Improvement of Fly-ash Reclamation with Organic, Organo-mineral and Mineral Amendments[1]

by

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Abstract Fly-ash deposits are usually difficult to reclaim due to poor chemical and physical properties. Using different kinds of composts, organic amendments, soil conditioners, and mineral fertilizer we established a reclamation trial on an ash-dump in the Helmstedt mining area (FRG), Vitality of the grasses sown, as well as the percent plant cover were highest on the plots amended with Ferlhum^R (bark compost) and Biosol^R, a product of fungal mycelium. If these organic amendments were supplemented by ACS^R, and organo-mineral complex, vitality and plant cover were improved. Microbial activity (arginine-ammonification rate) and biomass were highest on the compost plots, and lowest on those that had not received organic amendments. Supplementation with ACS^R increased microbial biomass levels. The positive effects of Biosol^R, ACS^R, and Ferihum^R, or combinations thereof, may have been due to a reduction of pH or salt concentrations in the soil solution, or an improved physical stability due to the formation of stable aggregates. Additional key words: Microbial biomass, arginine-ammonification.

Introduction

Coal fired electric power plants are producing huge amounts of fuel ash. For disposal, the ash is mixed with water and the slurry is pumped into a lagoon where the ash settles and the water evaporates or is drained. Alternatively, the ash may be deposited dry in pits (Maciak and Pronczuk 1980). These dumps usually are a dusting desert, and it is highly desirable to prevent wind erosion. Preferably, this is accomplished by a rapid revegetation of the area. However, unless the area is covered with topsoil, several problems have to be resolved before vegetation may be established.

Most important, physical and chemical properties have to be improved. The water holding capacity is usually sufficient, but due to the lack of organic matter no stable aggregates are formed. This may result in compaction layers impenetrable by plant roots. This may be improved by the use of organic matter, such as mulches or composts (Bradshaw and Chadwick 1980).

Organic substances enhance the formation of stable clay mineral complexes either directly, or by promoting soil microbial activity (Tate, 1987). Microbial biomass has successfully been used for studying reclamation by Insam and Haselwandter (1985).

The purpose of the present study was to Investigate methods to improve short-term revegetation. Several fertilizers and soil conditioners, and combinations thereof, were tested for their potential to accerlerate reclamation by determining their effects on soil microbial biomass and activity (arginine-ammonification rate), as well as on the response by the vegetation.

Materials and Methods

The experiments were set up on the Braunschweigische Kohiebergwerke (BKB) ash-dumps near Helmstedt, FRG. Mean annual precipitation and temperature are 640mm and 9.6'C, respectively. Two years before initiation of the trial, the ash had been dumped, and a subsequent reclamation effort had failed. The trial was started on April 17, 1988 and set up in a split plot design with two replications. Plot size was 10 x 10m. Three organic substrates, as well as a mineral fertilizer were applied either without further amendment, or with sulfur, ACS^R, or Alginure^R (Table 1) Control plots were also included.

Table 1: Fertilizers and soil conditioners: chemical properties and application rates

	application rates ($g \cdot m^{-2}$)	WC (%)	OS (%)	pH	Nutrient Contents (%) N	P	K	Ca	Mg
waste compost	3600	49	65	7.2	1.4	0.7	0.4	4.0	0.6
bark compost	3600	48	70	6.1	0.1	0.02	0.2	0.1	-
Biosol^R	200	6	70	6.2	7.5	5.6	8	2	4
ACS^R	160	-	-	-	9.3	4.7	-	-	-
Alginure^R	138	55	45	9.4	0.3	-	-	-	-
Mineral fertilizer	20	-	-	-	21	-	-	-	-

WC...water content; OS...organic matter (% of dry weight)

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The nutrient content of the ash was as follows (% of dry weight): N 0.022; Ca 5.6, Mg 0.27, K 0.28, Na 0.07, organic C 0.97, 50% of the organic C was in form of inert coal particles. The organic substrates included municipal waste compost (8mm fraction, Kompostwerke Duisburg), bark compost (*Pice abies*, Ferihum^R^, Fehring Co^l^, Bielefeld), and dried fungal mycellum (Biosol^R^, Blochemie GmbH, Kundl, Austria), ACS^R^ (ACS Comp., Celle) is an organo-mineral complex, Alginure^R^ (TILCO, Stuttgart) is a Ca-alginate. Before plot establishment, the whole area received 200kg-ha^{-1} NPK (15:15:15) fertilizer.

