Effects of long term atmospheric deposition of lignite fly ash on soil physical properties of forest soils

P. Hartmann (a,b), H. Fleige (b) & R. Horn (b)
(a) Forest Research Institute, Department of Soils and Environment, Wonnhaldestr. 4, 79100 Freiburg i. Br., Germany,
(b) Christian-Albrechts-University zu Kiel, Institute for Plant Nutrition and Soil Science, Hermann-Rodewaldstr. 2, 24118 Kiel, Germany
contact: peter.hartmann@forst.bwl.de

INTRODUCTION

The long term deposition of atmospheric pollutants has altered the composition of 'natural' soils, in forests especially the forest floor horizons. The deposition of atmospheric pollutants in Saxony and Saxony-Anhalt (Germany) occurred from the beginning of the 20th century until the 1990s and originated from the nearby industrial regions. Until improved emission controls were in place, large amounts of fly ash, lignite dust, SO_2, NO_x and CO_2 were emitted and up to 280 Mg/ha fly ash accumulated in the soils nearby (fig.1). We want to present the long term effects of fly ash enrichment on soil physical properties (porosity, hydraulic properties, water repellency) of forest soils.
(data published in [A],[B],[C],[D])

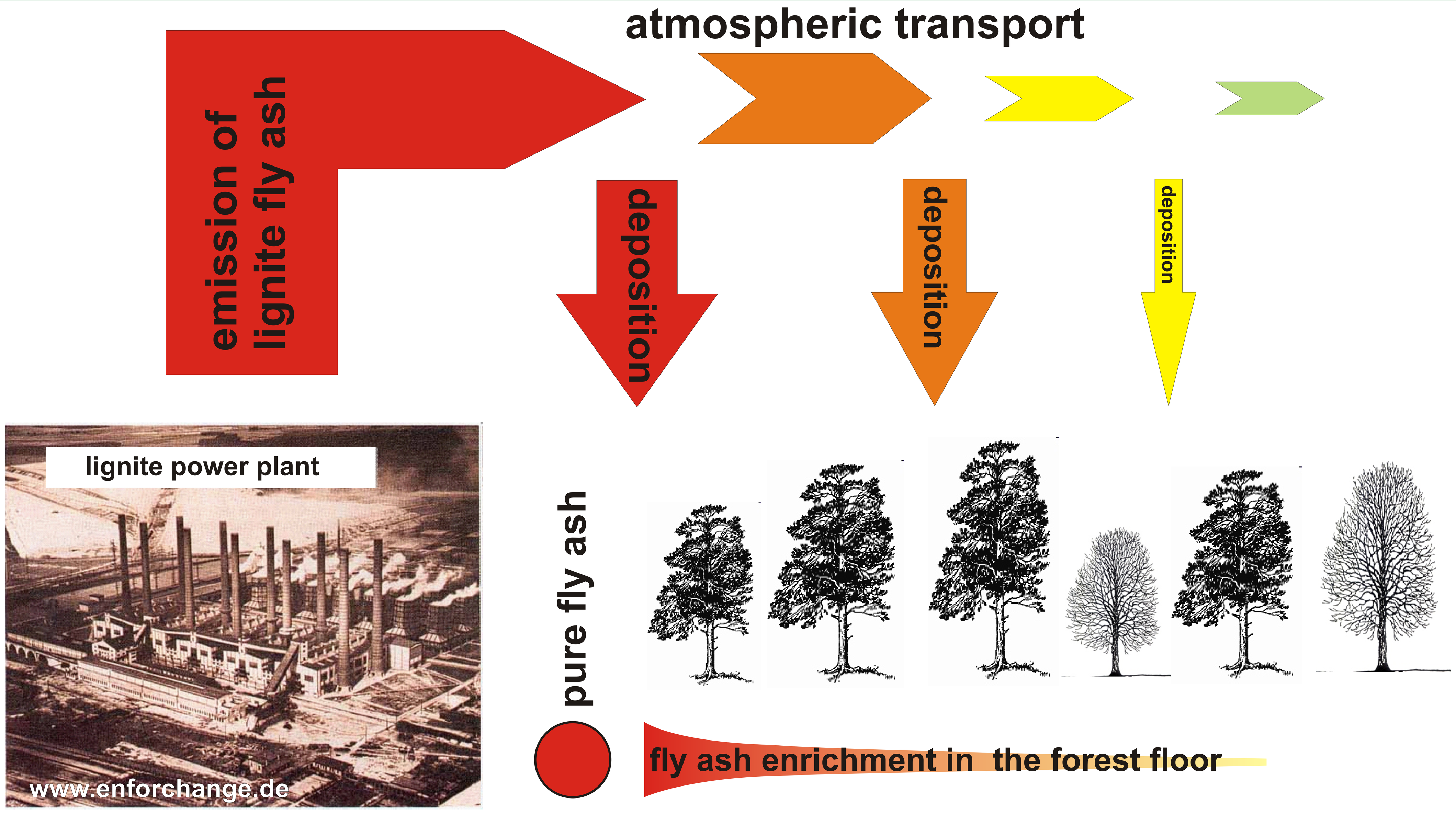

Fig. 1: schematic lignite fly ash emission-deposition system.

