RECLAIMING COARSE TACONITE TAILING WITH MUNICIPAL SOLID WASTE COMPOST[1]

Glenn D. Melchert, A. Paul Eger, Zena Kassa, and Steven W. Dewar[2]

Abstract: Coarse-textured taconite tailing cover about 3,000 ha on Minnesota's Mesabi Iron Range. These tailing are deficient in nutrients, cation-exchange capacity, and moisture-retention capacity and are highly erodible. Previous reclamation efforts, in most cases, have been unable to meet the regulatory requirement for 90% vegetative cover after 3 yr. Small-scale test plots have demonstrated that municipal solid waste compost can be used to successfully reclaim tailing areas, which also provides a use for the compost. There has been a general reluctance to use municipal compost for reclamation activities, however, owing to concerns relating to the release of metals and organics. A field demonstration study was initiated to examine the feasibility of applying the compost on a larger scale and to examine its impacts on water quality and runoff from the reclaimed areas. Three 0.1-ha plots were located on the south-facing slope (15% slope) of a coarse tailing dike. Three treatments were studied: (1) a control with no treatment, (2) standard diammonium phosphate fertilizer application of 448 kg/ha, and (3) a compost treatment with 224 kg/ha fertilizer and 44.8 Mg/ha (dry weight) of municipal solid waste compost. All plots except the control were seeded with a grass-legume mixture and mulched with hay. Runoff collection plots were set up, and lysimeters were installed in each plot. Three months after planting, ground cover was 67%, 39%, and 0% for the compost, standard fertilizer, and control plots, respectively. Biomass, as kilograms per hectare, was 976, 225, and 0 for the compost, standard fertilizer, and control plots, respectively. Chloride, sulfate, calcium, magnesium, sodium, and nitrate were elevated in the soil water of the compost plot. Nitrate was the only chemical that exceeded water quality standards; however, these concentrations are not expected to significantly impact the local aquifer because the compost is only applied once and the concentrations of all parameters decreased with time.

Additional Key Words: water quality, heavy metals, nutrients, water balance, biomass, percent cover, erosion, Minnesota.

Introduction

Across the Mesabi Iron Range in northeastern Minnesota there are over 10,000 ha of land covered with taconite tailing waste from eight taconite mining operations. Portions of this tailing, especially the dikes, are comprised of relatively coarse-textured material, which covers over 3,000 ha. State mineland reclamation rules require that these areas be vegetated and achieve a vegetative cover of 90% after three growing seasons, except for slopes that face south or west, where a limit of five growing seasons applies (MNDNR 1980). To date, companies have found it particularly difficult to meet the 3- and 5-year requirements on coarse-textured tailing.

Coarse tailing is low in organic matter, nitrogen, phosphorus, cation-exchange capacity, and electrical conductivity (Noyd et al. 1992). Coarse-tailing slopes that are sparsely vegetated or bare often appear droughty and exhibit extensive gullying. The gray color of the tailing results in large temperature extremes, especially on slopes that face south or west, and the large open expanses typical of these basins subject these areas to considerable wind

---

[1] Paper presented at the 1994 National Meeting of the American Society for Surface Mining and Reclamation, Pittsburgh, Pennsylvania, April 24-29, 1994.

[2] Glenn D. Melchert, Hydrologist, A. Paul Eger, Principal Engineer, Zena Kassa, Research Analyst, and Steven W. Dewar, Mineland Reclamation Specialist, Minnesota Department of Natural Resources, Division of Minerals, St. Paul, Minnesota.

Proceedings America Society of Mining and Reclamation, 1994 pp 175-183
DOI: 10.21000/JASMR94030175

https://doi.org/10.21000/JASMR94030175

erosion. These factors all contribute to the difficulty in vegetating coarse tailing.