A mixture of grasses was sown at a rate of 250kg-ha^{-1}, including *Festuca rubra* var. genuina (20%), *F. ovina* (15%), *F. tenuifolla* (30%) and *Agrostis tenuis* (15%). The seed was applied as a mixture with water and the respective amendment (ACS^R^ or Alginure^R^). The organic substrates and sulfur were applied manually and incorporated 10cm. Two times, July 8 and Sept. 9, 1986, the area of plant cover was estimated (Braun-Blanquet, 1964). On Sept. 9, the vitality of the plants was also recorded. For soil biological analyses, soil samples from the surface 10cm were taken with a core sampler (1cm I.d.) on July 7, 1986 and April 4, 1987. Each plot was divided into 4 subplots, from each of which 10 random samples were taken and bulked. The soil samples were sieved (2mm), adjusted to a water content corresponding to approx. - 300kPa water tension, and stored at 4° C for up to 6 weeks.

Microbial biomass (C_{mic}) was determined with the substrate induced respiration method (SIR) (Anderson and Domsch 1978). Because of high carbonate contents, the method was modified. Instead of CO_2 production, the O_2 consumption was measured.

For the calculations, a respiratory quotient of 1 was used, following C_{mic} (μgCmic·g^{-1} soil) = O_2 consumption (μgO_2•g^{-1} soil h^{-1}) *28. Further details are given by Insam (1989). Arginine-ammonification was measured with the method of Alef and Kleiner (1987).
Additionally, the pH (0.01m $CaCl_2$) and the electrical conductivity of soil extracts (water-to-soil ratio 1:1) were deterrmined.

Results

On both sampling dates, significant differences in plant cover were found (Table 2, Fig. 1). In particular, Ferihum^R^ and Biosol^R^ did show good results. Generally, the addition of ACS^R^ significantly improved plant cover. Alginure^R^ and sulfur did not result in significant improvements. The same pattern was found for the vitality index (Table 2, Fig. 2). ACS^R^ significantly improved the vitality, and the plants on organic substrate plots looked more vital than those on the control plots.

For microbial biomass, three months after initiation of the trial, significant differences were found between organically amended and control or mineral fertilizer plots (Table 2, Fig. 3). In the second year, the differences were more distinct. Then, C_{mic} was highest on the Ferihum^R^ plots. ACS^R^ significantly increased C_{mic}. Again, Alginure^R^ and sulfur did not show any statistically significant effect.

A pattern similar to that for C_{mic} was observed for arginine ammonification rates (Table 2, Fig. 4).

Table 2: Influence of fertilizers and soil conditioners on microbial biomass and arginine-ammonification rates - Analysis of Variance

Dependent variable	Source of variation	d.f.	F-ratio	Significance level
microbial biomass (1986)	Main effects	8	5.13	.000
	Fertilizer	5	6.53	.000
	Soil conditioner	3	2.50	.006
microbial biomass (1987)	Main effects	8	15.25	.000
	Fertilizer	5	23.43	.000
	Soil conditioner	3	1.62	.186
arginine-ammonification (1986)	Main effects	8	5.92	.000
	Fertilizer	5	6.86	.000
	Soil conditioner	3	4.25	.007
arginine-ammonification (1987)	Main effects	8	3.15	.003
	Fertilizer	5	2.86	.018
	Soil conditioner	3	4.25	.017

