Recultivation of a potassium mining waste dump with municipal sewage sludge compost

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Abstract
The mining company, Glückauf Sondershausen Entwicklungs- und Sicherungsgesellschaft mbH (Germany), has its origin in the potassium and salt industry. The mining dumps have a high salt content and contain a high potential for the contamination of soil and water resources. An effective measure to protect the environment is to cover the dumps with suitable minerals to prevent saline water penetrating into the near-surface water. In our study, we set up a recultivation layer by mixing municipal sewage sludge compost (SSC) with a sandy soil to investigate the influence of this material on the quantity and quality of seepage water and to analyze the growth of bioenergy crops. These crops can be used for biogas generation. Sewage sludge composts have a high water storage capacity and contain a huge amount of plant available nutrients.

Key Words
Recultivation layer, energy crops, infiltration, evapotranspiration.

Introduction
Mining activities, especially lignite and potassium mining have along tradition in central parts of Germany. As a result of these mining activities a lot of dumps and tailings are located in the region and they are dangerous for the environment (Knappe *et al.* 2004). An environmental friendly and simple solution to protect these dumps is the covering of the surface as well as the slopes with suitable materials to obtain a vegetation layer to minimize the leachate and to use the established soil layer for the production of biomass. A suitable material can be municipal sewage sludge compost (SSC) with its formidable chemical and physical characteristics, like a high content of organic matter and a high water storage capacity (Gomiscek 1999, Bernsdorf *et al.* 2008).

The potassium dump near the town Sondershausen (Thuringia, Germany) has a surface area of 65 ha. To avoid the impact of high water soluble salt penetration into the ground and into the surface water, three layers must to be set up (Kali-Halden-Richtlinie 1999). This study is focused on the establishment of the top layer - the so-called “recultivation layer”. Different mixing ratios between SSC and sandy soils are shown and discussed regarding the decreasing of the leaching capacity of essential nutrients.

Methods
The experimental plot with an area of 3600 m² was set up in July 2007 on a plateau site of the potassium dump near the mentioned town Sondershausen. With the trial the following parameters have been tested:

- two different types of the thickness of the recultivation layer (70 and 100 cm) and
- three mixture ratios between the SCC and a sandy soil (SSC added at 0, 50 and 75% by volume).

Every year the following three crop rotations were cultivated: *Zea mays, Triticum aestivum, Dactylis glomerata, Sorghum sudanense* and *Brassica napus*.

To control the water and solute balance of the SSC-variants, 48 simple (non-weighable) gravitation lysimeters, with a diameter of 40 cm and a depth of 70 and 100 cm, were installed (the vessels were filled with mentioned substrates) and the leachate was collected once per month as a mixed sample and analyzed in both quantitatively and qualitatively. The chemical analysis was focused on parameters, which are essential for the plant growth, especially nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_4-N), ortho-phosphate (PO_4-P), pH-value and electrical conductivity. Furthermore, 50 simple lysimeters (seepage water sampler), with a diameter of 20 cm and a depth of 100 cm, were set up as an additional outdoor trial under quasi laboratory conditions to get detailed information about seepage water quantity and quality by different mixing ratios of SSC with a sandy soil and cropping of different plants.

The chemical characteristics of SSC, nutrients as well as pollutants are shown in Tables 1 and 2. The nutrient content is in case of SSC addition elevated, e.g. the amount of nitrogen increases up to 0.97%. The main part is bound in the organic matter. The threshold values of the pollutants do not exceed the limit values of the German soil protection order (BBodSchV 1999).

Table 1. Chemical characteristics of the SSC – nutrients.

Parameter		Addition of SSC in Vol-%		
		0	50	75
pH		7.5	7.3	7.4
Content of salt	mg/100g	46.1	105	177
OM	%	0.40	9.30	21.60
N_t	%	0.02	0.51	0.97
NH_4-N	mg/100g	0.12	1.06	1.97
NO_3-N	mg/100g	0.07	0.45	2.11
C_t	% TS	0.23	6.29	13.67
C/N		11.5	12.3	14.1
P	mg/100g	1.6	56.0	79.1
K	mg/100g	6.4	59.9	101.0
Mg	mg/100g	6.4	87.8	104.0

Table 2. Chemical characteristics of the SSC – pollutants.

Parameter		Addition of SSC in Vol-%			
		0	50	75	100
As	mg/kg	5.2	5.3	5.2	4.4
Ni	mg/kg	33	23	29	20
Pb	mg/kg	9.5	22	18	43
Cr	mg/kg	49	48	48	77
Cu	mg/kg	11	37	35	87
Cd	mg/kg	<0.1	0.18	0.17	0.5
Hg	mg/kg	0.01	0.047	0.05	0.21
Zn	mg/kg	86	150	170	310
Σ PCB	mg/kg	n.d.			n.d.
Σ PCDD/PCDF	ng TE/kg	0.1			10
Σ PAH	mg/kg	0.06			1.89

Physical characteristics of the dump covering substrate are important for the water balance too. Therefore, a specific vegetation-test with sunflowers was carried out. The measured field capacity of the substrate was about 49% Vol-% and the plant available water was about 39 Vol-%. This means that the substrate has a high water storage capacity and is able to store huge amounts of precipitation, which leads to the reduction of seepage water (Tauchnitz 2006).