Recent plot studies have shown that organic amendments, such as municipal solid waste (MSW) compost, will improve soil structure and substantially increase the growth of grasses and legumes on coarse tailing compared with present standard reclamation practices (Norland et al. 1991, 1992). The use of compost may be a viable approach to meet reclamation standards at problem sites. Municipal solid waste compost slowly releases macro and micro nutrients, increases cation-exchange capacity and water-holding capacity, complexes heavy metals, and increases microbial populations in the tailing (Veith and Norland 1992, Wirth 1991, Heil and Barbarick 1989, Stark 1987).

The research base necessary for environmentally acceptable use of composted municipal solid waste on mineland reclamation projects in Minnesota is very limited. Many potential compost users have expressed concern about the levels of contaminants in the composts. Although landfill materials are transformed into a useful soil amendment by composting, potentially hazardous levels of trace metals may be introduced into the soil environment and food chain (He et al. 1992). MSW compost products are inherently variable (Walker and O'Donnell 1991), and potential environmental impacts must be evaluated before they are used extensively.

The objectives of this project were to determine: (1) the feasibility of applying MSW compost to a large area, (2) the effectiveness of MSW compost applications in meeting vegetative cover standards, and (3) impacts on water quality that may occur at these sites through the use of municipal solid waste compost as a soil amendment.

Site Description

The study area is about 11 km (7 miles) west of Hibbing in northeastern Minnesota (93°2' N latitude, 47° 22' W longitude). The plots are located on a coarse-tailing dike within the National Steel Pellet Co. tailing basin. Taconite tailing are the waste products from the processing of taconite rock to produce iron ore. Tailing particles range in size from fine gravel to clay and consist mostly of silica (Myette 1991). In general, at the study site, 25% of the material is coarse sand or larger (>2.0 mm), while about 8% of the material is silt and clay (<0.075 mm). The tailing is pumped as a slurry to a tailing basin, where the solids settle and the water is reused. Depositional processes occurring in the tailing basin are similar to those occurring with the formation of deltas, with the coarsest particles settling nearest the spigot while the finer materials move into the basin interior to settle out of suspension. The slurry lines are periodically lengthened as the tailing builds up. Coarse tailing is usually utilized to construct a dike, which encircles or subdivides the basin.

During installation of the lysimeters, it was observed that much of the coarse tailing consists of interbedded coarse and fine particles. These layers were typically less than 2 cm thick and sloped away from the center of the dike.

This area experiences short, mild summers and long, cold winters with monthly averages ranging from -12.3°C in January to 18.1°C in July and a mean annual temperature of 4°C. Mean annual precipitation is 688 mm, of which about 510 mm is lost through evapotranspiration (Myette 1991).

Materials and Methods

MSW Compost

The compost used was produced by the East Central Materials Recovery/Compost Facility near Mora, MN and was classified as a class 1 material. The municipal waste it receives comes from households and small industry from a 5-county area with a mostly rural population of about 100,000. According to Minnesota's guidelines (Wirth 1991) a compost is class 1 if it is processed without sewage sludge, has composted for at least 180 days, and if contaminant levels do not exceed Minnesota Pollution Control Agency limits (table 1). A class 1 rating allows for unrestricted application rates. Further details on the composting process can be found in Dewar and Norland (1994 in press).

The compost was sampled and analyzed for moisture content, organic and inorganic constituents, nutrient content, and trace metals. The entire suite of semivolatile and pesticide compounds, PCBs, and the trace metals silver, arsenic, selenium, copper, nickel, zinc, mercury, cadmium, and chromium were analyzed according to EPA methods (SW846).

Table 1. Comparison of allowable contaminant concentration limits for class 1 MSW compost (dry weight basis) and sample results from the compost used in this experiment.

Contaminant	Concentration, mg/kg	
	Limits	Compost results
Arsenic	NAp	5.0
Barium	NAp	90
Cadmium	10	3.75
Chromium	1,000	58
Copper	500	285
Lead	500	175
Mercury	5	1.45
Nickel	100	25
Selenium	NAp	0.30
Silver	NAp	3.1
Zinc	1,000	785
PCB	1	<1

NAp indicates not applicable, no limits set.

