Soil composition in slots between pavement plates of side walks and adjacent lawns of a residential and heavy industry area

Wolfgang Burghardt[A] and Mukti Khanna[A]

[A]Soil Technology, Fk of Biology and Geography, University Duisburg-Essen, Germany, Email wolfgang.burghardt@uni-due.de

Abstract
In a heavy industrial area the top soil composition of lawns was compared with soil in slots between plates of side walks adjacent to lawns. The sand fill in the slots comprises soil material with a particle size that is finer than medium sand and also includes higher organic matter content. Compared to the lawn soils there was a strong accumulation of organic matter, silt and heavy metals in the top layer (0-0.2 cm) of soils in the slot fills. All materials and compounds decreased in the slots with depth. Different pattern of decrease occurred for mineral particles, organic carbon, iron, specific magnetic susceptibility, manganese, lead, zinc and cadmium. The origin of soil materials in the slots between plates of side walks was discussed.

Key Words
Pavement plates, soil neighbourhood, particle sorting, heavy metal content, mechanical filter function.

Introduction
Dominant topics of urban soil research have been brown fields and leisure park areas. Many of the other urban soil uses have not or seldom been areas of investigation. Among them are side walks. The importance of soil in the slots between cobbles and concrete plates is that they are for many people the daily, and often the only soil contact. Wenikajtys and Burghardt (2002) presented results of differentiation of compounds of soils in the slots with depth. Nehls *et al.* (2008) concentrated their work on slot filling from black carbon content and properties. There is a lack on soil dust research in urban areas. However, several authors (e.g. Hoeke and Burghardt 2002; Hoeke 2003) have investigated the processes and amount of soil dust release and transport, and showed the great importance of dust for urban soil formation in the Ruhr area, Germany.
The results from Wenikajtys and Burghardt (2002) indicate that in the composition of dust of sidewalks not only streets but also open soil parcels are involved due to their close proximity. Important contributions are likely to be from industrial dust deposition in some areas.

Material and methods
The study areas were two locations in the heavy industry city of Duisburg, Ruhr area, Germany. The first location was a low block residential area, constructed in 1962 on arable land about 1 km north of iron works with manganese breaking plant and pig iron foundry, both closed in 1985, and 500 m north of a motorway. The following three sidewalks were investigated along: (i) a main street (site 1) with low traffic, (ii) a side street (site 2), and (iii) a service road (site 3). Sites 1 and 2 had trees along the street. Site 3 was located nearer to former industrial plants than site 1 and 2. At site 3 the adjacent houses were about 5 m away. The distance of houses was much further for sites 1 and 2. The age of the pavement of all three sites was about 40 years at the time of sampling. The second location (site 4) was situated along a small green area in front of a close apartment building row and opposite a large iron foundry and steel plant complex at the conjunction of a main street with higher traffic and a side street. Currently much green is located around the area, which was lacking before. The age of the side walk plates is uncertain. Aerial photos showed no change to buildings for at least 80 years. All soils of site 1 - 4 were from fills of construction rubble covered by soil material. The width of the slots was about 4 mm. Samples were taken from top soils of the lawn adjacent to the side walk and from the slots between concrete plates of side walks. Analytical standard methods were used for particle size distribution, heavy metal extraction with aqua regia and determination with ICP. C and N were analysed by combustion at 1100°C and measured with a gas analyser (Analysator Euro EA). The specific magnetic susceptibility was analysed with a Forgenta Magnetic Analyzer (FMA 5000).

Results and discussion
The slots between the pavement plates were filled by construction with coarse sand and medium sand. The sand bed underneath the plates was often hardened by lime. The composition of the slot fillings from sand limited the size of particles, which could intrude into the sand. Large particles were separated and remain on the side walks. The sand filling entered fine and finest sand, silt and clay. Their content decreased with depth

(Figure 1). The amount of penetrated soils into the slots was calculated by assuming the occurrence of original sand in 2-5 cm depth of the slots. Location 1 to three showed an accumulation of up to additional 60%, location 4 of up to 160% soil (Figure 2). That means the originally loose sand filling had become dense with time. All grain sizes occurred. Main particle size fraction was silt which accumulated in all depth. At site 4 dominated coarse silt.

