

Vegetation and temporal variability of particle size distribution (PSD) and organic matter of urban road deposited sediments in Frankfurt am Main

Distribution des tailles de particules et de leur teneur en matière organique dans les rejets de voiries urbaines à Frankfurt am Main en fonction de la végétation et de la saison

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RÉSUMÉ

Les caractéristiques des rejets de voiries (RDS) prélevés sur plusieurs voiries urbaines à Francfort-sur-le-Main et avec différentes granulométries (0 à 2 mm, 2 à 4 mm, 4 à 8 mm) sont présentées en fonction de leur proportion en masse et de leur teneur en matière organique (mesurée avec la perte au feu, LOI). En général, la proportion en masse de la fraction de 0 à 2 mm est considérable (plus de 80 %) dans tous les sites étudiés, sans influence des caractéristiques du site (p. ex. impact du trafic). Le pourcentage en masse des particules dans les fractions de 2 à 4 mm et 4 à 8 mm est d'importance mineure. Cependant, les valeurs de LOI sont plus élevées dans les fractions grossières (2 à 4 mm, 4 à 8 mm), en particulier dans les sites avec une végétation donnant lieu à des débris hétérogènes de feuilles et de fleurs. La LOI dans la fraction de 0 à 2 mm est plus faible et les résultats sont plus homogènes. Dans cette fraction, l'influence de la végétation sur la LOI est significative (6 % dans les sites sans végétation pertinente et 24 % dans les sites où la végétation est dense (moyenne)). De plus, les valeurs de LOI étant plus faibles pendant l'hiver que pendant les saisons de végétation (printemps, été, automne), on peut constater que la saison a une influence évidente. Ainsi, la végétation et les saisons sont des paramètres importants qui influencent les caractéristiques des particules présentes dans les RDS. Les résultats permettent de mieux connaître les caractéristiques des particules présentes dans les RDS, qui sont des paramètres cibles importants pour les polluants dans le traitement des eaux de pluie.

ABSTRACT

The characteristics of road-deposited sediments (RDS) taken from several urban road sites in Frankfurt am Main with different particle size fractions (0-2 mm, 2-4 mm, 4-8 mm) are presented with respect to their mass proportion and organic matter (measured as Loss of Ignition, LOI).

Generally, the mass proportion in the 0-2 mm fraction is significant (over 80%) in all investigated sites without influences of site characteristics (e.g. traffic impact). Particle mass percentage in the size fractions 2-4 mm and 4-8 mm is of minor relevance. However, LOI values are higher in the coarse fractions (2-4 mm, 4-8 mm), especially in sites with relevant vegetation due to heterogeneous leaf and blossom litter. LOI in the fraction 0-2 mm is lower and the results are more uniform. In this fraction, the influence of vegetation on the LOI is significant (6% in sites with no relevant vegetation and 24% in sites with high vegetation (mean)). Furthermore, a clear influence of the season can be observed through lower LOI values in the winter quarter compared to the vegetation quarters (spring, summer, autumn).

Thus, amount of vegetation and temporal variations are significant parameters influencing the particle characteristics in RDS. The results contribute to a greater knowledge of particle characteristics in RDS, which are important target parameters for pollutants in stormwater treatment.

KEYWORDS

Loss of ignition, particle size distribution, road-deposited sediments, seasonal effects, vegetation

1 INTRODUCTION

Road-deposited sediments (RDS) are the source of particles and corresponding pollutants (e.g. heavy metal) in road runoff (Loganathan et al., 2013; Kayhanian et al. 2012). Polluted road runoff discharged into receiving waters may cause environmental problems (House et al., 1993).

Therefore, it is essential to investigate the quantities and composition of RDS in relation to site specific conditions and seasonal variability. Besides the particle size distribution (PSD), the organic matter (measured as Loss on Ignition, LOI) is a further interesting parameter for estimating the behaviour of pollutants and particle properties for removal processes (e.g. density of particles for sedimentation).

