EFFECTS OF SEWAGE SLUDGE APPLICATION ON A REVEGETATED MINESOIL IN WEST VIRGINIA[1]

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Abstract -- Municipal sewage sludge from Morgantown, West Virginia ("Morganite") was applied to a sparsely vegetated minesoil in Monongalia County, West Virginia to improve the vegetative cover and forage production on the site. Four rates (0, 22.4, 44.8, and 78.4 Mg/ha) of sewage sludge were surface applied to plots measuring 33 m long by 12 m wide in a completely randomized design with three replications in March 1986. Vegetation was evaluated and soil samples were collected and analyzed during May and September of 1986 and 1987. Water samples were collected from ponds which received the drainage from the treated area during 1986. As expected, grass cover and biomass increased as sludge application rates increased. Legume and weed biomass decreased as sludge rates increased. Metals (copper, lead, and zinc) contained in the sludge were found at increasing concentrations in the minesoil with heavier application rates. These metal concentrations in the minesoil, however, were not at levels which adversely affected plant growth or surface water quality.

INTRODUCTION

Approximately 5 million dry metric tons of municipal sewage sludge are produced in the United States each year. About one-half of the sludge is land applied. Sludge application on land improves the nutrient status, organic matter content, and water holding capacity of the soil (Hornick et al. 1984, Khaleel et al. 1981, Sommers 1977). Much research has been conducted on application of sewage sludge to agricultural lands, and guidelines for correct application procedures are available (Baker et al. 1985, Elliott 1986, Feliciano 1982, King 1986, Page et al. 1983, U.S. EPA 1983, 1984).

Many studies have also been conducted on application of sewage sludge to disturbed lands to aid reclamation and revegetation (Fresquez et al. 1984, Joost et al. 1987, Sopper and Kerr 1979, Sopper et

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al. 1982, Stroo and Jencks 1985, Topper and Sabey 1986), and guidelines for application have been written for the Northeast (Baker et al. 1985). Loomis and Hood (1984) suggest that sewage sludge may decrease the rate of pyrite oxidation and reduce the formation of acid mine drainage in minesoils. Seaker and Sopper (1984) found that application of stabilized municipal sludges can be used to successfully establish vegetation on mined lands.

The benefits of amending soils and minesoils with sewage sludge are well-known, however, land application does present some potential hazards. Heavy metals in the sludge are normally adsorbed onto cation exchange sites or complexed in the organic fraction of soils and may be available for plant uptake (Gestring and Jerrell 1982, Korcak et al. 1979, Mahler et al. 1982, Mullins and Sommers 1986, Page 1974, Pietz et al. 1983, Valderes et al. 1983). Application of sludge to acid-producing materials or acidic minesoils is especially a potential problem due to solubilization of heavy metals and their movement into ground and surface water supplies (Hinkle 1982). This study was conducted to examine the effects of a one-time application of municipal sewage sludge from Morgantown, WV, ("Morganite") on the vegetation, minesoil, and surface water quality of a sparsely vegetated surface mine in West Virginia.

MATERIALS AND METHODS

Study Site

The study site was located on an area mined by King Knob Coal Company, 15 km southwest of Morgantown, Monongalia County, WV. Surface mining of the Waynesburg Seam of coal has been ongoing at this site since the early 1970's. Overburden associated with the Waynesburg Seam of coal is comprised of approximately 75 to 80 percent sandstone, with small amounts of siltstone, red and gray shales, and limestone (Cardwell et al. 1968). The haul-back method of contour mining was employed and equipment used during mining was typically bulldozers, front-end loaders, and trucks. Reclamation involved backfilling, topsoiling, liming (4.5 Mg/ha), fertilizing (672 kg/ha of 10-20-20), and reseeding to provide pasture and hayland. The plant species seeded were red clover (*Trifolium pratense* L.), tall fescue (*Festuca arundinacea* Schreb.), orchardgrass (*Dactylis glomerata* L.), and birdsfoot trefoil (*Lotus corniculatus* L.). Table 1 shows representative minesoil data collected near the reclaimed area in 1983.

Sludge Application

The Morgantown wastewater treatment plant uses an anaerobic secondary sewage treatment process utilizing rotating biological contacters (RCB). The destructive flood of November 1985 incapacitated the plant and necessitated the cleanout of the digestor tanks. The accumulated sludge was pumped from the digestors into tank trucks, mixed and stabilized with lime (pH 12), and hauled to the study site. Sludge was surface applied by a Terragator vehicle from McCutcheon Enterprises, Inc., Vandergrift, PA. Physical and chemical properties of the sludge before the lime was added are shown in table 2. Application rates were based on the organic N content of Digestor 2 and the amount of sludge needed to supply 336 kg N/ ha. The calculated sludge application rate was 78.4 dry Mg/ha, or 522.7 Mg/ha of material with 15 percent solids.

