	0.001	3
As	0.0011	0.0002	0.0003	0.0007	0.0009	0.05
Cr	0.0004	0.0004	0.0006	0.0004	0.0002	0.05
Cd	0.0004	0.0004	0.0006	0.0004	0.0002	0.005
Pb	0.0018	0.002	0.0031	0.0044	0.0012	0.05
Hg	0	0	0	0	0	0.001

The measured values of pollutants concentration in various samples with particle size from 0 to 63 mm in Table 2 demonstrate that copper achieves the highest values in samples 4 and 3. Comparing the measured concentrations with threshold limit values due to [7] proves that no pollutant exceeds the given values and therefore it follows that the ecological assessment of sample materials meets the required quality requirement.

In Table 3 the measured concentration values of analyzed sample for the dry matter can be seen and the threshold limit value of pollutants for the samples with particle size 0–63 mm.

Table 3. Comparison of measured concentrations of pollutants in the dry matter (particle size 0–63 mm) with threshold limit value of concentrations.

Pollutant	Concentraction / mg kg^{-1} dry matter					
	1	2	3	4	5	Treshold [7]
NEL	295.84	16.15	289.66	90.44	9.86	700
PAU	0.197	0.199	1.826	0.222	0.123	40
Cu	74.67	17.54	67.46	50.44	6.906	100
Ni	3.93	2.99	20.73	4.44	3.083	100
Zn	96.11	21.13	225.603	42.889	22.445	500
As	4.084	1.77	5.481	2.669	2.915	50
Cr	93.612	19.535	255.312	96	44.027	250
Cd	0.232	0.08	0.279	0.133	0.037	5
Pb	20.187	6.977	93.46	20.889	6.413	150
Hg	0.149	0.061	0.227	0.039	0.012	3

The values presented in Table 3 show that sample 3 proves the highest concentration of PAU, Cr and Zn. According to accomplished analysis it can be stated that only one sample of five taken from rail bed material in the region of the city Košice proves insufficient ecological quality and this is sample 3 taken from the rail switch as the Cr concentration (255.312 mg kg^{-1} dry matter) exceeded the threshold limit value 250 mg kg^{-1} dry matter due to [7].

In sample 3 (ecologically insufficient quality) the concentration of monitored pollutants is decreasing due to the following order: NEL, Cr, Zn, Pb, Cu, Ni, As, PAU, Cd, Hg.

The ecological assessment of rail bed samples was carried out for the particles sizes as well:

a) from 0 mm to 8 mm
b) from 0 mm to 32 mm

The dependency of various pollutants concentrations in selected samples in modified standard solutions on particle size is diagrammatically demonstrated in figures such as Figure 1 presenting copper, Figure 2 arsenic and Figure 3 NEL (nonpolar substances – oil substances).

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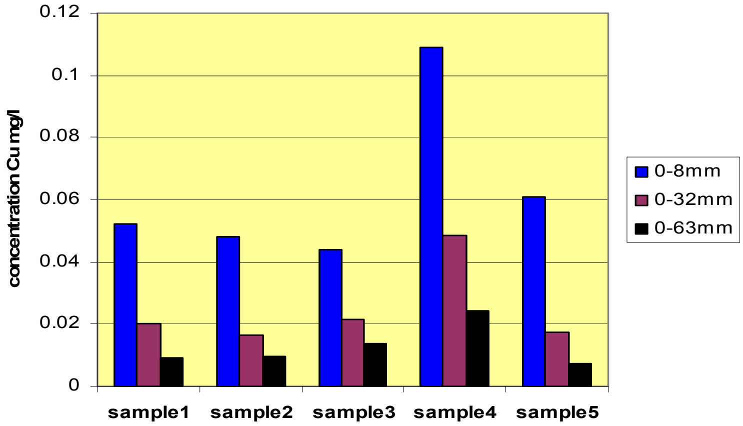

Figure 1: Effect of particle size on copper concentration in aqueous solution
(threshold limit value=0.1 mg/l).

Figure 1 shows sample 4 with particle size 0–8 mm highlighting the fact that the Cu concentration exceeded the threshold limit value (0.1 mg/l) and this is the reason for not having the required ecological quality.

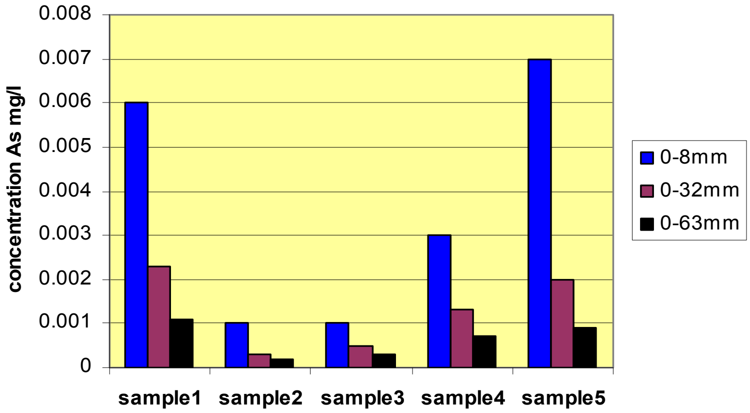

Figure 2: Effect of particle size on arsenic concentration in aqueous solution
(threshold limit value=0.05 mg/l).

