Physical and Chemical Properties of Stockpiled Materials at a Mine Site in North Dakota

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Stripmining of coal in North Dakota currently involves removal and stockpiling of surface or "topsoil" material before the remaining overburden is removed and the coal is mined. The stockpiled material is subsequently spread on the surface of the shaped mine spoil and is the medium in which seeds are placed to establish a vegetative cover.

Some have suggested, notably Curry (1975), that biogeologic changes may occur in stockpiled materials that will have a deleterious effect on its suitability as a plant growth medium. Since physical stability, salt status and mineral nutrition are important aspects of productive agricultural soils, several stockpiles were sampled and evaluated for selected chemical and physical properties which could be used as indicators of potential plant productivity.

PROCEDURE

Six stockpiles, located at the North American Coal Corporation's Indian Head mine near Zap, North Dakota, were sampled on December 5, 1975, April 2, 1976 and May 17, 1976. Approximately 20 pounds of material were taken from the crown of each stockpile to a depth of about six inches in the December and April samplings. The May samples were taken with a Giddings hydraulic probe in foot increments to 10 feet, except in stockpiles designated as SP1 and SP4, where the sampling depth was 8 feet and 6 feet, respectively. The probe samples were 1.4 inches in diameter. Samples in May were taken from three points, labeled A, B, C, from each stockpile, except only one point was sampled on stockpile SP1. The approximate distance between sampling points was 50 feet. Information on the time of stockpiling, and the approximate thickness of each stockpile is provided in Table 1.

Samples taken in December and April were evaluated for physical properties, including particle size analysis by the hydrometer method (Day, 1965), non-erodible fraction and wind erodibility index by procedures described by the Soil Conservation Service (1975), per cent dispersion by the double hydrometer method (Sherard, et al., 1976), and saturated conductivity and crust strength (modulus of rupture) by methods of Richards (1954).

The samples collected on May 17 were placed in plastic bags to prevent water loss while in transit to the laboratory. Analysis on these samples included the following:

a) Per cent water by weight at time of sampling.
b) Per cent water by weight at equilibrium with 0.33 atmospheres pressure.
c) Per cent water by weight at equilibrium with 15 atmospheres pressure.
d) Bulk density.
e) Electrical conductivity (EC) of a 1:1 soil water suspension.
f) Hydrogen ion activity, pH, of a 1:1 soil water suspension.
g) Nitrogen (N), as nitrate (NO_3), soluble in water.

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Table 1. Location, age and approximate thickness of stockpiles.

Stockpile	Location	Soils stripped in vicinity of stockpile	Stockpiling date (Earliest to most recent)	Thickness (feet)
SP1	SE1/4 Sec30 T144-R88	Flaxton	Fall, 1972 - Spring, 1973	8
SP2	NE1/4 Sec36 T144-R89	Rhoades, Daglum, Cabba, Belfield	Fall, 1975 -[1] Spring, 1976[2]	20-35
SP3	NE1/4 Sec36 T144-R89	Rhoades, Daglum, Cabba, Belfield	Fall, 1974 - Spring, 1976[3]	15-25
SP4	NE1/4 Sec36 T144-R89	Rhoades, Daglum, Cabba, Belfield	Summer, 1975 - Spring, 1976[4]	15-20
SP5	NE1/4 Sec36 T144-R89	Rhoades, Belfield Cabba, Belfield	Summer, 1975 - Spring, 1976	15
SP6	NE1/4 Sec36 T144-R89	Belfield, Flaxton, Williams	Summer, 1975 - Spring, 1976	30-35

[1]*Physical data on material stockpiled this period.*
[2]*Thickness of material added was 15-20 feet.*
[3]*Thickness of material added was 8 to 10 feet.*
[4]*Thickness of material added was 3 to 4 feet.*

Table 2. Selected physical properties of surface materials at or near North American Indian Head Mine, Zap, North Dakota.