PROPERTIES OF ATMOSPHERICALLY DEPOSITED LIGNITE FLY ASH

The pure lignite fly ash deposition is characterized by a sandy texture and a low bulk density with a high porosity and hydrophilic properties (table 1, [A]).

Table 1: soil physical properties of a pure fly ash deposit

particle density S	2.6 g cm^{-3}
bulk density B	0.4 g cm^{-3}
air capacity ac (pores >50 m)	25 Vol.-%
plant available water paw (pores 50 to >0.2 m)	30 Vol.-%
water content at the wilting point pwp (pores <0.2 m)	25 Vol.-%
wilhelmy-plate contact angle (rec-adv)	0-93°
water drop penetration time	56 sec.

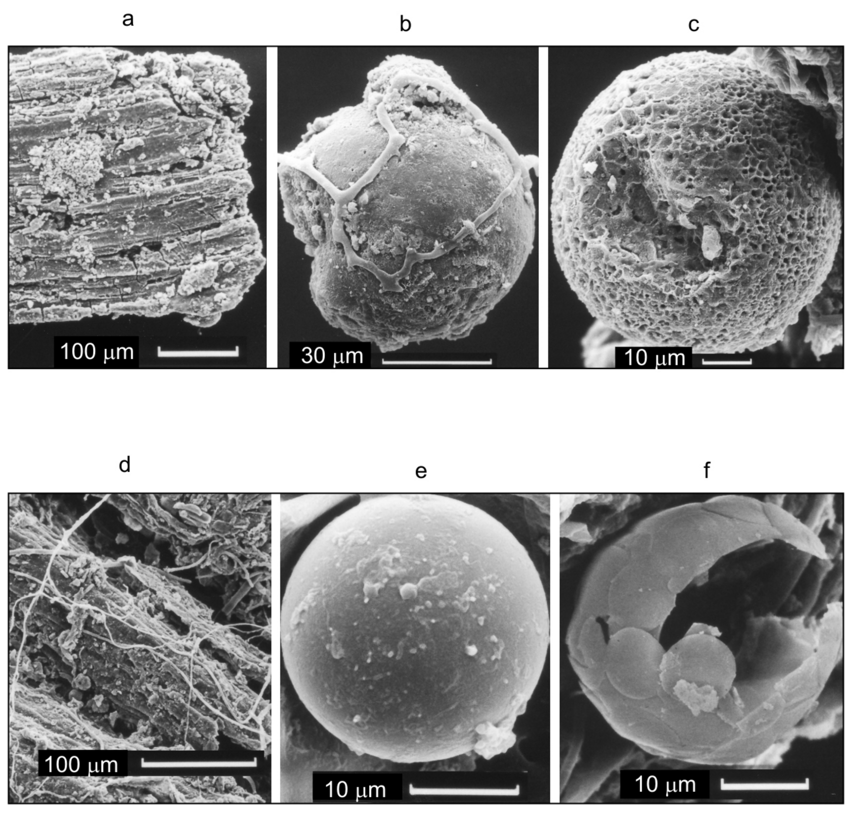

Fig. 2: Scanning electron micrographs of the pure fly ash (a-c) and of a fly ash enriched forest floor horizon (d-f). a: lignite rest; b,c and e,f: mineral fly ash particle; d: organic structure. [C]

The enrichment of mineral fly ash particles could be proven directly by scanning electron microscopy and by texture analyses. Besides organic lignite residuals (fig. 2a), mainly mineral fly ash particles were found (fig. 2b,c,e,f). These mineral particles are characterized by spherical morphologies partially with hollows and a decreasing grain size with increasing distance to the emission sources (fig. 3).