Plot Establishment

A south-facing slope of an unvegetated coarse tailing dike was selected because this aspect is the most difficult to vegetate successfully. This dike was graded to fill the gullies and to form a uniform slope. The final slope averaged 15%.

Three 0.1-ha plots (80 m by 12.5 m) were established (fig. 1). One plot was a control that was left bare, one was vegetated using reclamation methods typical for the industry (standard reclamation), and one had compost and fertilizer applied. No treatments were applied to the control plot. This plot was disced, however, so its surface would be similar to that of the other plots.

The standard reclamation plot received an application of 448 kg/ha (400 lb/acre) of granular diammonium phosphate fertilizer (18-46-0). The fertilizer was applied with a broadcast spreader and then incorporated into the tailing to a depth of 15 cm with a disc. Then the plot was seeded at a rate of 56 kg/ha (50 lb/acre) with a grass-legume cool-season mix with a broadcast spreader. After seeding, the plot was immediately mulched with hay at the rate of 2.2 Mg/ha (2 t/acre). The mulch was then crimped to a depth of about 7.5 cm.

The MSW compost plot received an application of 44.8 Mg/ha (20 t/acre) of municipal solid waste compost and 224 kg/ha (200 lb/acre) of granular diammonium phosphate (18-46-0). The compost was applied with a standard rear-throw manure spreader. The fertilizer was applied with a broadcast spreader, and then the compost and fertilizer were disced to a depth of 15 cm. Fifty-six kilograms per hectare of the grass-legume seed mix and 2.2 Mg/ha of hay mulch were applied and incorporated in the same way as for the standard reclamation plot.

Prior to vegetating, a backhoe was used to bury three 0.26 m^2 pan lysimeters at a depth of 61 cm in each plot. Lysimeters were placed 20 m apart and 6 m from the high edge of the plots. After the plots were seeded, a 1.5- by 12.5-m (18.75 m^2) runoff plot within each plot was established to collect runoff water. Sets of suction lysimeters were installed near each pan lysimeter at depths of 15, 30, and 61 cm (fig. 1).

Water Quality

Water samples were collected from the runoff plots on a weekly and/or event basis. Total runoff and total sediment loss were measured for each plot. Samples were collected from the pan and suction lysimeters when sufficient quantities of water were available. Since the only water applied to these plots was from precipitation, the interval between sample collections varied. Water samples collected from the runoff plots were analyzed for total