Sample	Particle Size Sand	Silt	Clay	Texture[3]	Saturated Conductivity	Nonerodible[4] Fraction	Wind[5] Erosion Index	Dispersion	Crust Strength
	(% by weight)				(inches/day)	(% by weight)	I	%	(bar)
Belfield[1]	38.9	40.6	20.5	l	—	51.4	36	4.9	—
Rhoades[1]	29.5	49.5	22.0	l	—	81.8	0	10.0	—
Flaxton[1]	68.8	15.0	16.2	sl	43.3	18.4	106	5.2	0.04
Flaxton(R)[2]	59.6	23.8	16.6	sl	17.7	48.8	41	5.0	0.31
SP1	64.5	19.6	15.9	sl	82.7	33.4	69	16.2	0.17
SP2	14.0	43.0	43.0	sic	0.22	54.4	29	5.8	4.5
SP3	8.6	46.4	45.0	sic	5.1	30.0	74	10.8	3.5
SP4	33.4	48.6	18.0	l	18.5	49.4	41	13.7	1.8
SP5	17.4	45.8	36.7	sicl	1.1	40.5	56	8.5	0.45
SP6	21.8	48.4	29.8	cl	8.7	49.0	41	5.6	3.4
Spoil 1	63.0	15.2	21.7	scl	0.01	98.0	0	81.2	4.2
Spoil 2	14.3	43.4	42.3	sic	0.01	96.8	0	65.3	9.7
Spoil 3	18.8	42.8	38.3	sicl	0.01	98.5	0	83.8	9.6

[1]*Nonmined surface soils in close proximity to mine. Flaxton soil surface exhibited evidence of wind erosion.*
[2]*Flaxton soil material taken from stockpile SP1 and respread as topsoil material.*
[3]*l - loam, sl - sandy loam, sic - silty clay, sicl - silty clay loam, cl - clay loam, scl - sandy clay loam.*
[4]*Aggregrates larger than 0.84 millimeters equivalent diameter.*
[5]*Refers to relative erodibility.*

h) Phosphorus (P) soluble in sodium bicarbonate solution.

i) Potassium (K) soluble and exchangeable in ammonium acetate solution.

Water content was determined gravimetrically. Pressure plate and membrane apparatus (Richards, 1954) were used to obtain 1/3 and 15 atmosphere water contents. Bulk density was determined on one-foot increments of samples. Analyses (e) through (i) were conducted in the NDSU Soil Testing Laboratory by the standard procedures employed to evaluate plant nutrient status (NCR-13, 1975).

RESULTS AND DISCUSSION

Physical Properties

Texture

The texture of the surface of stockpiled topsoils, sampled December 5, ranged from sandy loam (sl) to silty clay (sic), illustrating the variable nature of the materials (Table 2). The A horizon textures of sampled soils in proximity to the mine were sandy loam and loam. Data presented in Table 2 show that the spoil textures were moderately fine and varied from sandy clay loam to silty clay.

Saturated Conductivity

Water flow through these stockpiled materials is correspondingly as variable as the texture. Saturated conductivity (Table 2) of these materials varied from less than 1 to over 80 inches per day. Generally the lower conductivity resulted from the finer (more clayey) texture.

Wind Erodibility

Wind erodibility of stockpiled material indexed by the value I, (Table 2) was intermediate or moderate, lying within the range of values of adjacent nonmined fallowed soils. Nonmined Flaxton soil had the highest wind erodibility index, indicating high wind erosion susceptibility. Evidence of erosion susceptibility was confirmed by field observation of summer fallowed Flaxton soil adjacent to the mine. Stockpiled Flaxton (SP1) and respread Flaxton (R) had lower wind erosion index values than the nonmined site. The lower I values of the stockpiled Flaxton could be a result of greater silt plus clay fractions found in the disturbed materials (Table 2), thereby suggesting the stockpiling and spreading operation can reduce the wind erodibility.

Dispersion

Dispersion tests reflect soil aggregate stability by indicating the degree of physical breakdown to smaller particles (Table 2). All dispersion percentages were less than 20, which compared favorably with those of nonmined surface samples. These results indicate that stockpiled materials were not as structurally unstable as the mine spoil samples, which all had dispersion percentages over 65.

Crust Strengths

Crust strengths were moderate to high on the sampled stockpiles (Table 2). Nonmined soil surfaces usually have crust strengths below 0.5 bar. Samples from SP2 had 4.5 bar crust strengths and 4 of the 6 stockpiles had crust strengths over 1. These data indicate that crusting will take place if this type material is left on the surface. The

Table 3. Bulk density of stockpiled "topsoil" at several depths and several stockpiles — May 17, 1976.