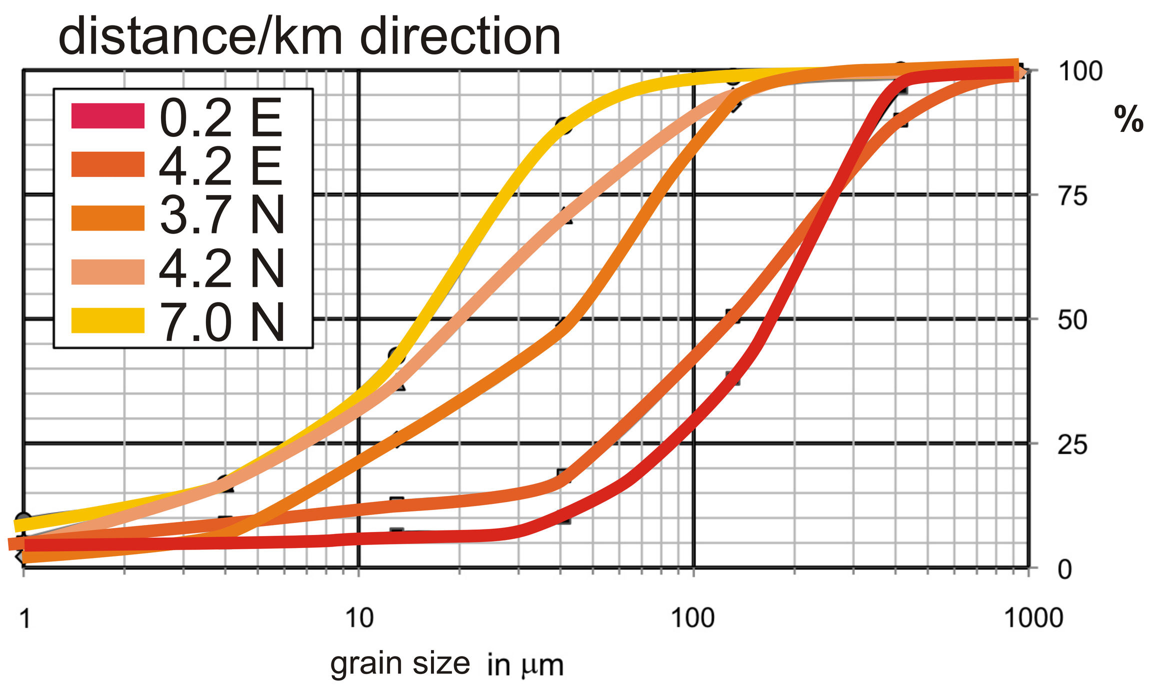

Fig.3: Grain size distributions of the mineral components of the pure fly ash (red, distance 0.2km) and of fly ash enriched forest floor horizons with increasing distance to the main emission source [C].

INFLUENCE OF FLY ASH ENRICHMENT ON FOREST FLOOR HORIZONS

There were partially significant effects of fly ash enrichment on soil physical properties of forest floor horizons (table 2). Close to the emission sources (where there was an accumulation of sandy fly ash), particle density, air capacity (ac), and saturated hydraulic conductivity were increased, whereas the water available to plants (paw) and water repellency (disturbed samples) was decreased. With increasing distance from the emission source of the fly ash, corresponding with less accumulation of ash of decreasing size (silt), air capacity ac and saturated hydraulic conductivity were comparatively reduced, whereas paw and water repellency increased [A,B]. For undisturbed samples, no differences concerning water repellency were found. Water repellent structures of the fly ash enriched forest floor horizons were probably the result of recently formed organic, hydrophobic coatings, whereby the initially high wettability of the mainly mineral, hydrophilic fly ash particles was reduced [D]. The investigated properties are partially highly correlated with each other and indicate that the enrichment of fly ash changed the total functionality of forest floor horizons. No impact of fly ash was found for the top mineral horizons in contrast to soil chemical parameters such as pH and CEC, where an influence was found even at 30-cm depth [E].

Table 2: Effects of fly ash enrichment on soil physical properties of forest floor horizons

property of forest floor horizon	amount of fly ash enrichment + + 0	short explanation
particle density S		mineral fly ash particles have a higher particle density than forest floor humus
carbon content		carbon content in fly ash particles is lower than in forest floor humus
bulk density B		loose deposition of highly porous fly ash in turns with needles/leaves preserves a low bulk density
ac (pores >50 m)		sandy fly ash particles amplify the high coarse porosity of forest floor horizons
sat. hydraulic conductivity		due to an increased macro-porosity, flow paths are even extended
paw (pores 50 to >0.2 m)		pores corresponding to the plant available water are more pronounced in forest floors with silty fly ash enrichment
paw in the root zone		for great amounts of fly ash enrichment (10-15cm) there is a distinct increase in paw as the rootzone is extended
water repellency (disturbed)		initially, water repellency (disturbed samples) is distinctly reduced due to the admixture of mainly hydrophilic fly ash particles
water repellency (undisturbed)		organic coatings seem to provide hydrophobic structures in the long-term, the initial wettability is reduced

References:

[A] Hartmann, P., Fleige, H., & Horn, R. (2009). Physical properties of forest soils along a fly-ash deposition gradient in Northeast Germany. *Geoderma, 150*, 188-195.

[B] Hartmann, P., Fleige, H., & Horn, R. (2010). Changes in soil physical properties of forest floor horizons due to long-term deposition of lignite fly ash. *Journal of Soils and Sediments, 10*(2), 231-239.

[C] Hartmann, P., Fleige, H., & Horn, R. (2010). Nachweis von Flugaschedeposition in Waldböden und Auswirkungen auf bodenphysikalische Eigenschaften. *Die Bodenkultur - Journal for Land Management, Food and Environment, 61*(2), 5-17.

[D] Hartmann, P., Fleige, H., & Horn, R. (2010). Water repellency of fly ash-enriched forest soils from eastern Germany. *European Journal of Soil Science, 61*(6), 1070-1078.

[E] Fritz, H., & Makeschin, F. (2007). Chemische Eigenschaften Flugaschebeeinflusster Böden der Dübener Heide. *Archiv für Naturschutz und Landschaftsforschung, 46*(3), 105-120.

C | A | U
Institute for plant nutrition and soil science, Christian-Albrechts-University Kiel

EN FOR Change
www.enforchange.de

financial support by the
Federal Ministry of Education and Research
fona
PtJ Projektträger Jülich Forschungszentrum Jülich GmbH

FVA Forest Research Institute Baden-Württemberg