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Research into the impact of speed bumps on particulate matter air pollution

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ABSTRACT

Most traffic accidents occurs when a vehicle collides with another vehicle, pedestrian, animal, road debris or other stationary obstruction, such as a tree or utility pole. One of the most popular speed regulation implement is speed bumps. Speed bumps are installed in residential areas and towns to regulate the speed of traffic. When vehicles pass through them air pollution with particulate matter increases due to emissions from vehicles during braking and particulate matter dispersion. Transport is one of the particulate matter emission sources of the size of 10 μm (PM10) and less that are harmful to humans and nature in general, have been studied. Air pollution with particulate matter at speed bumps was assessed analysing speed bumps structures of different types installed in Lithuania's different residential areas. According to the research it was found particulate pollution at different car number and relative humidity. As determined according to the results of the performed research, air pollution with particulate matter increases by 2–5 times. Pollution near the trapezium-shaped pedestrian crossings increased 55.7% and near the plastic circular speed bumps – 58.6%.

1. Introduction

Road vehicle emissions account for about 70–80% of the pollutants getting into the air. Basing on research results, pollution with small particulates, not larger than 10 μm in diameter (PM10, PM2.5), is some of the most serious air quality problems in towns [21,22,25,26]. Their daily average concentrations in urban areas exceed the standards every year [3,7,14,17].

Basing on air pollution studies, nearly 34% of fine particulates get into the atmosphere from non-asphalt roads and roads untreated with any materials [18]; however, a fair amount of pollution is caused by particulate matter from vehicles travelling along asphalt roads [6,20,27]. Atmospheric pollution caused by the use of speed bumps (SBs) is particularly responsible for increased pollution [2,4,11,13].

Installation of traffic calming signs rarely solves the problem of traffic safety on dangerous road sections [28]. Therefore, use of SBs has proved to be an efficient method for regulating vehicle speed on roads [9,10,23]. Due to sharp braking of the vehicles travelling towards SBs wear of the tyres increases and larger emissions of particulate matter in exhaust gas and other pollutants generate. Changing velocity causes additional ambient air turbulence [1,5,8,12,15,16,19,24].

The aim of this research is to evaluate ambient air pollution with particulate matter resulting from the use of SBs. The actual and caused air pollution was compared with the limit values established in accordance with the requirements laid down in Directive 2008/50/EC of the European Union.

2. Methodology

SB measurements are selected so as not to interrupt the work of special services. The materials and the whole structure of SB are resistant to heavy vehicles load and can be used in the places of communal and goods vehicle traffic. SBs are universal because they can be installed on a lane of any width; temporary SBs can be used in the places where temporary speed reduction is necessary. They are installed into asphalt with metal spikes. In the case of concrete surface, they are infixed with bolts. They are particularly durable and stable, and distinguished by 'hard' operation. A SB reduces vehicle speed by up to 3–8 km/h (Fig. 1a).

Tests for air quality at traffic calming devices were performed at ten sites in Lithuania. To evaluate the influence of these devices on an increase in air pollution, they were divided into two groups:

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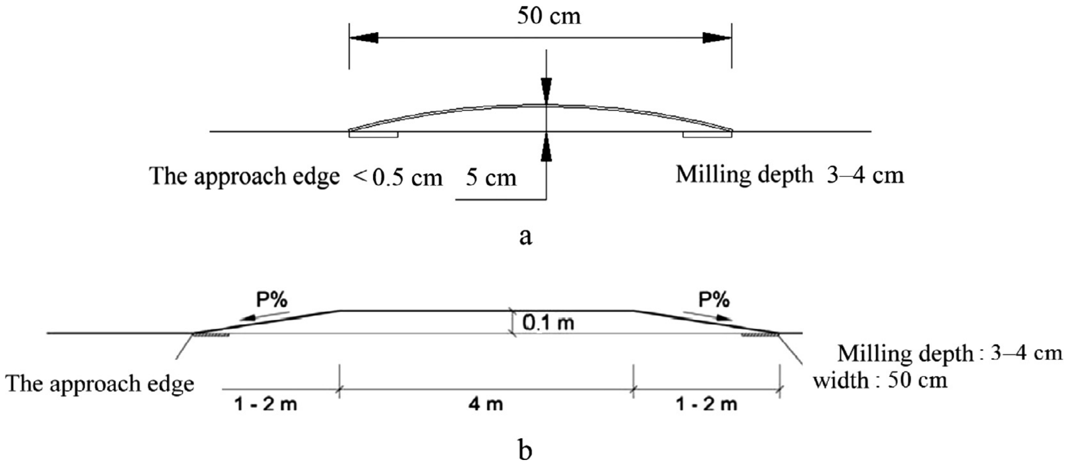

Fig. 1. Structure of prefabricated plastic speed bump (a) and raised trapezium-shaped crosswalk (b).