One objective of this study is to identify important influencing factors on the amounts and content of organic matter. Therefore, RDS were analysed for the LOI of different particle size fractions. RDS were collected from several road surfaces in Frankfurt a. M. representing typical urban site conditions.

2 MATERIAL AND METHODS

The study sites are located in a suburban district of Frankfurt am Main. The amount of vegetation was calculated using the geographical estimation of the percentage tree canopy coverage (TCC). Furthermore, surrounding vegetation was evaluated qualitatively.

Tab. 1: Description of road sites in Frankfurt am Main, Nordend

Road site	AADT annual average daily traffic	TCC over road cross-section (%)	Vegetation within 50 m of sampling	Assessment vegetation	Sampling period
Brahmsstraße (BRS)	700	0	no vegetation	none	Q1/17 – Q1/18
Eckenheimer Landstr. (ECL)	13,700	15	trees	low	Q1/17 – Q2/18
Frauensteinstraße (FRS)	150	50	private gardening	high	Q1/17 – Q2/18
Glauburgstraße (GBS)	8,000	0	trees	low	Q1/17 – Q2/18
Nibelungenallee (NIB)	27,000	30	trees and lawn	high	Q2/16 – Q2/18
Nordendstraße (NES)	900	30	trees, playground	medium	Q2/16 – Q2/18
Rat-Beil-Straße (RBS)	16,600	5	trees, cemetery	medium	Q2/16 – Q2/18
Stettenstraße (STS)	150	0	private gardening	low	Q1/17 – Q1/18

RDS were collected during three years covering all seasons of the year by a combination of brushing and vacuuming as described by Gelhardt et al (2017). After drying the RDS (105 °C), their PSD was determined using a vibratory shaker (Retsch AS 200 Control) with stainless steel sieves (mesh sizes 8, 4 and 2 mm). The organic matter was analyzed by Loss on Ignition (LOI) according to the German standard method (DIN 38409-H2, 1987).

3 RESULTS AND DISCUSSION

3.1 Particle size distribution and LOI of road-deposited sediments

Fig. 1 shows the results as the mass proportions and LOI (mean) in fractionated RDS taken from sites with no/low and medium/high vegetation.

Regarding the PSD of particles in RDS, a wide spectrum between 0-8 mm is apparent. Fractions above 8 mm were determined to be between 0.8 and 6.8% (not illustrated). The 0-2 mm fraction is predominately important for road runoff (Kim and Sansalone, 2008; Zhao et al., 2016). Mass proportions above 80% occur in the 0-2 mm fraction, whereas the 2-4 mm and 4-8 mm fractions are underrepresented. This is confirmed by investigations in Berlin, where RDS samples have similar average mass proportions (89%) in the 0-2 mm fraction (Barjenbuch and Vengaus 2007).

The LOI value is higher in the coarse fractions, especially in sites with relevant vegetation. Furthermore, the values deviate considerably (standard deviation 2-4 mm: 27%; 4-8 mm: 32%). The reason for this effect is the heterogeneity of the vegetation content (e.g. leaves, blossoms). Compared to the coarse fractions, the LOI value of the 0-2 mm fraction is lower (6-16% in sites with low vegetation and 18-34% in sites with high vegetation) and the results are more uniform (standard deviation 0-2 mm: 13%). This is confirmed by investigations in Hawaii, USA in which RDS (20 samples) with PSD of 0-2 mm have an LOI of 10.5 to 48.2% (mean: 17.4% with a standard deviation of 7.7%) (Sutherland, 2003). In Manchester, UK, Carraz et al. (2006) determined LOI values between 3.8% and 22.6% in 0-2 mm RDS (mean 7.8%).