Figure 1: Percent plant cover (a) 3 and (b) 5 months after recultivation

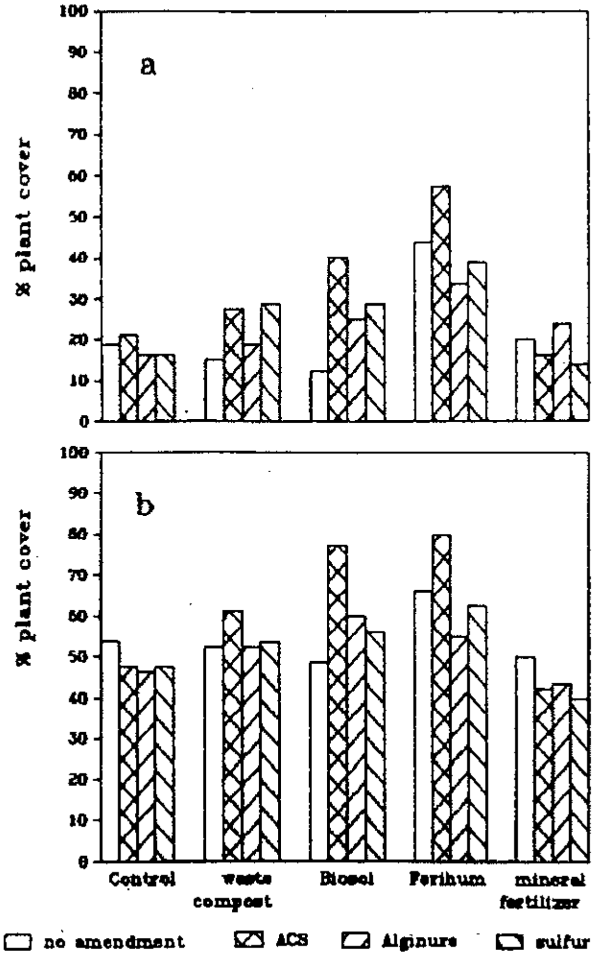
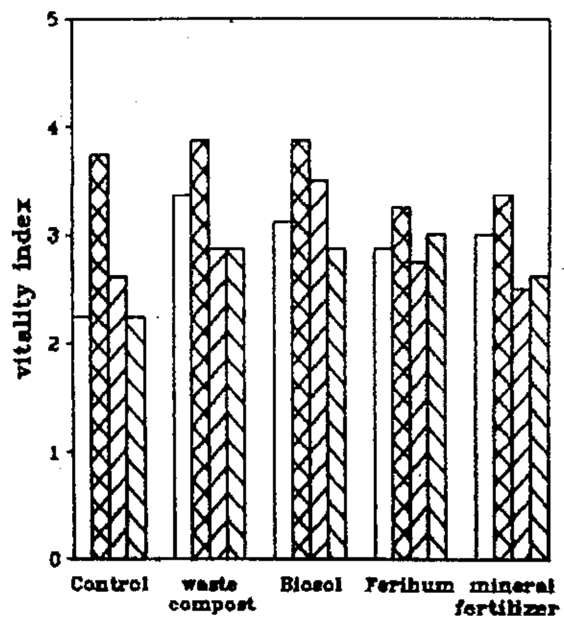


Figure 2: Vitality of the plants 5 months after recultivation (estimation, 5=vital, 4=vital, leaf tips chlorotic, 3=plants up to 50% yellow-brown, 2=plants over 50% yellow-brown, 1=plants dead). Data are the means of 4 estimations per plot from each of two replicates. Legend see Fig. 1.