Stockpile	Depth (feet) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
	grams per cubic centimeter									
SP 1	1.67	1.68	1.76	1.81	1.59	1:76	1.60	1.56		
SP 2—A	1.38	1.48	1.13	1.33	1.11	1.34	1.42	1.41	1.66	1.53
B	.92	1.20	1.41	1.62	1.45	1.52	1.30	1.71	1.39	1.31
C	1.26	1.48	1.58	1.49	1.58	1.66	1.57	1.55	1.51	
Mean	1.19	1.39	1.37	1.48	1.38	1.51	1.43	1.56	1.52	1.42
SP 3—A	1.07	1.42	1.48	1.48	1.24	1.45	1.71	1.64	1.10	1.49
B	1.50	1.35	1.52	1.42	1.30	1.27	1.32	1.62	1.44	1.31
C	1.28	1.43	1.33	1.70	1.43	1.56	1.36			
Mean	1.28	1.40	1.44	1.53	1.32	1.43	1.46	1.63	1.27	1.40
SP 4—A	1.16	1.13	1.52	1.48	1.63	1.91				
B	.84	.99	1.32	1.23	1.51	1.99				
C	.96	1.02	1.32	1.71	1.39					
Mean	.99	1.05	1.39	1.47	1.51	1.95				
SP 5—A	1.32	1.35	1.39	1.37	1.42	1.64	1.35	1.73	1.66	1.30
B	1.28	1.41	1.30	1.32	1.38	1.48	1.29	1.12	1.28	1.40
C	1.29	1.20	1.63	1.36	1.37	1.19	1.45	1.41	1.42	1.34
Mean	1.30	1.32	1.44	1.35	1.39	1.44	1.36	1.42	1.45	1.35
SP 6—A	1.55	1.49	1.15	1.94	1.43	1.43	1.39	1.45	1.35	1.16
B	1.42	1.52	1.52	1.65	1.47	1.64	1.40	1.22	1.52	1.30
C	1:41	1.70	1.47	1.46	1.70	1.30	1.42	1.43	1.47	1.43
Mean	1.46	1.57	1.38	1.68	1.53	1.46	1.40	1.37	1.45	1.30

magnitude of crust strengths was related to sodium adsorption ratio (SAR) of the stockpiled material; for example the SAR was 10, 8 and 7 for SP2, SP3 and SP4 respectively. High crust strengths in spoil samples 1, 2 and 3 (Table 2) were attributed to their high SAR levels (over 30).

SAR levels less than 4 usually are found in surfaces of undisturbed (nonmined) soils. Of more than 20 undisturbed surface soils tested, in the general area of the mine, all had SAR values of 2 or less with crust strengths of 0.5 bar or less. The higher SAR and crust strengths of these stockpiles reflect some mixing of A, B, and perhaps C horizon materials.

Bulk Density

Data of bulk density are presented in Table 3. The densities are in the range normally found in soils of similar texture (Cassel and Bauer, 1975). The average bulk density of these stockpiled materials is higher than that of adjacent spoil materials, which tend to be finer textured. The soil material was removed and stockpiled with scrapers. Hence, the bulk density values reflect the compacting effects of heavy equipment.

Extent of compaction of soil with a given texture is dependent upon water content at the time of compaction (Felt, 1965) and upon organic matter

Table 4. Per cent water by weight of several stockpiles at several depths at time of sampling — May 17, 1976.

Stockpile	Depth (feet) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
	per cent water by weight									
SP 1	12.57	15.81	12.22	12.41	11.78	13.67	20.41	17.56		
SP 2—A	20.25	16.96	13.68	11.59	13.20	22.27	22.07	13.98	12.85	9.75
B	18.43	20.92	19.58	19.02	19.11	12.75	11.51	10.53	11.35	11.72
C	21.40	19.51	16.92	25.53	12.51	13.48	19.01	14.51	12.61	
Mean	20.22	19.13	16.73	18.71	14.94	16.17	17.53	13.01	12.27	10.74
SP 3—A	19.69	12.60	11.13	11.86	10.61	12.33	12.77	17.47	14.38	10.80
B	14.60	11.70	19.10	19.73	14.88	10.96	10.66	9.72	13.63	10.95
C	19.34	11.38	11.66	10.90	11.51	12.52	11.94			
Mean	17.88	11.89	13.96	14.16	12.33	11.94	11.79	13.60	14.01	10.88
SP 4—A	13.60	21.09	20.32	16.46	21.37	21.61				
B	14.14	22.29	10.54	20.95	12.05	17.47				
C	17.20	13.31	20.41	20.38	17.73					
Mean	14.98	18.90	17.09	19.26	17.05	19.54				
SP 5—A	17.86	20.76	19.52	13.35	17.64	15.58	14.53	14.65	18.11	11.62
B	16.08	19.14	17.04	23.66	19.97	17.16	14.00	13.68	13.79	20.21
C	18.81	19.60	14.56	12.61	16.76	13.95	15.51	12.66	12.77	15.45
Mean	17.58	19.83	17.04	16.54	18.12	15.56	14.68	13.66	14.89	15.76
SP 6—A	16.50	10.89	9.20	10.77	11.10	15.67	12.91	12.37	18.14	20.49
B	17.86	11.15	10.00	9.74	15.66	13.08	16.75	15.51	16.25	19.47
C	15.94	14.18	9.57	10.09	13.02	18.25	13.56	12.62	16.18	14.60
Mean	16.77	12.07	9.59	10.20	13.26	15.67	14.41	13.50	16.86	18.19

