Influence of Geological Background Trace Metal Loading on Metals Content of Compost and Sewage Sludge

Richard Stehouwer, Penn State University

Marion Reinhofer, Peter Trinkaus, Herwig Proske, Andreas Kellerer-Pirklbauer, Joanneum Research

Herbert Pirkl, Technisches Buro fur Geologie

Graz, Austria

State College, USA

Introduction

Sustainable soil based recycling of materials derived from organic wastes, such as composts and biosolids, is predicated on the production and use of products that meet minimum quality criteria, which include concentrations of trace elements that could have adverse effects on human, animal, plant or soil health. Any attempt to reduce concentrations of these metals in the end products must identify the sources and pathways by which the metals are entering the feedstocks, the wastewater, or the production process. While trace metal loading of feedstocks and wastewater is strongly influenced by human activities, it may also be influenced by naturally occurring background concentrations in regional bedrock and soils. Pathways could include:

- metal uptake by plants used as feedstocks,
- dry and wet deposition of dust on feedstocks or on impervious surfaces where it can be washed into the sewerage system,
- inclusion of soil material and eroded sediments in feedstocks or in wastewater, and
- mineralization of ground and surface water.

Amlinger (1996) showed that the geology and soil parent materials (particularly the presence or absence of limestone or dolomite) in the region from which compost feedstocks originated was clearly reflected in the Ca and Mg content of the resulting compost. Fricke et al., (1992) investigated regional differences in trace element concentrations of composts produced in Germany and suggested these were related to the trace element content of regional geology and soils.

Austrian trace element concentration limits for composts and sewage sludge to be used for compost are presented in Table 1. The class A+ compost limits for organic farming are identical to EU limit values and limits for the other compost classes are derived from these.

Table 1. Austrian trace element limit values for composts and sewage sludges used as compost feedstock.

Trace Element	Compost Class†			Sewage Sludge for Compost Production		Land Applied SS in Styria¶
	A+	A	B	QSS Comp‡	SS Comp§	
Cd	0,7	1,0	3,0	2	3	10
Cr	70	70	250	70	300	500
Hg	0,4	0,7	3,0	2	5	10
Cu	70	150	500	300	500	500
Ni	25	60	100	60	100	100
Pb	45	120	200	100	200	500
Zn	200	500	1800	1200	2000	2000

† Class A+ may be used in organic agriculture, Class A may be used in agriculture, Class B may be used for non-food production purposes
‡ Quality Sewage Sludge Compost
§ Sewage Sludge Compost
¶ Limits for land applied sewage sludge in the Austrian state of Styria.

Overall in Austria, 61% of composts produced from source separated biowastes fail to meet A+ limit values, with limits for Pb and Zn most frequently exceeded. In the Austrian province of Styria, however, Ni is the most problematic metal with 71% and 12% of biowaste composts failing to meet class A+ and A limits respectively. This frequency of above limit compost products creates problems for marketing and utilization of the composts. Background soil trace metal concentrations for the province of Styria indicate that several metals exceed or are at the upper end of the normal background range for Austrian soils (Table 2) while Cr and Ni actually approach Austrian soil protection limits.

Table 2. Austrian soil protection limit values and mean background soil concentrations in the state of Styria.

	Cd	Cr	Cu	Ni	Pb	Zn
	mg kg^{-1}					
Austrian Soil Protection Limit	2	100	100	60	100	300
Normal Background Soil Range	<0.5	5 – 100	2 – 40	5 – 50	2 – 20	1 – 80
Styrian Mean Background Soil Level	0.25	80	50	60	30	140

These data suggest that at least for some metals, the concentrations in composts and in biosolids could be influenced by background soil concentrations. If this is the case it would greatly limit the ability of production facilities to reduce concentrations of these metals in composts and biosolids. This research was undertaken to determine if a clear relationship existed between geological background metals concentrations and their concentrations in biowaste and sewage sludges exists in Styria.

Materials and Methods

The availability of several georeferenced data sets containing total concentrations of trace metals in stream sediments and soils in much of Styria, and 10 years of analytical data for all composts and biosolids produced in Styria allowed us to utilize a geographical information system to assess relationships between naturally occurring background metals concentrations and the concentrations in geographically corresponding composts and biosolids.

Georeferenced chemical composition data were obtained primarily from two large data sets of stream sediment and soil samples that covered most of the Austrian State of Styria.

- Stream sediment trace metal data were obtained from 8200 sediment samples collected from within Styria. Sample points were located along natural drainage systems, near stream confluence points, and in areas where sediments were least likely to have been influenced by human activities. (Thalmann et al., 1989)
- Soil data from the Styrian soil inventory (Styrian Agricultural Research Center, 2000). Soil samples were collected primarily from agricultural soils on a 4 x 4 km grid over the entire area of Styria. Samples were collected from depths of 0-5, 5-20, and 20-50 cm. Only subsurface sample data were used in this analysis to avoid possible surface contamination from human activities.

The geochemical data were used to generate maps of likely background concentrations for each trace metal (Examples are shown in Fig. 3).

Compost and sewage sludge data were obtained from anaytical records on file with the Styrian State Government. Data for all source separated biowaste composts and all sewage sludges produced in Styria from 1990 – 2000 were assembled into two separate data sets that included the location of each production facility (Figs 1 and 2).