(1) trapezium-shaped SBs, 3 m long and 10 cm ± 1 cm high, length of the raised area – 4 m ± 0.20 m (also known as a raised pedestrian crossings) (Fig. 1b);
(2) the longitudinal section of the trapezium-shaped SB consists of one elevated section and two sloping areas called ramps (altogether forming a trapezium) (Fig. 1b);
(3) length of ramps – from 1 to 2 m: 1 m – in a 30 km/h speed zone; 1.40 m – where the permitted speed is 40 km/h; 2 m – where the permitted speed is limited to 50 km/h;
(4) prefabricated plastic (circular) SBs, approximately 0.5 m long and 5 cm high (Fig. 1b).

Two types of different SB structures – raised trapezium-shaped and prefabricated plastic bumps – were analysed in this research (Fig. 2).

Raised trapezium-shaped asphalt or prefabricated pedestrian crossings and a raised pedestrian crossing (RPC) were used in seven measurement sites. In the remaining three sites measurements were performed at circular plastic prefabricated bumps. The site for dust concentration research is selected according to the direction of the wind. The research site has to be downwind. The wind parameters and PM concentration measured using half–hourly averaging time. The data measured at constant weather conditions. Mismatches on the wind direction and strength, or precipitation (rain) or other factors research for the time being terminated, thus, it was to avoid inconsistencies. Concentration determination studies has not been made at wind gusts or variable direction strong wind, it has been done to minimize the impact on the results. The analyser of PM_{10} concentration (a β sensor) was calibrated each time with a known concentration of PM_{10} standard, thus the impact of moisture parameters on the measurement results was avoiding.

During measurements the concentration of dust (particulate matter) was measured with the analyser having two β sensor together in the control site and in the research site at SB. At the same time it was visually identified and calculated the number of light and heavy vehicles. Measurements were made in the range of particulate matter less than 10 μm in diameter (PM_{10}) of 0–10,000 $\mu g/m^3$. The research was carried out at a height of 0.5 m and at a distance of 1.5 m from the roadside. During research dust concentration in ambient air was measured simultaneously in two research sites: sites 1 and 2 (Fig. 3). Measurement site 1 was selected at the SB where speed on the road is calmed. Measurement site 2 was selected at a distance of 150–400 m from the place where speed on the road is calmed, i.e. in the control site where vehicles can travel without any hindrances (Table 1).

Based on the studies it was determined PM_{10} concentrations in the control sites and at different types SB by comparing with the standard of the ambient air. It was found a correlation between the vehicles having passed through SB and the emission of PM_{10}. It was estimated the relative humidity in each area, and according to the PM_{10} in the control and at SB point were composed their dependences.

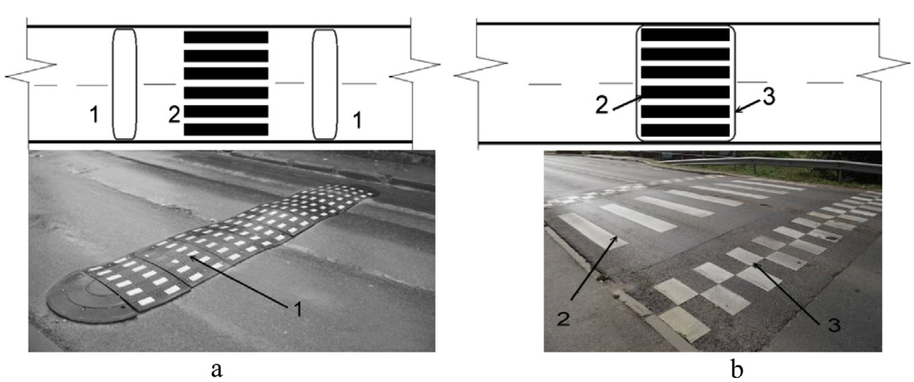

Fig. 2. Basic diagrams and the samples of use of speed bumps: a – prefabricated plastic speed bump, b – raised trapezium-shaped SB, 1 – speed bump plastic element, 2 – pedestrian crossing, 3 – speed bump asphalt element.