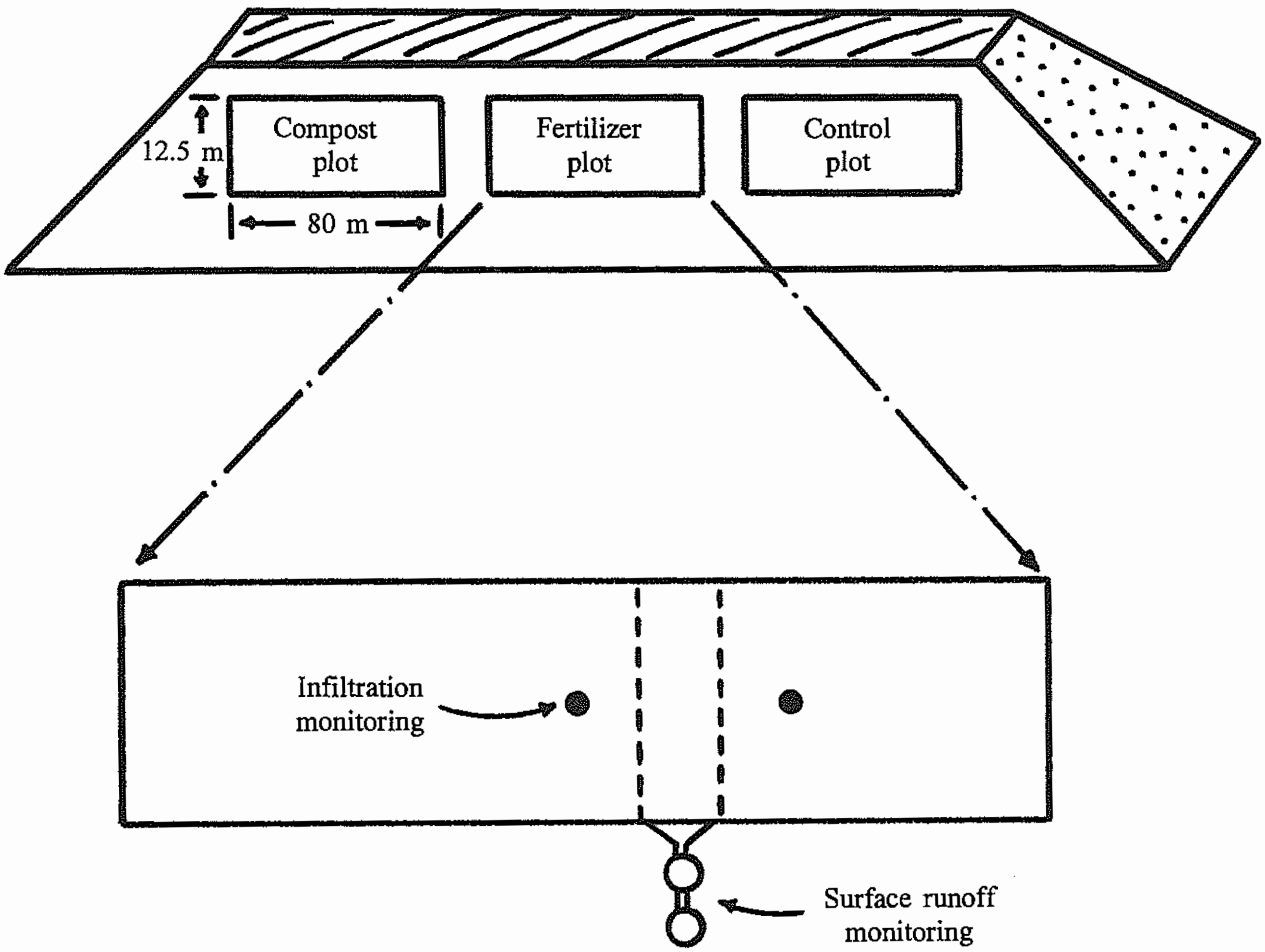

Figure 1. Test plot design and sample locations.

sediment, pH, specific conductance, major anions and cations, iron, and manganese. Selected samples were analyzed for heavy metals. Metals samples were filtered through a 0.45-μm filter prior to preservation with ultrapure nitric acid. The metals were either analyzed with flameless atomic absorption (EPA methods 206.2, 270.3, and 245.1) or ICP (EPA method 200.7). Water collected in the pan and suction lysimeters was measured and generally sampled for the same parameters as the runoff plots. Precipitation was measured on site with a weighing bucket rain gage.

Vegetation Sampling

In early August 1993, 3 months after planting, percent ground cover and biomass were measured on each plot. Percent cover was measured using a systematic point-quadrat sampling method (Raelson and McKee 1982) to estimate cover within a 95% statistical confidence. Biomass was estimated by clipping all aboveground plant material from six randomly selected 0.11-m^2 quadrats.

The two major plant species, timothy *Phleum pratense* and alfalfa *Medicago sativa*, were analyzed for nutrients and trace metals. Twenty randomly selected plants of each species for each treatment were collected and composited. The entire above-ground portion of the timothy plants and the top 6 inches of each alfalfa plant were used. The plants were dried at 70°C and ground in a Wiley Mill to pass a 1-mm sieve. The dried plant mass was dry ashed and digested in 10% HCl, and the resulting solution was analyzed by ICP-AES (Inductively Coupled Plasma Atomic Emission Spectroscopy) according to EPA methods.