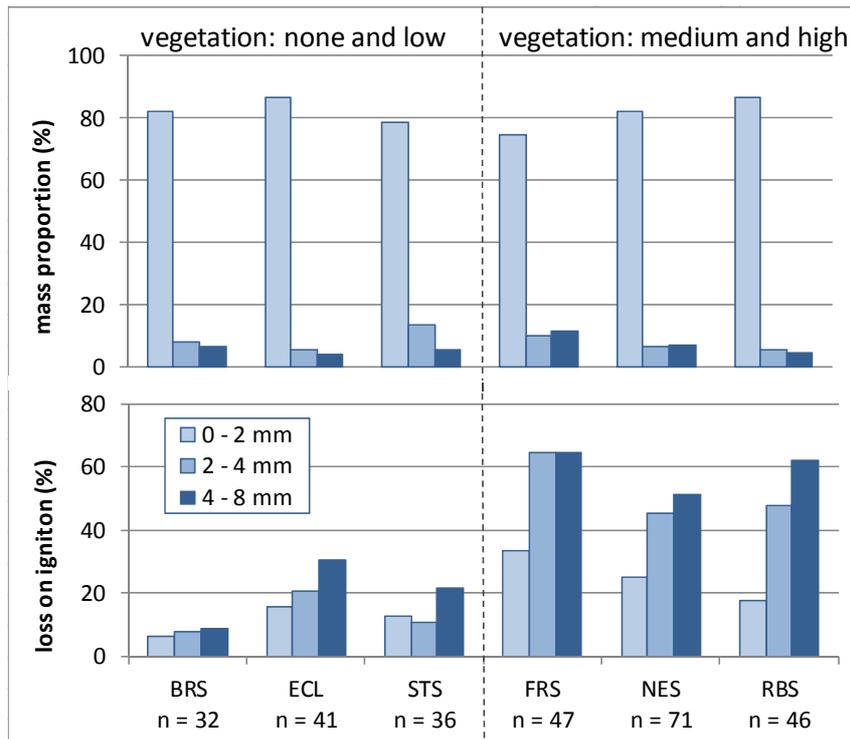


Fig. 1: Distribution of PSD (%) and LOI (%) of road deposit sediments taken from six road sites with varying vegetation (mean; n= number of RDS samples)

3.2 Influence of vegetation and seasonal variations on the LOI of road-deposited sediments with 0-2 mm fraction

To assess the influence of vegetation on the LOI, data from RDS (0-2 mm) were evaluated in terms of the estimated vegetation impact (Fig 2, left). Additionally, the seasonal effects were examined by illustrating the LOI of RDS from sites with high and moderate vegetation in four quarterly sampling periods in 2007 (Fig 2, right).