Table 1.--Representative minesoil data collected near the King Knob site where municipal sewage sludge from Morgantown, WV was surface applied (Adamo 1986).

Minesoil Classification: Typic Udorthents, loamy-skeletal, mixed, non-acid, mesic
Surface textures: sandy loam, loam, clay loam
Bulk density: 1.2 to 1.5 Mg/m^3
Water Retention (33 to 1,500 kPa): 7 to 10 percent

Depth (cm)	pH[1]	N	O.M.	CEC	K	Ca	Mg	P	Fe	Mn	Zn	Cu
		-----%----		-----cmol (+)/kg--------				-----------ug/g-------------				
0-10	7.2[2]	0.20	4.5	27.6	0.4	20.2	1.9	12.5	51.4	17.2	2.6	3.4
11-20	6.9	0.13	3.1	25.6	0.3	17.6	2.1	9.9	71.7	21.9	2.4	4.8
21-30	6.6	0.11	2.6	23.3	0.2	15.8	1.8	8.9	64.6	26.5	2.0	3.4

[1]Soil chemical analyses were conducted by the same methods as described in the text.

[2]Values are the means of eight sample replicates.

Table 2.--Physical and chemical properties of municipal sewage sludge from Morgantown, WV[1].

	Solids	Org N	NH_4-N	Total N	P	K	Ca	Mg
	%							
Digestor 1	15[2]	2.6	0.8	3.4	1.5	0.4	3.6	0.2
Digestor 2	16	2.1	1.1	3.2	1.6	0.5	2.6	0.1

	pH	Cu	Cd	Zn	Ni	Pb	Cr
		ug/g					
Digestor 1	7.3	444	9	1000	52	67	275
Digestor 2	7.7	349	9	799	48	58	308

[1]Analyzed by the Ohio Agricultural Research and Development Center, Research-Extension Analytical Laboratory, Wooster, OH.

[2]Values are the means of five samples from each digestor.

A level 0.5-ha area was chosen on the King Knob mine site and divided into twelve experimental plots measuring 12 m wide by 33 m long. One of four sludge application rates with three replications per treatment were randomly assigned to one of the twelve plots. The rates were 0, 22.4, 44.8, and 78.4 Mg/ha calculated on a dry weight basis. The sludge was applied in March 1986 and was not incorporated into the soil. Also, sewage sludge was applied to three, 2-ha areas surrounding the experimental plots.

Sampling Methods and Analysis

In each experimental plot, five randomly placed quadrats measuring 50 cm by 50 cm (0.25 m^2) were used for vegetation sampling. Total plant cover, bare ground, and litter cover were visually estimated in each quadrat. Plant species in the quadrat were identified and their cover estimated. The aboveground biomass in each quadrat was clipped at ground level; separated into grass, legume, and weed components; and placed in paper bags. The bags were taken to the laboratory, dried in a forced-air convection oven at 60°C for 48 hrs, and weighed to determine dry weight.

Minesoil samples were taken to a depth of 15 cm at each quadrat and composited into one sample for each plot. Samples were analyzed for pH using a 1:1 soil:water suspension, and organic matter by acid dichromate digestion (Soil Survey Staff 1984). Cation exchange capacity (CEC), K, Ca, and Mg were determined by ammonium acetate extraction (Soil Survey Staff 1984). Micronutrients and metals (Fe, Mn, Cu, Zn, Cd, Pb) were extracted with diethylenetriaminepentaacetic acid (DTPA) (Lindsay and Norvell 1978). Exchangeable and nonexchangeable H and Al were determined by 1<u>N</u> KCl extraction (Soil Survey Staff 1984). Total N was determined by the Kjeldahl method (Soil Survey Staff 1984), and available P was determined using sodium bicarbonate (Olsen et al. 1954). Vegetation and soil samples were collected in May and September of 1986 and 1987.

Vegetation and soil data were analyzed by analysis of variance and treatment means were separated by Duncan's multiple range test with computer facilities at West Virginia University.

Three water samples were collected from three ponds that receive drainage from the entire 6.5-ha study site. Samples were taken in March (before sludge application), July, and September of 1986 and analyzed by the WV Department of Natural Resources Water Resources Laboratory.

RESULTS AND DISCUSSION

Surface application of sewage sludge onto the vegetation smothered the vegetation for several months. Total cover and plant biomass were decreased as a result of heavy sludge application (table 3). However, after six months, it was evident that nutrients in the sludge increased cover and grass aboveground biomass. Legume biomass and number of legume species were decreased as sludge rates increased in September 1986 because increased nutrient levels in the minesoil caused increased grass growth and competition. Weed biomass increased with increased sludge rates in September 1986, probably because of the large weed seed bank in the sludge. Weed seeds are better suited to

Table 3.--Vegetation characteristics of a reclaimed surface mine after application of three rates of municipal sewage sludge from Morgantown, WV, in May and September 1986.