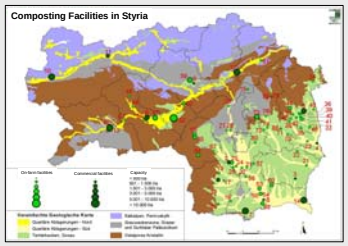

Figure 1. On-farm and commercial composting facilities in Styria in relation to major geologic formations.

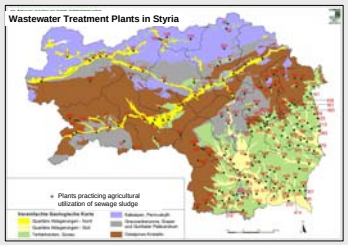

Figure 2. Wastewater treatment plants in Styria in relation to major geologic formations.

Relationships between background geologic trace metal concentrations and corresponding concentrations in composts and sewage sludges were assessed first by determining the geologic formation in which facilities were located and determining the metals concentration distribution for all materials produced in that region (Fig. 3)

All compost and wastewater facilities were ranked for each metal based on the mean concentration of the metal in the materials they produced. For each metal the upper and lower 10% of facilities were located on background geochemical maps for that metal (Fig. 4).

Results

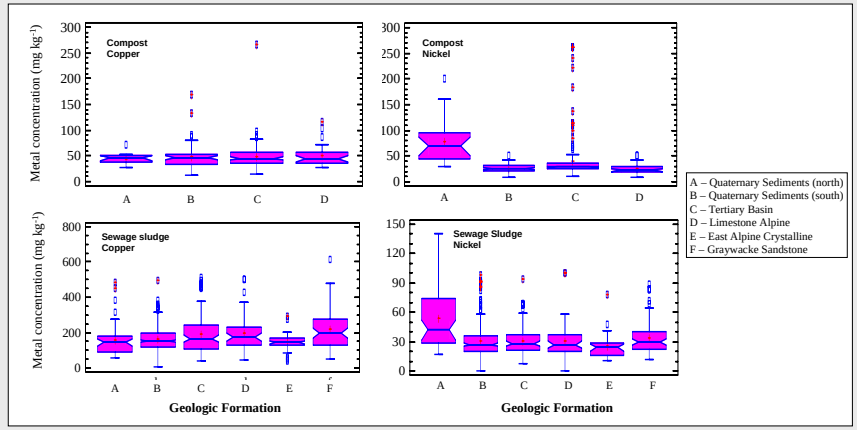

Figure 3. Distrribution of Cu and Ni in composts and sewage sludges produced in facilities located in various geologic formations.

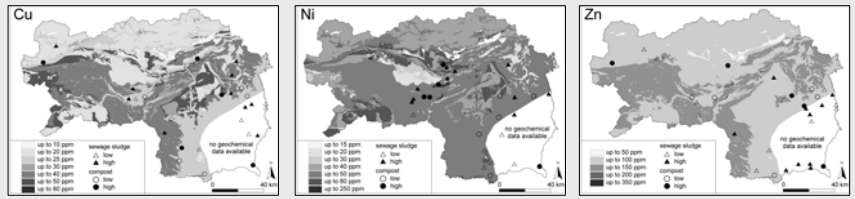

Figure 4. Locations of wastewater treatment plants and composting facilities producing sewage sludge and compost with the upper (high) and lower (low) 10th percentile concentrations of Cu, Ni, and Zn in relation to probable background geologic concentrations of those metals.

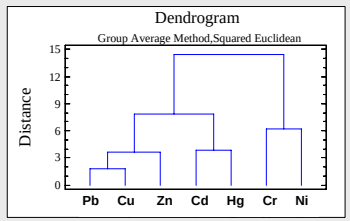

Figure 5. Dendrogram analysis of associations between trace metals in composts produced in Styria.

- Distribution of Cu in composts and sewage sludge was not different in the different geological regions (Fig.3). Similar results were found for Cd, Hg, Pb, and Zn (data not shown)
- Distribution of Ni in composts and sewage sludge was significantly higher in the Quaternary Sediment (north) region than in other regions (Fig 3.). Similar results were observed with Cr (data not shown).
- Facilities producing material with high or low Cu and Zn showed no apparent relationship with background levels, and no apparent clustering (Fig. 4)
- Facilities producing material with high Ni showed a tendency to be clustered in or near regions of higher background Ni levels (Fig. 4).
- Dendrogram analysis showed a strong association of Ni and Cr in composts (Fig. 5)

Conclusions

- For most metals analyzed in composts and sewage sludges there was no clear relationship between concentrations in these products and background concentrations in regional soils and geology.
- For Ni, and less strongly for Cr, there was evidence that background concentrations in soils and regional geology. The association was most clear for composts and sewage sludges with the highest concentrations of these metals.
- The association between Ni and Cr in composts and sewage sludges also suggests an influence of regional geochemistry as there are known areas of serpentine materials in Styria.
- These results suggest it will be very difficult for composting plants and waste water treatment facilities located in regions with high background levels of Ni to reduce concentrations in the material they are producing.
- It may be impossible for such facilities to consistently produce materials that meet current Austrian and European Union limit values for composts allowed to be used in organic farming.
- The soil protection concept upon which these limit values are based may not be practicable in all regions of Europe.