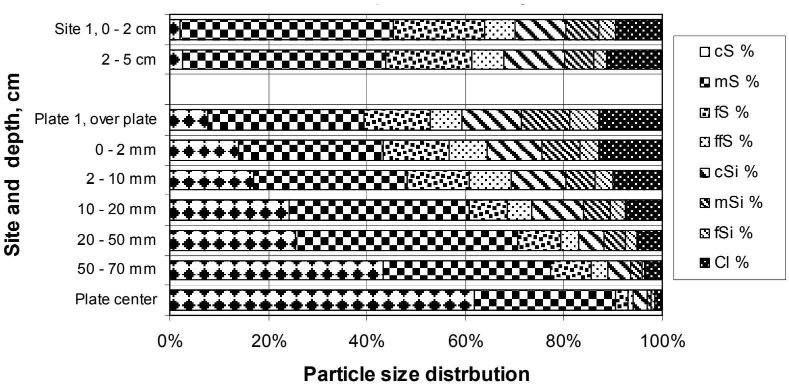

Figure 1. Particle size distribution with depth of top soil of lawn of site 1, and of slots between plates of the adjacent side walk.

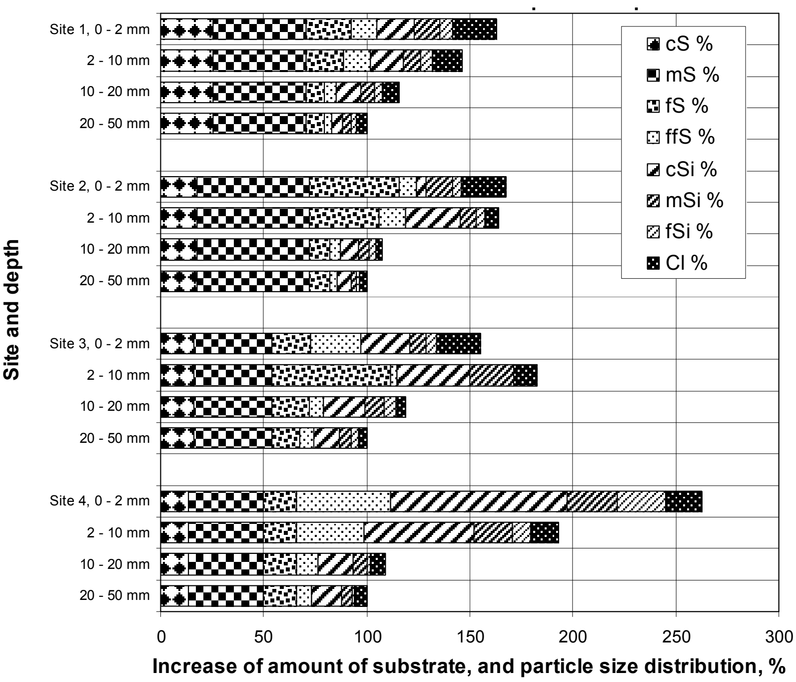

Figure 2. Change of grain size distribution with depth by dust intrusion into the sand fill of slots between pavement plates.

The C content (Figure 3a) from organic matter and black carbon was in the soils of the lawns and in the slots high. At site 4 it was much higher than in the others. In the slots the C content decreased with depth. This is not so pronounced for site 3 and 4. The N content (Figure 3b) shows similar results. But for site 4 it was lower. C/N ratio (Figure 3c) was for all soil samples from lawns and from slots in the range of about 15 or less which is typical for natural soils. There is no indication of noticeable accumulation of black carbon. This was also found for the top layer of slot filled site 4 with C/N ratio of 22. Underneath the top layer the C/N ratio increased to values above 50 to 80. Coal has C/N ratios of about 28 to 35. That means that the C/N ratio of site 4 indicates the occurrence of black carbon in the soil of slot fill. The soils were strongly contaminated by heavy metals (Figure 4). The origin of pollution is likely to be from industry, traffic in the streets and domestic heating. Some sources will be represented by individual metals. For heavy industry areas this will be iron and for some places also manganese. Lead will be more typical for traffic sources. Zinc and cadmium will be common for all sources. All top soils of the lawn had as expected high iron contents.. The iron content increased from site 1 to 3. Site 4 was similar to site 1. The slots of the pavement had a strong iron accumulation in the top layer, which is about 2 fold of the soils, and for site 4 about 4 fold. Sites 1, 2 and 4 showed the same trend in decrease for iron as occurred for organic carbon. For site 3 another distribution pattern with depth occurred. The iron content increased until the depth of 2 cm. The contents clearly show the influence of the local iron industry.The distribution pattern for iron is similar to specific magnetic susceptibility. For site 4, the pattern of values from the top soil of the lawn and of the pavement slots was with 7 times higher than for iron. The manganese concentrations were higher than for most natural soils. The soils of the lawn had contents from 1 to 6 g/kg, the lowest values at site 4 and the highest at site 3. The contents show a clear influence from a local iron industry. The manganese content of the slots was 3 to 5 times higher. The distribution with depth pattern differed from that of iron. Beside site 4 the manganese content increased. One explanation will be reduction processes during water logging in the sand of pavement plates. Manganese will be more soluble and washed into deeper sand layers near the surface.