Due to low As concentration values (see Figure 2) it can be assumed that As in rail bed samples is present in the form which is less soluble in water.

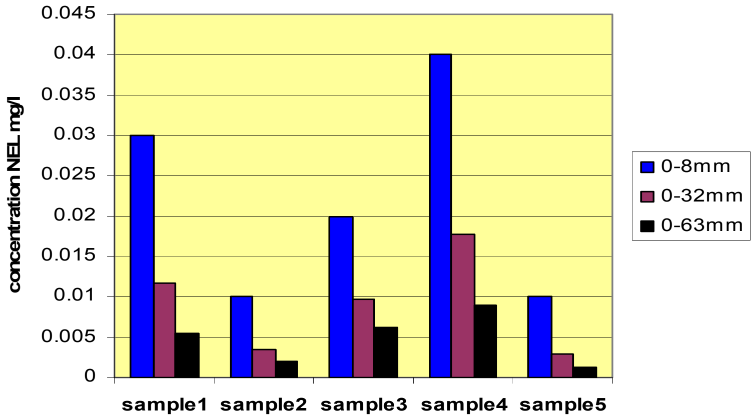

Figure 3: Effect of particle size on NEL concentration in aqueous solution
(threshold limit value=0.1 mg/l).

The threshold limit value of NEL concentration is 0.1 mg/l as it is evident in Figure 3 , all the measured NEL concentration values are lower in all samples.

Comparison of the measured Ni, Zn, Cr, Cd, Pb and Hg concentration values e.g. in sample 1 with the threshold limit values is shown in Table 4. Similar low Ni, Zn, Cr, Cd, Pb and Hg concentrations were identified in samples 2 to 5 and the effect of particle sizes on concentration of these elements in the aqueous solutions were proved.

Table 4. Effect of particle size on the Ni, Zn, Cr, Cd, Pb and Hg concentrations in the aqueous solution in sample 1 in comparison with the threshold limit value

Pollutant	Concentration mg/l			
	0–8 mm	0–32 mm	0–63 mm	Treshold limit value [7]
Ni	0.095	0.0039	0.0018	0.1
Zn	0.015	0.0059	0.0027	3
Cr	0.002	0.0008	0.0004	0.05
Cd	0.002	0.0008	0.0004	0.005
Pb	0.01	0.0039	0.0018	0.05
Hg	0.0001	0	0	0.001

The effect of particle size on Cu, PAU and Cr concentrations in the dry matter is presented in Figures 4, 5 and 6.

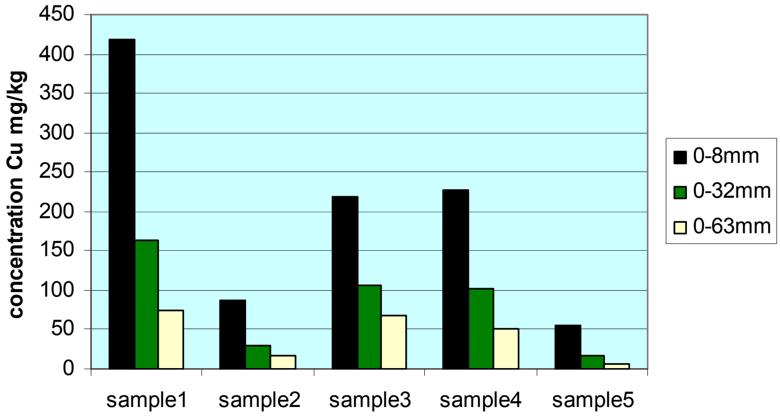

Figure 4. Effect of particle size on the copper concentration in the dry matter (threshold limit value = 100 mg kg^{-1} dry matter)