Table 5. Per cent by weight at 0.33 atmospheres pressure of stockpiled samples at several depths. Sampled May 17, 1976.

Stockpile	Depth (feet) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
	per cent water by weight									
SP 1	20.58	21.03	19.63	17.80	18.27	20.14	23.05	22.14		
SP 2—A	30.21	31.10	25.03	24.17	26.35			34.07		28.36
B	27.42	31.07	33.27	26.80	33.40	36.08	36.32	33.89	31.96	34.65
C	31.32	30.01	29.00	36.04	31.46	33.66	31.57	32.08	31.48	
Mean	29.65	30.73	29.10	29.00	30.40	34.87	33.95	33.35	31.72	31.51
SP 3—A	34.73			35.09	32.99		34.06	31.55		32.66
B	32.60	32.67	31.24	34.60	32.07	33.07	31.41	32.52	33.79	32.21
C	33.92	32.92	34.25	33.92	33.13	32.83	31.43			
Mean	33.75	32.80	32.75	34.54	32.73	33.27	32.30	32.04	33.79	32.44
SP 4—A	35.15	34.46	33.21	38.16	34.31	34.53				
B	36.73	37.96	33.09	37.08	34.02	33.25				
C	35.08	34.57	35.59	32.85	29.17					
Mean	35.65	35.66	33.96	36.03	32.50	33.89				
SP 5—A	26.19	26.88	28.43	26.89	28.11	29.62	30.87	30.03	34.24	29.40
B	29.14	30.62	29.03	33.42	31.29	29.37	29.31	26.44	29.27	30.44
C	26.70	28.40	28.19	28.58	31.19		31.23			31.47
Mean	27.34	28.63	28.55	29.63	30.20	29.50	30.47	28.24	31.76	30.44
SP 6—A	23.48	22.59	22.42	25.74	23.82	26.51	24.53	23.42	29.25	31.10
B	23.21	18.27	22.87	23.41	24.23	24.88	27.03	29.10	25.63	25.74
C	24.24	24.48	20.98	25.16	24.41	26.24	23.84	29.38	21.48	32.52
Mean	23.64	21.78	22.09	24.77	24.15	25.88	25.13	27.30	28.79	29.79

content (Davidson et al., 1967). At a given organic matter content, the maximum bulk density (compaction) tends to decrease and to occur at increasingly higher water contents as texture becomes finer (more clayey). At a given soil texture, the maximum bulk density values that can be obtained decrease as organic matter content increases, and the maximum bulk density occurs at increasingly higher water contents.

Water Relations

Data of the per cent water by weight at time of sampling, and at equilibrium with 0.33 atmospheres and with 15 atmospheres pressure are presented in Tables 4, 5, and 6, respectively. (Water held in soil at equilibrium with 0.33 atmospheres and with 15 atmospheres pressure were taken as a measure of "field capacity" and "permanent wilting point," respectively). Water content at sampling (Table 4), within a given stockpile, varied by less than five percentage units in the upper foot. However, at certain depths of some stockpiles, the variation between the lowest and highest water content exceeded 10 percentage units.

Generally, variability is expected because topsoil stripping depth varies, because placement of soil material on a given stockpile occurs over an extended time period thus allowing differential

Table 6. Per cent water by weight at 15 atmosphere pressure of stockpiled samples at several depths. Sampled May 17, 1976.