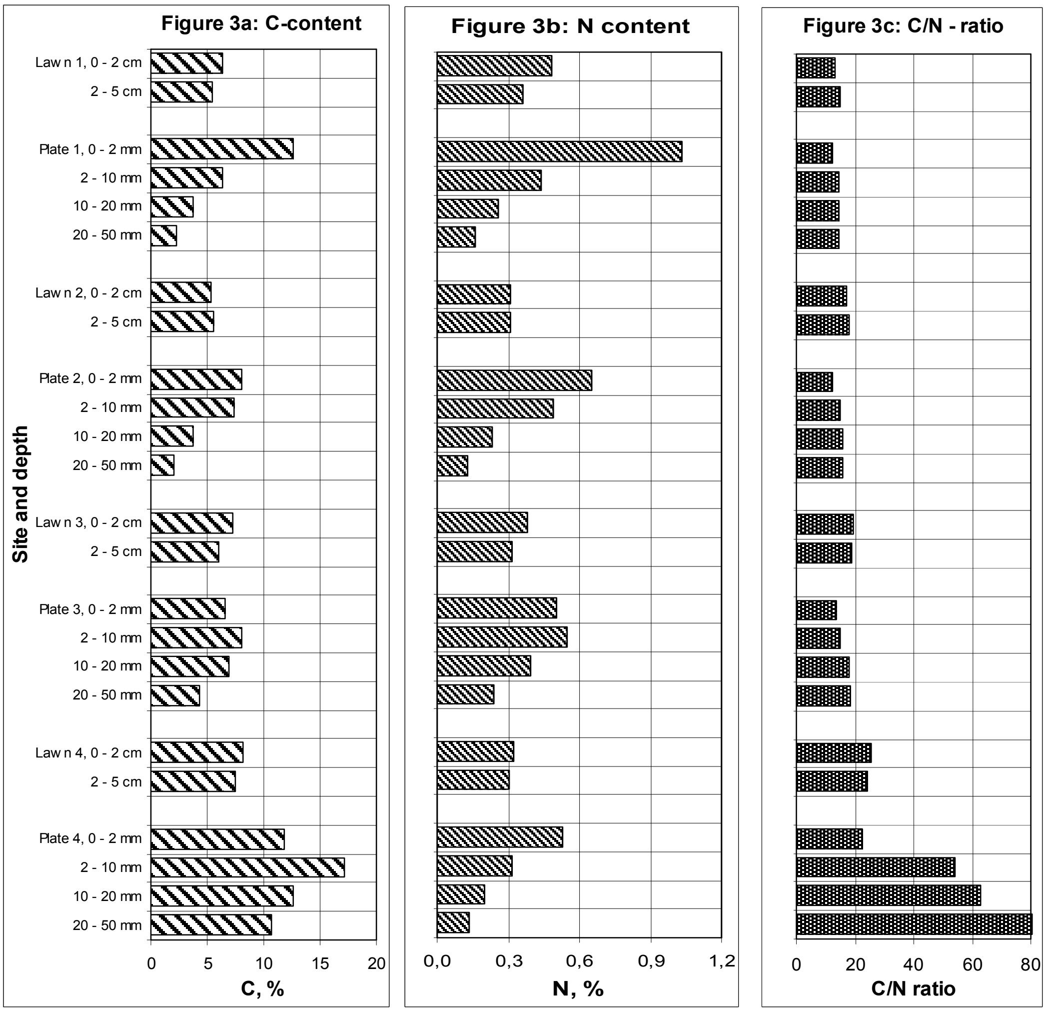

Figure 3. (a) C content, (b) N content and (c) C/N ratio from organic matter and black carbon.

Lead content was high in the soils of the lawn. It increased from site 1 to site 3. It was comparable low at site 4. This was not expected. Site 3 had as service road the lowest traffic and site 4 the highest one. Probably its origin is not only from traffic but also from industrial or domestic heating sources of the houses near by. The lead content was in the top layer of slots only slightly higher than in the soils of the lawn. Only for site 2 occurred a strong increase of about the 2 to 3 fold. For site 1 to 3 the highest lead accumulation occurred over all three top layers. Site 4 showed the decrease with depth. The elevated zinc content of the lawn was for all 4 sites with about 400 – 600 mg/kg nearly the same.

The accumulation in the top layer of slots was about 2 to 3 fold of the content of soils of the lawn. There were only low differences between the sites. The distribution pattern of zinc with depth in the slots was similar to iron. The contents decreased from top to the depth. Only site 3 showed the deviation in his pattern as described already for lead and iron. The soils of the lawn showed elevated cadmium contents between 1.3 and 3.1 mg/kg. The highest values occurred in site 3. The cadmium concentration increased in the slots up to 5 mg/kg. The distribution pattern with depth of the slots was similar of that of zinc and iron.