Results

Compost Contaminants and Application

Concentrations of all trace metals were below the maximum allowable limit for class 1 material. No pesticides or PCBs were detected, and the only semivolatile compounds detected were butylbenzylphthalate and bis(2-ethylhexyl)phthalate. The concentrations of these compounds were 5.1 and 41 mg/kg, respectively. Phthalates are commonly found in plastics, so these elements were most likely released from the small plastic particles present in the compost when the sample was heated during the extraction.

The use of farm equipment was reasonable for the application and incorporation of the MSW compost. The manure spreader distributed the compost rather evenly, but discing did not evenly incorporate the compost in the tailing. Most of the compost remained on or near the surface with only a small amount mixed to 15 cm. The disc, either while incorporating the compost or during crimping of the mulch, tended to concentrate the compost in narrow bands rather than uniformly distributing the material across the plot.

Vegetation

Percent cover and biomass were significantly higher in the compost plot than the fertilizer plot. Percent cover and biomass in the fertilizer plot were 39% and 225 kg/ha while these parameters were 67% and 976 kg/ha in the compost plot. The tissue analysis was set up as a screening procedure to determine if significant amounts of metals had accumulated in the plants. Table 2 compares the tissue concentrations from this study with sufficient (desired) concentrations for optimum growth (Jones et al 1991). Although zinc concentrations for both species in the compost plot were low, they were higher than the plants from the fertilizer plot. None of the trace metal concentrations were elevated above sufficient levels (Jones et al 1991).

Water Balance

Runoff was greatest in the control plot, and the bulk of it occurred during three storms in late June and early July. Rainfall events of less than about 2.5 cm and of low intensity generally did not produce runoff in any of the plots. Total runoff, as a percent of total precipitation of 58 cm, was 0.2, 1.5, and exceeded 4.5 for the compost, fertilizer, and control plots, respectively. For several large storms, the sediment load exceeded the capacity of the collection trough in the control plot and as a result some runoff and sediment was not measured.

Erosion was greatest in the control plot and minimal in the compost plot. Sediment loss for the year (May-October) was 0.7 Mg/ha, 2.5 Mg/ha, and 34.4 Mg/ha for the compost, fertilizer, and control plots, respectively.

Precipitation over the course of the study was only 7 cm above normal. For every month except July precipitation was normal or below normal. In July, precipitation was 13 cm above the normal 10 cm, with 15 cm falling over the first 11 days of July.

Evaporation from the plots was high, so there was little infiltration below the plant rooting zone and into the pan lysimeters. Of the 58 cm of rain that fell, only 1.9%, 1.8% and 1.5% infiltrated through the compost, standard reclamation and control plots, respectively. Nearly all of this occurred in early July after 10 cm of rain fell over 2 days.

Table 2. Concentrations of nutrients and metals in timothy and alfalfa from the study plots as compared to sufficient levels in the literature.

Parameters	Timothy			Alfalfa		
	Fertilizer plots	Compost plot	Sufficient[1]	Fertilizer plot	Compost plot	Sufficient[1]
Concentration, %:						
Phosphorus	0.25	0.19	0.11-0.18	0.25	0.19	0.26-0.7
Potassium	1.91	1.92	1.14-1.70	1.31	1.39	2.00-3.5
Calcium	0.22	0.24	0.09-0.35	2.38	2.68	1.80-3.0
Magnesium	0.23	0.11	0.06-0.25	1.06	0.42	0.30-1.0
Concentration, mg/kg:						
Aluminum	6.22	3.96	NA	38.5	14.0	NA
Boron	6.24	20.8	1-10	38.9	56.5	30-80
Cadmium	<0.12	<0.12	NA	0.16	0.34	NA
Chromium	<0.28	<0.28	NA	0.42	0.33	NA
Copper	3.49	4.96	7-45	3.52	6.69	7-30
Iron	168	35.8	22-54	326	152	30-250
Lead	<1.17	<1.68	NA	2.06	1.76	NA
Manganese	181	97.5	11-35	394	199	31-100
Nickel	1.22	1.03	NA	0.68	1.37	NA
Zinc	7.94	40.2	24-62	7.89	51.9	21-70

NA indicates not available.
[1]Values taken from plant analysis handbook by Jones and others (1991).