Stockpile	Depth (feet) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
	per cent water by weight									
SP 1	7.73	8.39	8.26	6.67	7.48	7.83	10.33	9.36		
SP 2—A	12.49	14.29	11.00	10.69	10.38	14.17	19.26	15.96	14.76	13.95
B	11.87	14.41	9.67	11.76	15.24	18.33	18.10	16.22	16.58	18.14
C	12.28	12.06	12.87	15.91	14.94	16.09	14.22	14.44	14.90	
Mean	12.21	11.09	11.09	12.77	13.51	16.18	17.18	15.52	15.40	16.05
SP 3—A	16.38	14.90	15.15	15.45	14.80	13.82	14.57	13.03	12.11	13.34
B	15.04	14.75	12.83	13.17	12.85	14.85	13.75	13.50	14.85	15.36
C	16.49	14.81	15.81	12.98	12.81	13.93	13.65			
Mean	15.95	14.81	14.58	13.85	13.47	14.19	13.98	13.24	13.48	14.35
SP 4—A	14.73	13.49	11.42	14.33	13.76	13.06				
B	13.88	12.44	12.05	13.66	13.09	12.52				
C	12.28	12.98	13.88	13.15	11.57					
Mean	13.62	12.96	12.44	13.70	12.79	12.79				
SP 5—A	10.78	11.34	12.08	11.47	15.18	12.89	13.11	13.26	15.78	13.68
B	12.40	13.00	12.52	13.92	13.66	12.54	14.02	12.99	14.30	14.55
C	11.40	12.25	12.02	12.04	15.91	14.14	14.45	16.79	14.04	15.03
Mean	11.52	12.18	12.20	12.46	14.90	13.18	13.85	14.33	14.69	14.41
SP 6—A	10.23	9.85	9.06	10.68	10.06	13.65	11.27	10.11	12.61	13.68
B	9.66	8.16	9.65	11.20	10.58	13.58	12.34	12.59	13.42	12.47
C	10.61	9.92	8.39	11.63	10.77	12.26	10.61	13.83	13.04	13.79
Mean	10.16	9.31	9.03	11.16	10.46	13.16	11.40	12.16	13.02	13.31

Table 7. Available water capacity and per cent available water present in stockpiled "topsoil" sampled May 17, 1976.

Stockpile	Available water capacity[1]	Available water present[2]	Per cent of available capacity
	inches per foot		
SP1	2.43	1.26	52
SP2	2.95	0.32	11
SP3	3.21	—0.12	0
SP4	3.60	0.79	22
SP5	2.67	0.50	19
SP6	2.45	0.47	19

[1]*Mean of three samples per depth increment for all depths sampled, except for SP1 (sampling not replicated). The available water capacity is the difference in water retention at 0.33 and 15 atmospheres.*

[2]*Available water present is the difference in water actually present and 15 atmospheres.*

drying before and after stockpiling, and because soil material in a given stockpile is not of uniform texture. In no case at any depth of any stockpile did the water content at sampling exceed the water content at "field capacity" (Table 5), but it was less, in some cases, than the water content at "permanent wilting point" (Table 6).

The available water capacity and amount of available water present, averaged over the sampled depths, are shown by data in Table 7. In all cases except stockpile SP1, the available water present was less than 25 per cent of the available water capacity. These data reflect the relatively dry condition of the stockpiled materials. "Topsoil" material stripped and stockpiled in late summer or fall, when it is usually dry and conditions are favorable to the stripping operation, could be expected to remain dry over the winter irrespective of depth of placement in the stockpile. Also, wetting of dry stockpiled materials to depths beyond 2 to 3 feet during the spring and summer is unlikely because of relatively low rainfall amounts and because of water removal by vegetation growing in them.

If stockpile water storage conditions similar to those observed on May 17 prevail, it would appear likely that plant cover establishment using these dry materials would prove less than satisfactory, particularly if the plants were seeded in mid to late summer. Water recharge of the relatively dry stockpiled soil material after spreading would be necessary in order to effect seed germination and seedling survival so as to achieve uniform plant stands.

Chemical Characteristics

Soluble Salts

Data of electrical conductivity which reflect the soluble salt concentration are presented in Table 8. These indicate that soluble salts were low, and would not effect availability of water or interfere with plant growth. It should be noted that the conductivity tests were made on 1:1 soil-water suspensions; hence, these data cannot be directly related to tests run on saturated extracts.

pH

Data of hydrogen ion activity, pH, are presented in Table 9. The pH range was from 7.6 to 8.6, slightly alkaline to moderately alkaline in reaction. The reaction is typical of the nondisturbed soils of the area.

Table 8. Electrical conductivity (EC) of stockpile samples from several stockpiles and several depths at sampling on May 17, 1976.