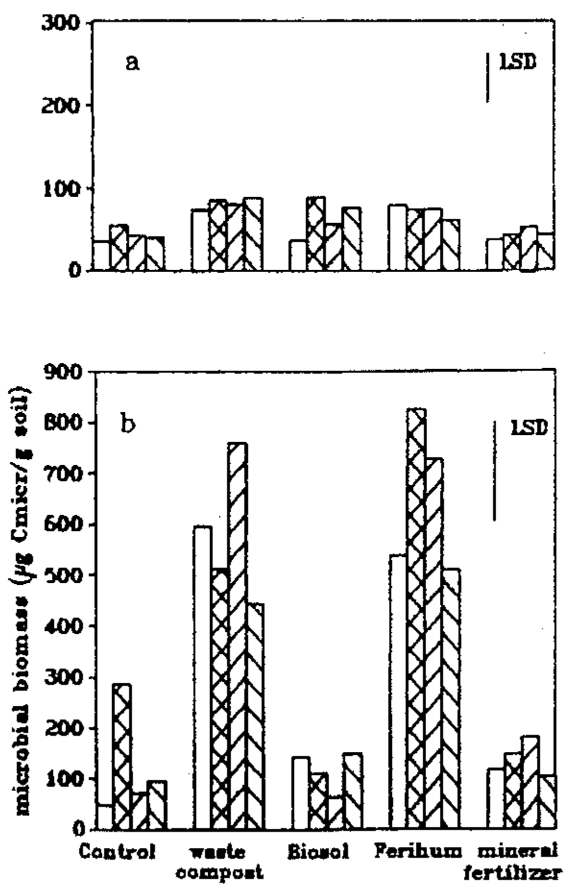
Discussion

The results confirmed the observations by Maciak and Pronczuk (1980) who found that organic substrates increased forage yields on ash deposits, but sulfur applications did not. No relationship was found between soil pH and plant cover or vitality. The pH was determined for bulked soil samples. Thereby, microsites were disregarded. Such microsites around decomposing organic particles might be areas of Intensive root growth.

The positive effects of Ferihum[R] may be attributed to an increase of soil porosity, and thereby improved root penetration and gas exchange.

With the exception of the Biosol[R] plots, plant growth was not related to electrical conductivity (Table 3). On the Biosol plots, where plant growth was very good, the conductivity was significantly lower than on the other plots. The lowering of the osmotic potential or the immobilisation of a toxic element may have been of importance here. Hodgson and Townsend (1973) found that in ashes, boron is frequently found in toxic concentration.
Findings by Griffiths and Jones (1965) suggest that fungal mycelium induces a microflora that is effective in bringing about aggregation. It may be that Biosol also acted in that way.

Figure 3: Effect of fertilizers and soil conditioners on soil microbial biomass. (a) First and (b) second year of trial. Legend see Fig. 1. LSD (least significant difference)



Organic substrates act as a carbon and nutrient source and thus have increased C_{mic}. An increase of C_{mic} by ACS[R] may be due to a promotion of stable aggregates. Microbial activity enhances aggregation. Conversely, clay-mineral complexes are known to act conservative for C_{mic} (Tate 1987). Frequently, an increase in C_{mic} is accompanied by an increase in microbial activity. Therefore it is not surprising that the arginine ammonification rate responded similar to the different treatments as C_{mic} did.

Aim of the trail was a rapid establishment of a closed cover of vegetation on fly-ash deposits. This was accomplished best by the use of Ferihum[R] or Biosol[R] in combination with ACS[R]. Ferihum[R] and waste compost also resulted in an increase in microbial biomass and activity. Still, the long-term suitability of the reclamation measures remains to be studied.

Figure 4: Effect of fertilizers and soil conditioners on arginine-ammonification rates.

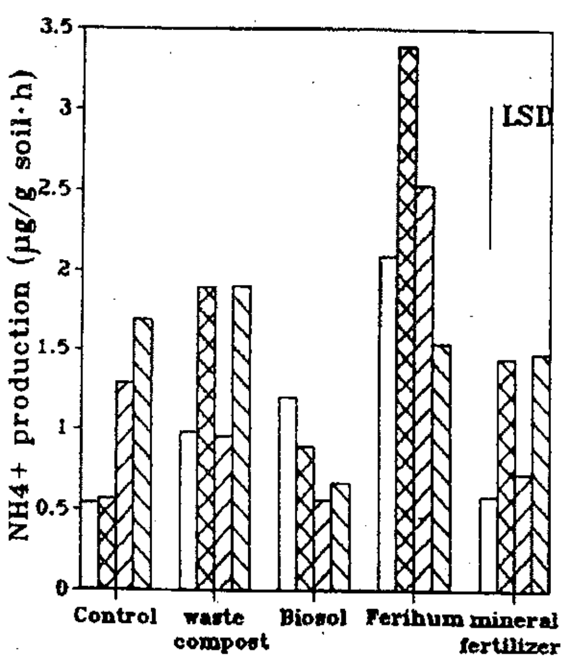


Table 3: Conductivity (uS cm-1) of soil extracts. Different letters indicate significant difference ($P<0.05$).

Control	402± 65	(a)
Mineral fertilizer	457±124	(a)
Biosol[R]	255± 39	(b)
Waste compost	535± 94	(a)
Ferihum[R]	443±109	(a)

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