Water Quality

As a result of a low rate of infiltration, there was only sufficient water in the lysimeters for sampling on 2-3 occasions. Despite the limited data base, some differences between the treatments were observed. Water infiltrating through the treated plots had higher specific conductance than the control. While this difference was generally about 20%, water in one of the lysimeters in the compost plot had a specific conductance value that was more than three times that of any other site. This water also contained the highest concentrations of sulfate (950 mg/L), chloride (220 mg/L), calcium, magnesium, sodium, nitrate (140 mg/L), and most of the trace metals except for zinc (tables 3 and 4). Although trace metal concentrations were generally low and below water quality standards, concentrations in the compost plot were slightly higher than in the other two plots (table 4).

Discussion

Using MSW compost as a soil amendment appears to be a successful method for reclaiming coarse taconite tailing without creating any additional serious environmental impacts. The compost served as a mulch which minimized runoff, and increased moisture retention. The compost plot had a 67% ground cover after 3 months, compared with 39% for the fertilizer plot. Plants in the compost plot appeared taller and more closely spaced than those on the fertilizer plot. The larger biomass in the compost plot may be due to a combination of increased growth and increased germination. Since ground cover typically increases significantly in the 2 or 3 yr after planting, the compost plot appears to have a good chance at meeting the 90% cover requirement. Norland and Dewar (1994) have shown that flat coarse-tailing plots, amended with similar MSW compost and fertilizer

Table 3. Water quality summary of lysimeter samples from the study plots[1].

Parameters	RAL	Control plot		Fertilizer plot		Compost plot	
		Median	Range	Median	Range	Median	Range
S.C.		675	550-900	937	825-1,100	1,125	800-3,800
pH	6-8	7.72	7.46-7.84	7.54	7.49-8.07	7.44	7.16-7.80
Alk	NA	350	312-504	544	479-712	366	235-479
SO_4	250	16.8	2-51	26.2	2.0-44.5	287	122-950
Cl	250	4.6	1-18	3.0	1.0-5.2	21.0	12.0-220
Ca	NA	47.5	34-51	42.0	32.2-51.0	77.0	42.7-131
Mg	NA	74.8	56-100	110	82-140	180	94-220
Na	NA	11.5	9.3-17.7	20.2	14.8-22.4	51.0	29.6-260
K	NA	9.9	4.5-21.1	10.8	4.95-13.35	14.2	9.4-34.0
Fe	0.05	0.01	<0.01-0.02	0.02	0.01-0.07	0.02	0.01-0.29
Mn	0.6	0.01	<0.01-0.01	<0.01	<0.01-0.01	0.01	<0.01-0.06
NO_3-N	10	1.1	0.50-1.46	9.0	5.2-20.81	30.1	9.6-140
NH_3-N	NA	0.05	NAp	0.06	NAp	0.02	0.02-0.14
TKN	NA	<0.02	NAp	<0.20	NAp	1.23	0.20-1.36
Total P	NA	<0.02	NAp	0.03	NAp	0.03	0.02-0.05

NA indicates not available.
NAp indicates not applicable (only 1 sample was analyzed).
RAL indicates recommended allowable limits for drinking water contaminants in private wells (MN Dept. of Health 1991).
[1]Alkalinity and metals concentrations are in milligrams per liter, pH is in standard units, specific conductance (S.C.) is in microsiemens. The number of samples (n) represented by the ranges is between 4 and 8.

applications, achieved 90% cover after 4 growing seasons. It will be much more difficult, however, for the fertilizer plot to meet reclamation standards.