Sludge Rate (Mg/ha)	Total Cover (%)	Grass Biomass (g)	Legume Biomass (g)	Weed Biomass (g)	Grass Species (Number)	Legume Species (Number)	Weed Species (Number)
				MAY 1986			
0	59 ab[1]	13 a	4 a	.4 a	1.8 a	1.0 a	0.6 a
22.4	68 a	13 a	4 a	.4 a	1.6 a	1.1 a	0.8 a
44.8	53 ab	10 ab	7 a	.2 a	1.0 b	1.0 a	0.9 a
78.4	42 b	7 b	2 a	.2 a	1.1 b	0.5 b	1.2 a
				SEPTEMBER 1986			
0	90 b	68 b	30 a	18 b	1.9 a	1.2 a	1.2 b
22.4	91 b	56 b	13 b	31 ab	1.5 a	1.0 ab	2.1 a
44.8	96 a	88 ab	10 b	59 a	1.7 a	0.7 b	1.9 a
78.4	97 a	105 a	1 c	65 a	1.7 a	0.3 c	2.6 a

[1]Values within columns of different dates with the same letter are not significantly different at $p < 0.05$.

germinate under harsh conditions created by the surface application of sludge.

Sludge application continued to influence the vegetation on the site through 1987 (table 4). Total cover was significantly higher on sludge-treated plots than on control plots and grass biomass increased with increasing sludge rates. Compared to control plots, legume biomass and number of species were still lower on the two heaviest sludge application plots after two growing seasons. Weed biomass during the second growing season was reduced to control levels.

Table 4.--Vegetation characteristics of a reclaimed surface mine after application of three rates of municipal sewage sludge from Morgantown, WV, in May and September 1987.

Sludge Rate (Mg/ha)	Total Cover (%)	Grass Biomass (g)	Legume Biomass (g)	Weed Biomass (g)	Grass Species (Number)	Legume Species (Number)	Weed Species (Number)
				MAY 1987			
0	60 c[1]	72 c	8 a	.2 a	1.9 a	1.0 a	0.6 a
22.4	77 b	126 b	5 ab	.2 a	1.6 a	0.9 a	0.2 a
44.8	84 b	150 b	2 bc	.2 a	1.7 a	0.6 ab	0.3 a
78.4	95 a	223 a	1 c	.3 a	1.7 a	0.4 b	0.7 a
				SEPTEMBER 1987			
0	95 b	82 b	5 b	3 a	1.1 a	0.9 a	1.3 a
22.4	98 a	124 ab	8 a	2 a	1.1 a	0.9 a	0.3 b
44.8	98 a	146 ab	2 c	4 a	1.1 a	0.3 b	0.8 ab
78.4	98 a	291 a	1 c	6 a	1.0 a	0.3 b	0.9 ab

[1]Values within columns of different dates with the same letter are not significantly different at $p < 0.05$.

Soil analyses revealed that minesoil pH did not appear to be influenced by sludge application (tables 5 and 6). The pH of sludge-treated plots was never significantly different from the control plots but was lower than the pH data initially reported in Table 2. Lime was surface-applied and incorporated several months prior to the 1982 minesoil sampling and, to my knowledge, no more lime has been applied since 1982 . Organic matter content of treated minesoils shows an increasing trend over time, but the values for sludge-treated plots are again not

Table 5.--Chemical characteristics of minesoil with four rates of surface-applied sewage sludge from Morgantown, WV, in May and September 1986.

Sludge Rate (Mg/ha)	pH	O.M.	K	Ca	Mg	H	Al	Fe	Mn	Zn	Cu	Pb
		%	----------cmol (+)/kg	---------				------------ug/g	----------------			
						MAY 1986						
0	4.7a[1]	1.6a	.9a	7.9a	.7a	.65a	.40a	101a	193a	1.4b	1.0b	4.5b
22.4	4.9a	2.0a	.9a	12.2a	.9a	.25a	.46a	101a	213a	3.6a	2.2a	5.6ab
44.8	5.0a	1.9a	.9a	14.6a	.8a	.42a	.23a	105a	229a	4.7a	2.6a	6.2a
78.4	4.8a	1.9a	.8a	10.0a	.7a	.59a	.33a	117a	204a	5.3a	2.8a	6.8a
						SEPTEMBER 1986						
0	5.0a	1.8a	.9a	7.4a	.7a	.60a	.36a	108b	241a	1.6c	1.1c	4.6b
22.4	5.3a	2.2a	.8a	12.1a	.8a	.55a	.13a	118ab	282a	4.8b	2.4b	4.4b
44.8	5.1a	2.2a	.9a	11.8a	.9a	.70a	.26a	125ab	245a	5.3b	2.4b	5.1ab
78.4	4.9a	2.1a	.9a	12.2a	.9a	.66a	.40a	138a	236a	8.5a	3.6a	5.6a

[1]Values within columns of different dates with the same letter are not significantly different at $p < 0.05$.