Stockpile		Depth (feet)									
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
		EC mmhos/cm									
SP 1		.5	.3	.3	.2	.3	.2	.4	.5		
SP 2—A		.6	1.1	.6	.7	.6	1.6	1.7	1.0	1.2	1.0
B		.5	1.4	1.0	.5	.5	1.0	.2	.2	1.0	1.1
C		.6	.7	.8	.9	1.1	1.1	1.2	1.4	1.5	
	Mean	.6	1.1	.8	.7	.7	1.2	1.0	.8	1.2	1.1
SP 3—A		1.2	1.3	1.3	1.0	1.0	1.2	1.2	1.3	1.2	1.1
B		1.1	1.1	1.0	1.1	1.2	1.3	.7	.9	.8	1.0
C		1.1	1.2	1.3	1.3	1.2	1.3	1.2			
	Mean	1.1	1.2	1.2	1.1	1.1	1.3	1.0	1.1	1.0	1.1
SP 4—A		.9	.6	.7	.6	.7	.7				
B		.7	.8	.4	.6	1.0	.9				
C		1.0	1.0	1.1	1.2						
	Mean	0.9	.8	.7	.8	.8	.8				
SP 5—A		1.2	1.3	.5	.5	.6	1.0	.8	1.1	.7	1.2
B		.7	.8	.8	.4	.5	1.0	1.0	.7	.8	.5
C		.6	1.3	.9	.6	.8	1.0	1.3	1.4	1.4	.7
	Mean	.8	1.1	.7	.5	.6	1.0	1.0	1.1	1.0	.8
SP 6—A		.4	.5	.4	.9	.6	.5	.6	.9	1.0	.9
B		1.0	.6	1.0	.5	.6	.6	.6	1.1	.9	.4
C		.5	1.0	.9	.9	1.0	1.0	1.0	1.1	1.0	1.1
	Mean	.6	.7	.8	.8	.7	.7	.7	1.0	1.0	.8

[1]*Measured on 1:1 soil : water suspension.*

Table 9. Hydrogen ion activity (pH) of stockpile samples from several stockpiles and several depths at sampling on May 17, 1976.

Stockpile		Depth (feet)									
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
		pH[1]									
SP 1		7.6	7.9	7.9	8.0	8.2	8.0	8.2	8.4		
SP 2—A		7.8	8.0	8.1	8.3	8.3	8.2	8.4	8.4	8.5	8.5
B		7.8	7.9	8.2	8.2	8.1	8.3	8.2	8.4	8.5	8.5
C		7.8	8.0	8.0	8.0	8.2	8.3	8.3	8.5	8.5	
	Mean	7.8	8.0	8.1	8.2	8.2	8.3	8.3	8.4	8.5	8.5
SP 3—A		8.0	8.2	8.4	8.4	8.5	8.5	8.5	8.5	8.6	8.6
B		8.0	8.0	8.0	8.1	8.2	8.4	8.5	8.5	8.6	8.6
C		8.1	8.2	8.2	8.4	8.3	8.3	8.4			
	Mean	8.0	8.1	8.2	8.3	8.3	8.4	8.5	8.5	8.6	8.6
SP 4—A		7.9	8.1	8.2	8.4	8.4	8.4				
B		8.1	8.2	8.3	8.3	8.4	8.4				
C		8.2	8.2	8.3	8.4	8.4					
	Mean	8.1	8.2	8.3	8.4	8.4	8.4				
SP 5—A		8.0	8.2	7.9	8.0	8.0	8.1	8.2	8.3	8.4	8.4
B		8.1	8.1	8.0	7.8	8.0	8.2	8.2	8.3	8.3	8.4
C		8.1	8.1	8.1	8.2	8.3	8.2	8.4	8.4	8.5	8.5
	Mean	8.1	8.1	8.0	8.0	8.1	8.2	8.3	8.3	8.4	8.4
SP 6—A		7.6	7.9	8.0	8.0	8.1	8.2	8.4	8.3	8.4	8.5
B		8.1	8.1	8.2	8.3	8.3	8.4	8.4	8.4	8.5	8.5
C		8.0	8.1	8.1	8.2	8.3	8.3	8.3	8.4	8.5	8.5
	Mean	7.8	8.0	8.1	8.2	8.2	8.3	8.4	8.4	8.5	8.5

[1]*Measured on 1:1 soil : water suspension.*

A pH of 8.5 or greater is considered to be an indication that sodium is present in large enough concentrations to cause dispersion (a physical breakdown of soil aggregates). Dispersion usually occurs when the sodium adsorption ratio (SAR) is 12 or greater. Ten samples from these stockpiles, ranging in pH from 8.2 to 8.6, were evaluated for SAR. In no case did the SAR exceed 10. Three samples of pH 8.2 ranged in SAR from 3 to 6; three samples of pH 8.4 ranged from 5 to 10; three samples of pH 8.5 ranged from 5 to 9; and at pH of 8.6 the SAR was 10. These data indicate that pH may not be a suitable indicator of a potential sodium problem. However, the high pH values (greater than 8.4) may indicate SAR levels above those normally found in nonmined soil surfaces.