Results

During the two year field trial period, the NO_3-N and NH_4-N concentrations in the seepage water decreased markedly (Figure 1). For example, the SCC-variant with the 50 Vol-% addition showed a significant reduction of the NO_3-N concentration in the collected seepage water from the initial 1200 mg/L to a maximum of 200 mg/L. Regarding the NH_4–N leaching, the 75 Vol-% variant showed at the beginning a significantly lower concentration than the 50 Vol-% variant.

The additional outdoor laboratory experiment showed considerable differences in seepage water between the variants. The SSC variant with 50 Vol-% addition stored more water than the variants with 75 Vol-% SSC. The influence of preferential flow can be verified by regarding the 75 Vol-% variants. The influence of the vegetation on the water balance is remarkable. *Dactylis glomerata* as a perennial plant reduced the seepage water down to 50%. Another crop which also can reduce the amount of seepage water and is recommended for planting at the recultivation layer is *Zea mays*. In comparison to the field trials, the outdoor laboratory experiments also showed a remarkable reduction of the NO_3-N and NH_4-N concentrations during the test period.

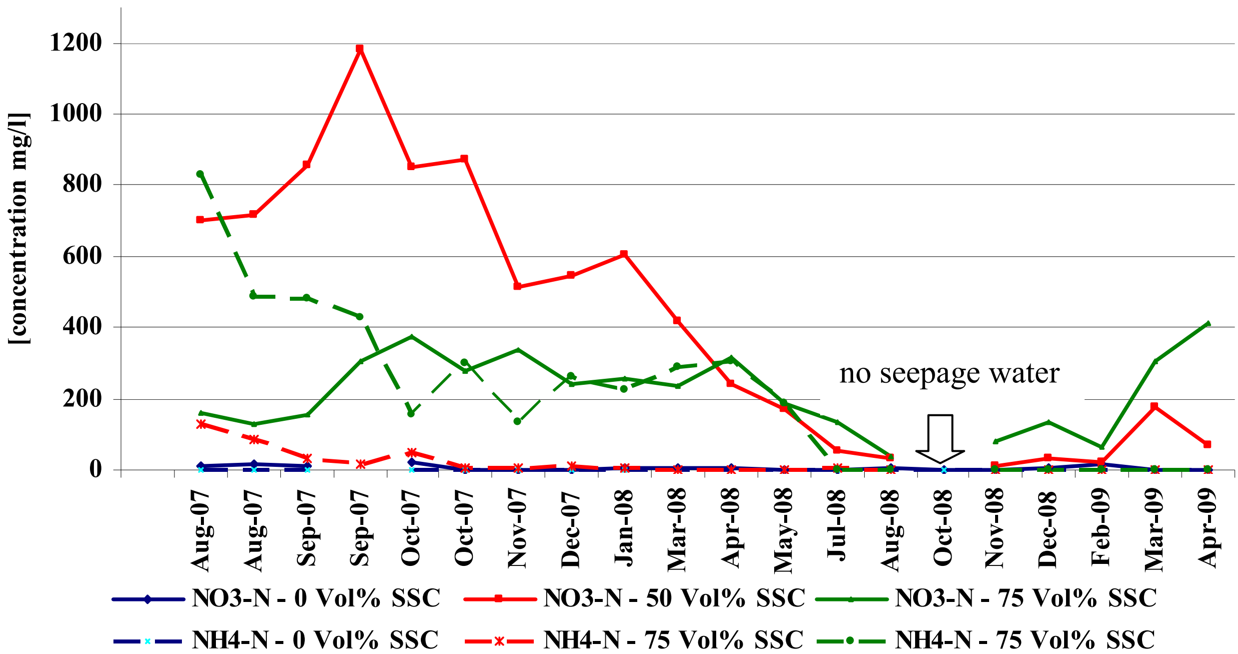

Figure 1. Concentration of NO_3-N and NH_4-N in the seepage water during the trial period.

Conclusion

The use of SSC in combination with a sandy soil can be recommended as a covering substrate for the recultivation of potassium mining waste dumps. The field capacity of the recultivation layer was elevated by mixing SSC with a sandy soil and consequently a higher amount of precipitation can be stored in this layer. After about one year, a significant reduction of the NO_3-N and NH_4-N concentrations in the seepage water was visible. The tested recultivation layers allowed the establishment and acceptable growth of plants which was connected with a reduction of the amount of seepage water. Further experiments are scheduled to refine the detailed construction of the recultivation layer as well as the use of the produced biomass for the production of renewable energy.

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