Table 6.--Chemical characteristics of minesoil with four rates of surface-applied sewage sewage sludge from Morgantown, WV, in May and September 1987.

Sludge Rate (Mg/ha)	pH	O.M	K	Ca	Mg	H	Al	Fe	Mn	Zn	Cu	Pb
		%	----------cmol (+)/g	---------				-------------ug/g	----------------			
						MAY 1987						
0	5.6a[1]	1.9a	.8a	9.6a	.7a	.14a	.16a	96a	235a	1.5c	0.7b	5.5a
22.4	5.8a	2.2a	.8a	15.3a	.9a	.59a	.09a	83a	304a	6.5b	2.6ab	6.2a
44.8	5.9a	2.5a	.9a	23.2a	1.0a	.43a	.29a	116a	337a	7.7ab	4.2a	6.4a
78.4	5.9a	2.2a	.9a	16.7a	.8a	.56a	.26a	157a	319a	9.2a	4.4a	5.6a
						SEPTEMBER 1987						
0	4.6a	1.4b	1.2a	6.6a	1.1a	.82a	1.87a	179b	216a	1.3b	2.2b	1.2b
22.4	5.1a	2.5a	.9a	13.4a	1.1a	.43a	.33b	211ab	207a	2.4b	4.4a	1.6ab
44.8	5.4a	2.8a	1.2a	19.5a	1.2a	1.20a	.47b	222ab	184a	4.2a	4.4a	1.9a
78.4	4.9a	2.7a	.9a	15.0a	1.3a	.54a	.93b	254a	185a	5.7a	5.3a	2.0a

[1]Values within columns of different dates with the same letter are not significantly different at $p < 0.05$.

significantly higher than control plots. Most studies report an increase in organic matter content in soils after treatment with an organic waste material (see Khaleel et al. 1981). In plots receiving the heaviest sludge application, iron concentrations were significantly higher only during the September sampling dates of both years. Zinc, copper, and lead were all signficantly higher in treated plots than in control plots at all sampling dates. Loading rates of Zn, Cu, and Pb at 78 Mg/ha of sludge were 34.8, 78.4, and 5.3 kg/ha, respectively. Cadmium was added at a rate of 0.7 kg/ha, but the equipment used for analysis did not detect any Cd in sludge-treated minesoils.

Analyses were not conducted to determine metal concentrations in forages growing on the site, but no visual symptoms of stress or reduced growth of plants in treated minesoils were apparent. Pietz et al. (1983) reported that applications of 258 Mg/ha of sewage sludge increased Cd, Cu, Ni, and Zn concentrations in a calcareous strip-mine spoil and uptake of these metals by corn also increased. Similar findings are reported by Korcak et al. (1979), Valdares et al. (1983), Gestring and Jarrell (1982), and Mullins and Sommers (1986).

Water samples collected from three ponds which received the drainage from the entire 6.5-ha sludge-treated area showed few differences from the water collected before the sludge was applied (table 7).

Table 7.--Chemical characteristics of surface water collected from ponds which received the drainage from sludge-treated minesoils in West Virginia.

	DATE[1]		
Characteristic	Mar 86	May 86	Sept 86
pH	7.3	6.9	7.5
NO_3-N (mg/l)	3.7	3.0	2.0
Cr (ug/l)	4.0	7.3	8.7
Zn (ug/l)	226.0	157.3	197.3
Cu (ug/l)	12.3	8.3	10.0
Cd (ug/l)	1.3	1.2	1.0
Ni (ug/l)	178.0	118.3	215.3
Pb (ug/l)	24.0	41.7	38.0
Al (ug/l)	2506.7	586.7	841.0

[1]March 86 sampling date was approximately 1 week prior to sludge application, while May and September were 2 months and 6 months after application, respectively.

[2]Values are the average of nine samples.

Chromium and lead concentrations appear to have increased since sludge application, but caused no concern to the Department of Natural Resources, who therefore did not collect and analyze water samples from the site after September 1986. Hinesly et al. (1984) found higher Zn, Cu, Cd, and Cr concentrations in water from sludge-treated lysimeters.

SUMMARY

A one-time application of municipal sewage sludge from Morgantown, WV significantly improved the plant cover and biomass produced on the site for two growing seasons following application. However, pH and macronutrient levels were not influended or only slightly influenced by sludge application. Heavy metals contained in the sludge were found at increasing levels in the treated minesoils, but the metals did not appear to affect vegetation or move into surface water supplies.

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