Even though compost applications have successfully increased vegetative cover in coarse tailing, there is some concern related to the uptake of the metals in the compost by vegetation. Taconite tailing generally have low trace metal concentrations and are deficient in micronutrients. The application of compost, with its higher metal content, may be beneficial to the vegetation. Our results indicate that there were no significant metal accumulations in the vegetation which suggests that the metal concentrations in the compost plot are not high.

In general, the application of MSW compost did not adversely affect the water infiltrating through the tailing. Although concentrations of major cations and anions were particularly high in one compost plot lysimeter, only sulfate and nitrate were above groundwater standards. The increase in concentrations is related to components that can be easily leached from the compost. Samples of compost which were extracted with water showed high concentrations of all major cations and anions. The difference in water quality among the lysimeters in the compost plot results from variability in the compost or uneven application of the material. Despite these elevated concentrations, the overall impact on groundwater in the area is expected to be small, since the amount of water moving down through the tailing is minimal.

Present reclamation costs for vegetating coarse tailing using standard techniques are about $500 per acre. The compost application used in this study was half the rate recommended by Norland and others (1992). Their

Table 4. Trace metal concentrations in test plot lysimeters compared to levels in MSW compost and groundwater in tailing area[1,2].

Parameters	Concentration, μg/L					
	RAL	Control plot	Fertilizer plot	Compost plot		Groundwater background[3]
				Median	Range	
Cadmium	4	<0.2	<0.2	0.2	<0.2-4	<1
Chromium	100	1.6	1.8	3.3	2.9-4.2	5
Lead	50	<2	<2	<2	<2-2	<10
Silver	20	<1	<1	5	4-16	NA
Arsenic	0.2	<4	<4	<4	<4	5
Barium	2000	<40	<40	<40	<40	60
Mercury	2	<0.2	<0.2	<0.2	<0.2	0.3
Selenium	20	<5	<5	<5	<5	<1
Copper	1000	<1	<1	10	8-18	<10
Nickel	100	<6	<6	15	13-27	3
Zinc	1000	<10	<10	20	13-30	<3

RAL indicates recommended allowable limits for drinking water contaminants (MN Dept. of Health 1991).
[1]Water analyses conducted on filtered samples.
[2]Samples represent composites of the three lysimeter samples. In the compost plot, each lysimeter was analyzed separately.
[3]Reported in Myette (1991) for tailing groundwater.

research showed, however, that this lower rate resulted in only 10% less vegetative cover than their recommended rate. By using the lower rate, the costs to transport and apply the compost are reduced by about 50%. Applying compost (once the material is on site) increases the cost by about 10% to 20% or $50 to $100 per acre. A major cost could be the shipment of compost to the site. If the compost is within 25 miles of the site, the hauling cost would be about $2.50/t. However, if the distance increased to 50 miles, the cost would double. Since the material contains about 50% moisture, the cost to apply 20 dry t/acre would be about $100 to $200 per acre, depending on the haul distance. Since mining companies have not had success in reclaiming the coarse tailing areas, they have had to revegetate these areas several times at an additional cost of up to $500 per acre each time. Despite these additional treatments, they have been unable to consistently meet reclamation standards for coarse tailing. The additional cost of a compost application may actually be the most cost-effective approach.

Conclusions

An application of 44.8 Mg/ha of MSW compost along with 224 kg/ha of diammonium phosphate fertilizer: (1) improved vegetative success as compared to the standard reclamation plot, (2) reduced erosion and runoff in the compost plot as compared to the standard reclamation plot, (3) resulted in acceptable trace metal concentrations in the vegetation, (4) resulted in water quality that was generally acceptable and improved with time, (5) is not expected to produce significant or lasting impacts on ground water quality because the compost is applied only once, and (6) may be the most cost-effective application rate for vegetating coarse taconite tailing.