Nitrate Nitrogen

The nitrate nitrogen (NO_3-N) concentration in soil is a basis for judging the nitrogen fertility status for plants (Plant Science Section, 1976). Data of NO_3-N are presented in Table 10.

The NO_3-N content varied within stockpiles as well as between stockpiles. The data likely

Table 10. Pounds nitrogen (N), as nitrate (NO_3) in several stockpiles at several depths at sampling on May 17, 1976.

Stockpile		Depth (feet)									
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
		pounds N, as NO_3^-, per 6 inches[1]									
SP 1		36	4	4	4	6	4	4	9		
SP 2—A		8	24	40	10	8	6	8	14	6	11
B		8	13	10	14	12	9	6	9	85	38
C		39	24	8	19	23	12	20	15	12	
	Mean	17	20	19	14	14	9	11	13	34	25
SP 3—A		25	14	17	12	24	26	27	15	6	7
B		33	24	30	110	40	20	8	8	12	7
C		29	26	25	20	11	14	9			
	Mean	29	21	24	47	25	20	15	12	9	7
SP 4—A		7	11	7	12	18	8				
B		8	15	6	8	4	4				
C		6	6	11	4	4					
	Mean	7	11	8	8	9	6				
SP 5—A		10	21	52	27	38	9	4	7	8	4
B		8	80	60	68	5	4	4	11	5	6
C		11	12	20	36	45	22	6	4	7	15
	Mean	10	37	44	43	29	12	5	7	7	12
SP 6—A		18	4	10	12	18	12	4	4	4	4
B		6	9	11	13	40	19	14	9	6	10
C		10	7	27	12	53	10	5	4	4	4
	Mean	11	7	16	12	37	14	8	6	5	6

[1]*Water extraction*

reflect the amounts present in the soil at the time of stockpiling, although at some depths the available soil water content was sufficient for microbial activity (Tables 4, 5, 6). The amounts of NO_3-N present (Table 10) are in the range found in soils, either fallowed or in continuous cropping. That there was a wide variation in NO_3-N content of the stockpiles need not be considered unusual even though the material came from the same soil in a given field. The reasons are that the NO_3-N is not uniform with depth for a given soil, soils vary in short distances, and the stockpiling occurs over a period of time. Time, too, can effect changes in content through such processes as mineralization of organic matter and uptake of the NO_3^- by the vegetation growing on the soil.

The variation of NO_3^- in the stockpile suggests that sampling of the material after spreading, to obtain a representative sample to determine the NO_3-N status, will pose a problem that is at least as great as in undisturbed soils.

Phosphorus

The amount of sodium bicarbonate soluble phosphorus (P) extracted from the stockpiled material is shown in Table 11.

Variation in extractable phosphorus was much less than the variation in NO_3-N. In only a few cases were the levels high enough to rate the soil material other than "very low" or "low" in phosphorus by NDSU soil test standards (Wagner et al., 1974). The uniformly low content of phosphorus suggests the number of samples necessary to obtain a representative estimate of the P status of the soil material is less than for representative estimates of NO_3-N.

The rather consistently "very low" to "low" phosphorus status of the stockpile soil is not unusual. A large acreage of soils in western North Dakota is deficient in phosphorus. In addition, the amount of extractable phosphorus in most soils decreases sharply below the A horizon (Zubriski, 1971), the zone of maximum organic matter accumulation. The stockpiled soil material is a mixture of A and B horizons. Addition of the B horizons increases its chances of being P-deficient.

Potassium

Data of ammonium acetate extractable potassium (K) are presented in Table 12. These reflect the sum of the soluble and exchangeable potassium. The amount of potassium extracted ranged from 110 to 630 pounds K per acre, but relatively few samples had less than 220 pounds. Based on standards of the NDSU Soil Testing Laboratory, samples with 220 or more pounds extractable potassium are rated "high" to "very high." (Wagner et al., 1974). These levels are common in soils in North Dakota.