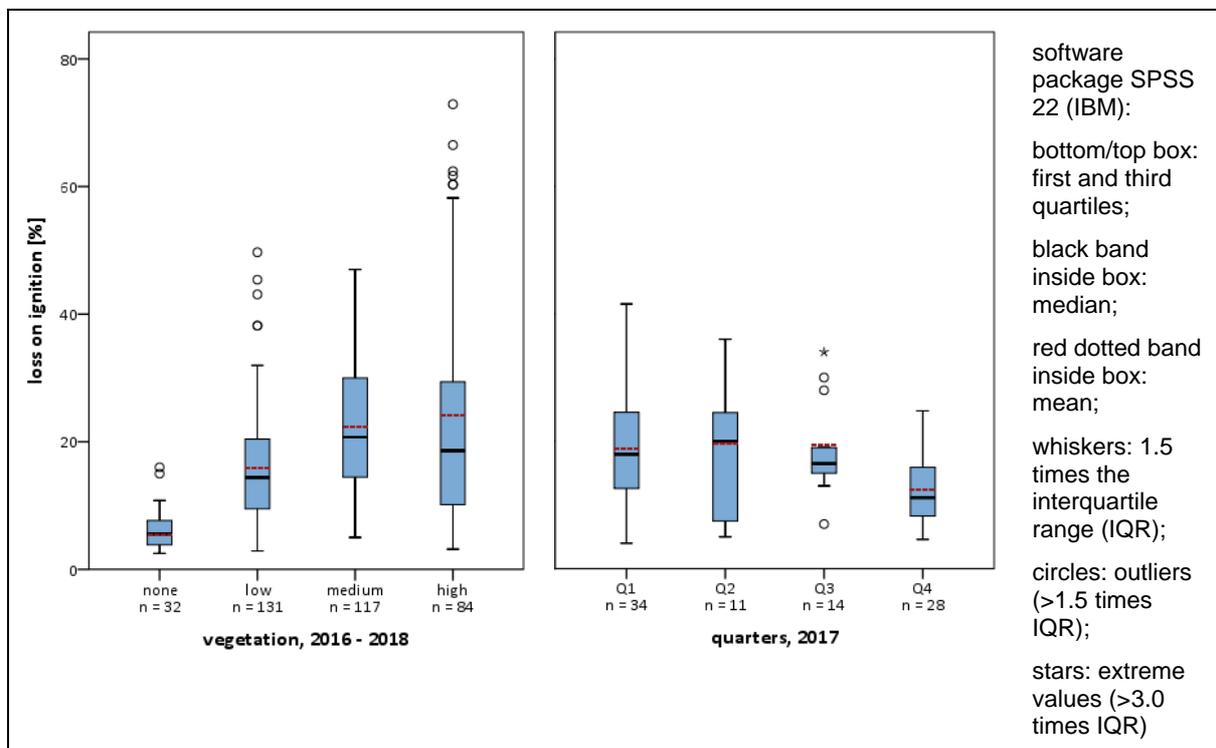


Fig. 2: Box plots of LOI of RDS (0-2 mm): left: relation to vegetation in eight sites; right: in different quarterly periods of 2017 in four sites with medium and high vegetation (n=number RDS samples)

It is evident that the LOI of RDS with grain sizes 0-2 mm is a function of the amount of vegetation (Fig 2, left). The mean values of LOI are 6% in sites with no relevant vegetation and 16% in sites with low vegetation. These values increase to 21% and 24% respectively in sites with medium and high vegetation. Additionally, extreme LOI values (above 70%) can be observed in sites with high vegetation.

Fig 2 (right) shows the seasonal variation of the LOI of RDS in four sites with medium and high vegetation in 2017. The mean LOI values in the first three quarters, which are influenced by vegetation, were approximately 20%. Whereas the LOI values and their variability in the winter quarter are significantly lower (mean: 12%).

These results are supported by investigations of RDS in Berlin. Barjenbruch and Venghaus (2017) examined eight grain fractions (< 0.063 to > 4 mm) of RDS samples for mass proportions and LOI. LOI values up to 80% were found in the coarse fractions, especially in the autumn quarter. Whereas in the winter quarter (December to March), the LOI value of the RDS did not exceed 10% in grain fractions < 2 mm.

4 CONCLUSIONS

- The fraction between 0-2 mm in RDS has a mass proportion above 80%, whereas the 2-4 mm and 4-8 mm fractions are underrepresented.
- Vegetation is an important influencing factor for the organic matter content of RDS.
- Appropriate assessment of vegetation beneath tree canopy coverage (TCC) requires investigation of indirect vegetation (e.g. adjacent gardens).
- Furthermore, temporal variations (seasonal effects) are important when considering the occurrence of organic matter in particle fractions with grain sizes from 0-2 mm, especially at sites with high vegetation.
- In order to assess the transport of particle-bound pollutants in road runoff, it is important to determine the PSD and the corresponding LOI of finer particle fractions (0-250 µm). These fractions appear to be predominant in road runoff (Kim and Sansalone, 2008; Gelhardt et al., 2017).
- Investigations on the amounts of selected heavy metals and their density in several PSD fractions of RDS are currently being conducted.

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