Literature Cited

Dewar and Norland. (1994 in press). Growth and trace metal content of poplars planted on tailing treated with municipal solid waste compost. In Proceedings 1994 National Meeting of the American Society for Surface Mining and Reclamation. (Pittsburgh, PA, April 24-29, 1994).
http://dx.doi.org/10.21000/JASMR94030203

He, X. T., S. J. Traina, and T. J. Logan. 1992. Chemical properties of municipal solid waste composts. J. Environ. Qual. 21:318-329.
http://dx.doi.org/10.2134/jeq1992.00472425002100030003x

Heil, D. M. and K. A. Barbarick. 1989. Water treatment sludge influence on the growth of Sorghum-Sudangrass. J. Environ. Qual. 18:292-298.
http://dx.doi.org/10.2134/jeq1989.00472425001800030008x

Jones, Jr., J. B., B. Wolf, and H. A. Mills. 1991. Plant analysis handbook. A practical sampling preparation, analysis, and interpretation guide. Micro-Macro Publishing, Inc. p. 152-156.

Minnesota Department of Health. 1991. Recommended allowable limits for drinking water contaminants. Section of Health Risk Assessment. 20 p.

Minnesota Department of Natural Resources. 1980. Mineland reclamation rules, ch. 6130. p. 5694-5717.

Myette, C. F. 1991. Hydrology, water quality, and simulation of ground-water flow at a taconite-tailings basin near Keewatin, Minnesota. U. S. Geol. Surv. WRI 88-4230. 61 p.

Norland, M. R. and S. W. Dewar. (1994 in press). Revegetation of coarse tailings. In Proceedings 67th Annual Meeting Minnesota Section AIME and 55th Annual Mining Symposium. (Duluth, MN, January 19-20, 1991).

Norland, M. R., D. L. Veith, and S. W. Dewar. 1991. Initial vegetative cover on coarse taconite tailing using organic amendments on Minnesota's Mesabi Iron Range. p. 263-277. In Proceedings National Meeting of the American Society for Surface Mining and Reclamation. (Durango, CO, May 14-17, 1991).
http://dx.doi.org/10.21000/JASMR91010263

Norland, M. R., D. L. Veith, and S. W. Dewar. 1992. Vegetation response to organic soil amendments on coarse taconite tailing. p. 341-360. In Proceedings 1992 National meeting of the American Society for Surface Mining and Reclamation. (Duluth, MN, June 14-18, 1992).
http://dx.doi.org/10.21000/JASMR92010341

Noyd, R. K., F. L. Pfleger, and E. L. Stewart. 1992. Native plants and vesicular-arbuscular mycorrhizal fungi. p. 361-369. In Proceedings 1992 National Meeting of the American Society for Surface Mining and Reclamation. (Duluth, MN, June 14-18, 1992).
http://dx.doi.org/10.21000/JASMR92010361

Raelson, J. V. and G. W. McKee. 1982. Measurement of plant cover to evaluate revegetation success. Agronomy Series 67, Department of Agronomy, PA State Univ. 45 p.

Stark S. A. 1987. Agricultural use of solid waste compost products in Minnesota. A survey of potential consumers. Prepared for Solid Waste Compost Project, Soil Science Dept., Univ. MN. p. 1-8.

Veith, D. L. and M. R. Norland. 1992. Bureau of Mines reclamation activities of the Mesabi Iron Range, Minnesota. p. 331-340. In Proceedings 1992 National Meeting of the American Society for Surface Mining and Reclamation. (Duluth, MN, June 14-18, 1992).
http://dx.doi.org/10.21000/JASMR92010331

Walker J. M. and M. J. O'Donnell. 1991. Comparative assessment of MSW compost characteristics. Biocycle 32(8):65-69.

Wirth, R. 1991. Introduction to composting. Minnesota Pollution Control Agency, Ground Water and Solid Waste Division. St. Paul, MN. 38 p.