SUMMARY

Stockpiled surface soil materials were tested for selected physical and chemical properties reflecting their suitability for topsoiling in the reclamation process. All stockpiled materials tested were from the North American Indian Head mine near Zap, North Dakota. Comparisons were made between physical properties of adjacent non-

Table 11. Pounds sodium bicarbonate soluble phosphorus (P) in several stockpiles at several depths at sampling on May 17, 1976.

Stockpile		Depth (feet) 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
						pounds P per 6 inches					
SP 1		14	11	10	10	14	12	14	13		
SP 2—A		8	22	8	6	6	5	8	10	6	5
B		8	9	7	7	13	12	8	6	4	6
C		13	8	4	7	8	7	7	5	6	
	Mean	10	13	6	7	9	8	8	7	5	6
SP 3—A		7	8	6	11	12	10	10	8	7	10
B		12	11	11	26	12	14	6	7	12	10
C		11	9	10	11	9	13	11			
	Mean	10	10	9	16	11	12	9	8	10	10
SP 4—A		8	10	8	12	13	20				
B		8	10	8	16	12	11				
C		13	7	13	24	7					
	Mean	10	9	10	17	11	16				
SP 5—A		5	4	7	5	13	13	5	7	10	9
B		4	13	16	40	28	19	11	7	9	8
C		3	4	3	6	10	6	7	8	4	17
	Mean	4	7	9	17	17	13	8	7	8	11
SP 6—A		5	5	4	5	5	5	16	9	2	5
B		5	8	4	8	10	3	7	4	2	17
C		9	8	32	13	21	16	10	9	5	3
	Mean	6	7	13	9	12	8	11	6	3	8

Table 12. Pounds soluble and exchangeable potassium (K) in several stockpiles at several depths at sampling on May 17, 1976.

Stockpile		Depth (feet)									
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
		pounds K per 6 inches[1]									
SP 1		440	350	260	220	365	455	280			
SP 2—A		275	280	335	330	240	295	350	345	290	285
B		225	390	290	245	430	350	335	305	330	325
C		455	355	290	435	380	355	305	365	345	
	Mean	315	338	302	333	347	330	330	335	318	305
SP 3—A		350	345	330	340	320	325	320	260	260	310
B		305	310	290	420	370	390	245	290	315	295
C		325	305	335	315	305	300	275			
	Mean	323	317	315	355	331	335	280	275	290	305
SP 4—A		355	355	245	380	290	390				
B		285	240	310	320	285	285				
C		260	270	315	485	285					
	Mean	300	285	290	395	285	340				
SP 5—A		200	175	440	285	385	330	315	285	370	175
B		255	480	530	655	630	470	340	410	600	290
C		295	285	375	340	365	370	260	285	285	330
	Mean	250	315	445	425	455	390	305	325	420	265
SP 6—A		310	220	200	260	255	245	310	335	160	175
B		180	270	160	225	230	150	185	140	110	195
C		220	245	380	240	340	285	155	140	105	110
	Mean	235	245	250	245	275	225	215	205	125	160

[1]*Extracted with 1N* $NH_4C_2H_3O_2$

mined soils and those measured on the stockpiled materials. Two of 6 tested stockpiles had samples with high clay contents (over 40 per cent). Permeability to water varied from a low of less than 1 to over 80 inches per day. Wind erosion index indicated that stockpiled materials generally had lower wind erosion susceptibility than adjacent nonmined surface soils. Moderate to high crust strengths were observed on stockpiled materials. Stockpiled materials were relatively dry even as late as May 17. All but one stockpile had less water than 25 per cent of the "available water capacity."

Chemically the material sampled did not contain excess soluble salts. The pH was slightly to moderately alkaline in reaction. Although some of the moderately alkaline samples were as high as 8.6, the sodium adsorption ratio (SAR) was 10 or less. Nitrate nitrogen content was variable, both within and between stockpiles; the levels ranged from "very low" to "high" by NDSU soil test standards. The sodium bicarbonate soluble phosphorus was relatively uniform within and between stockpiles; soil test levels were almost exclusively "low." Ammonium acetate extractable potassium on the other hand, was almost exclusively "high" or "very high."

The chemical and physical properties tested indicated that stockpiled materials reflect the mixing of surface and subsurface (A, B and perhaps C horizon) materials. Better control of the stripping operation will be required in order to provide for soil horizon segregation if the goal is to have materials for spreading that are most similar in physical and chemical properties to the surface of undisturbed soils.

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