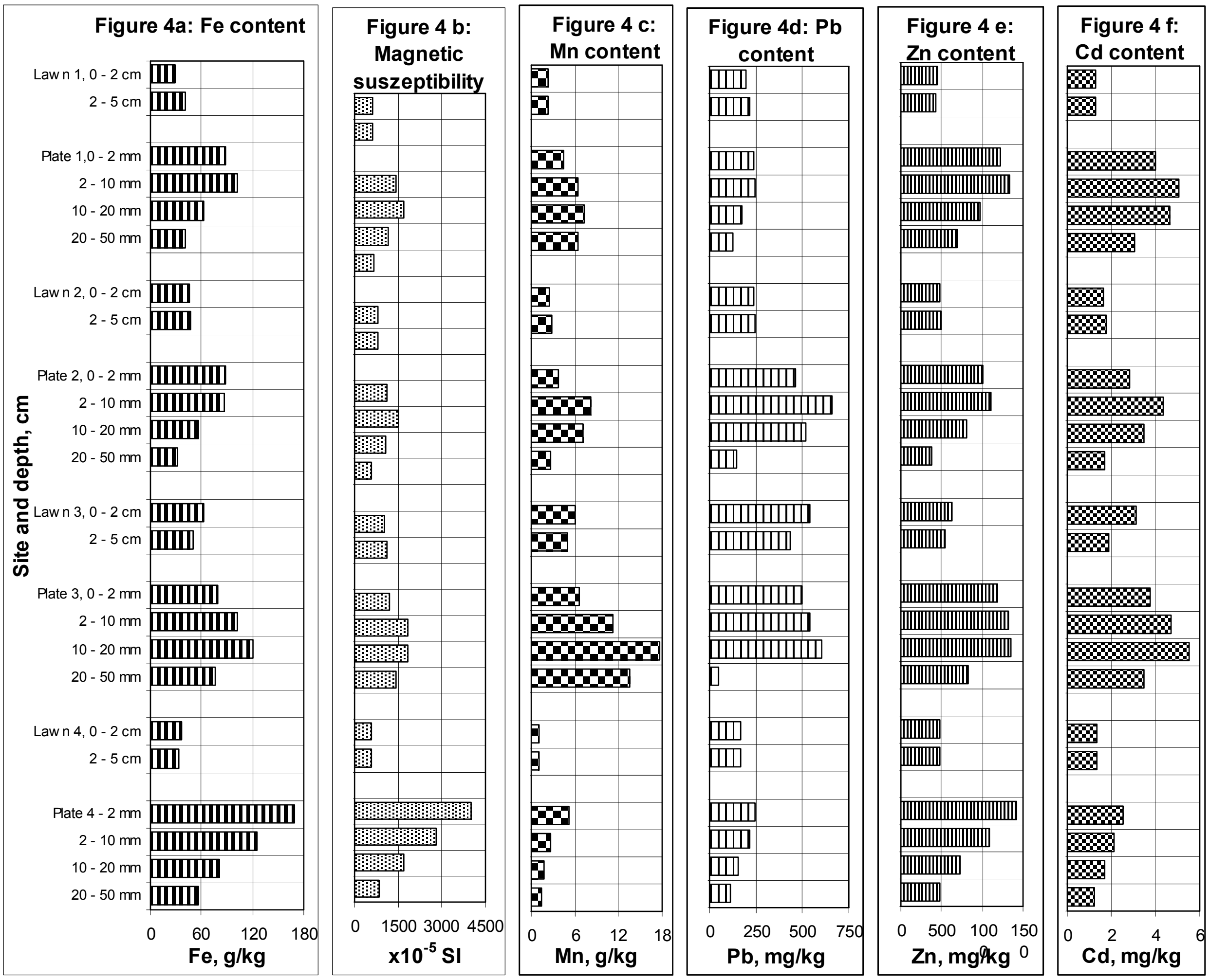

Figure 4. (a) Fe content, (b) magnetic susceptibility, (c) Mn content, (d) Pb content, (e) Zn content and (f) Cd content.

Conclusion

The soils in the slots of pavement of side walks are distinctly higher in polluted materials than in the soils of adjacent lawns. One reason will be the separation of the sand fraction by the mechanical filter effect of the sand filling of the pavement slots. Thus fine soil particles of fine sand and finer will be accumulated in the fill of slots. There is no clear indication that there is much dust deposed directly from street and from traffic. The C/N ratio shows that the material found on side walks is more related to the organic matter of adjacent soils. The black carbon deposition from industry and traffic seems to be to low to be distinct indicated by C/N ratio. The effect of the two different heavy industry sites is clearly recognized by the strong increase in heavy metal contents specific for each of the areas. However, the deposited amount of industrial dust seems to be low compared to the amount of soil material deposed on walk ways.

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