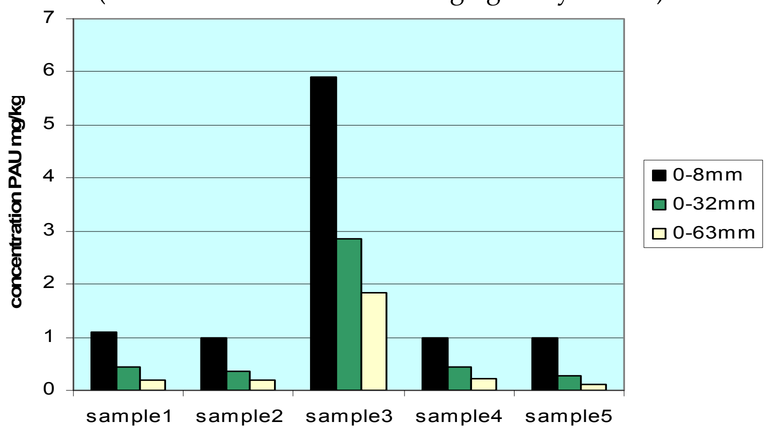

Figure 5. Effect of particle size on the PAU concentration in the dry matter (threshold limit value = 40 mg kg^{-1} dry matter)

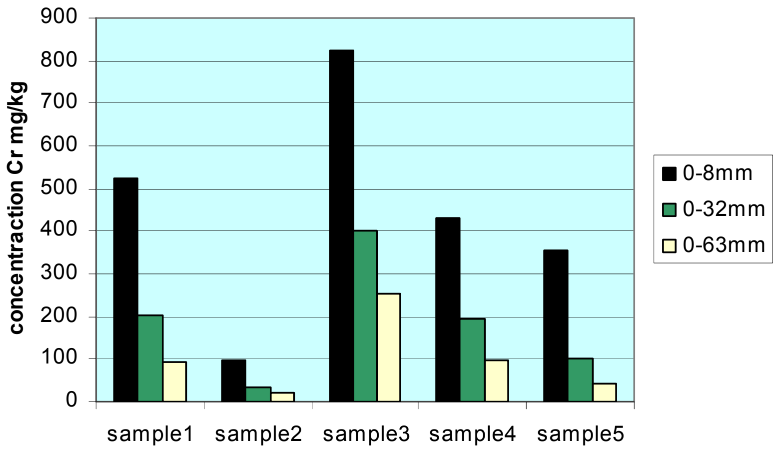

Figure 6. Effect of particle size on the Cr concentration in the dry matter (threshold limit value = 250 mg kg^{-1} dry matter)

According to Cu concentration values in Figure 4 it can be exemplified that samples 1 and 3 with particle sizes 0–8 mm and 0–32 mm and sample 4 with particle size 0–8 mm show insufficient ecological quality because they exceed the threshold limit value i.e. 100 mg/kg dry matter.

Due to measured concentration values of pollutants shown in Tables 2, 3, 4 and in Figures 1 to 6 the following facts can be concluded:

- the smaller the particle size the higher is the concentration of analyzed elements (it is the consequence of high specific surface)
- total concentration of analyzed dangerous elements in sample 3 is decreasing in the following order:
  - in aqueous solution:
    - particle size 0–8 mm: Cu, NEL, Zn, Ni, Pb, Cr and Cd, As, Hg
    - particle size 0–32 mm: Cu, NEL, Zn, Ni a Pb, Cr and Cd, As, Hg
    - particle size 0–63 mm: Cu, NEL, Zn, Ni, Cr and Cd, Pb, As, Hg
  - in the dry matter:
    - particle size 0–8 mm: NEL, Cr, Zn, Pb, Cu, Ni, As, PAU, Hg, Cd
    - particle size 0–32 mm: NEL, Cr, Zn, Pb, Cu, Ni, As, PAU, Hg, Cd
    - particle size 0–63 mm: NEL, Cr, Zn, Pb, Cu, Ni, As, PAU, Hg, Cd
- in analyzed samples there is a low arsenic and mercury concentration.
- The current presence of more than one heavy metal can cause synergistic increase of toxicity in soil [8].The concentrations of different toxical elements in aqueous solution are decreasing in the following order (Cd+Zn) > (Ni+Cu) > (Pb+Cr) > (As+Hg).

4. CONCLUSION

According to final assessment of rail bed material the ecological quality of rail bed material was determined as a whole (it concerns the fraction 0 – 63 mm). The accomplished analyses showed that only sample 3 from five ones taken from the rail switch in the region of the city Košice has insufficient ecological quality. In this sample high Cr concentration was measured i.e. 255.312 mg/kg dry matter. The threshold limit value for Cr due to [7] is 250 mg/kg dry matter. It can be assumed that exceeding the Cr concentration could have been brought about by loose particles caused by railway carriage wheel friction or probably by emission of transported materials by railway. This ecologically insufficient material can be replaced by fractions 0 – 8 mm or 0 – 32 mm which meet the quality requirements. This is the reason for carrying out analyses in different granular material classes. The further analyzed pollutants i.e. NEL, PAU, Cu, Zn, Ni, Pb, As, Hg and Cd in all 5 samples with particle size from 0–63 mm did not exceed the threshold limit value of concentration.

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