SPENT OIL-SAND FERTILITY STUDY

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ABSTRACT

Physical and chemical analyses of spent sand indicate that this material is very infertile. The spent sand samples analysed had an average pH of 7.2 and low Na content indicating that there was no residual problem resulting from the NaOH used in the oil production process. Freshly processed sand however does have a high pH and higher Na contents.

Overburden samples from several dump-sites varied considerably in soluble salt content (salinity), were of sandy loam textural class and had low organic N, NO_3-N and extractable P contents. The variation in salinity found in these overburden samples suggests a need for extensive sampling and analysis of these materials prior to their inclusion in a full-scale reclamation program. These materials, if non-saline, would aid in seedbed construction, and retention of moisture and nutrients.

Analyses of the organic materials (decomposed peat, raw sphagnum and sedge peats) indicate that they may supply plant nutrients (N and P) in addition to aiding in seedbed construction and moisture retention.

Barley growth on spent sands, supplied with adequate NPK and S, in greenhouse experiments was adversely affected by additions of boron at 2 mg/Kg and beneficially affected by additions of Ca at 30 mg/Kg. Singular additions of other essential plant nutrients (Cu, Zn, Fe, Mn, Mo, Mg) had no significant effect on barley yield. In a similar experiment the yield of alfalfa was significantly decreased by addition of Cu at 5 mg/Kg.

In a greenhouse experiment involving growth of barley on media comprised of spent sands, overburden and peat, barley yield was primarily governed by NPK addition but peat and overburden addition to spent sand did result in growth increase.

In a greenhouse experiment involving the additions of sewage sludge, decomposed peat, sedge and sphagnum peats to spent sands, barley yields were significantly increased by the sludge, sedge and decomposed peat additions and decreased by the sphagnum peat additions. The deleterious effect of the sphagnum may be due to its low pH (4.1) and a competition for N between the plants and bacteria in the decomposition of sphagnum.

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INTRODUCTION

One of the major environmental concerns regarding the oil sands development by open-pit mining is the effective and lasting revegetation of the disturbed areas. In broad terms there are three major types of disturbed materials which result from the present activities; the spent sand (also referred to as Tailing Sand) from which most of the hydrocarbons have been removed, the "lean oil sands" which are uneconomical to process and the overlying materials which contain essentially no hydrocarbons. The latter material is heterogeneous in composition and includes various types of peat deposits, aeolian sands, glacial till and other glaciofluvial and glaciolacustrine deposits.

Massey (1972) reported that spent sands were very infertile in respect to N, P and K but that the peat and overburden materials were higher in available nutrients. He also reported that the spent sand was very alkaline in reaction and contained a substantial amount of sodium. He concluded that the use of overburden and peat would help to form a suitable seedbed for plant growth, reduce the alkalinity and increase the nutrient-supplying power and water-holding capacity of the medium. The inclusion of a commercial mixture of trace elements (unspecified composition) resulted in no difference in growth in a growth room experiment using various "soil" materials from the area (Massey 1969).

Subsequently Lesko (1974) concluded that grasses can be established on pure tailing sand provided that the surface is contour trenched before hydroseeding. However, direct seeding of trees, shrubs and herbs in tailings without peat or clay was not effective. He also found that although the sands are alkaline when fresh, one or two years of natural exposure results in neutralization.

This report covers two areas.

(a) Physical and chemical analysis of spent sands and some other materials (overburden, peat and soil from the disturbed areas) which are available for reclamation purposes.

(b) Greenhouse experiments using spent sands, and some of these other materials and including additions of macro and micro essential nutrients.

METHODS AND MATERIALS

Spent sand samples and some other materials, (soils, peat "overburden" and "lean tar sands") were obtained from the Fort McMurray district. These samples were subjected to physical and chemical analysis. Texture, density and hydraulic conductivity were determined by methods described in Black (1965). Field capacity moisture content was determined as described by Miller and McMurdie (1953).

Saturated soil extracts and 1N NH_4OAC extracts were prepared as described, respectively, by Bower and Wilcox (1965) and Chapman (1965); DTPA extracts as described by Lindsay and Norvell (1969). Spent sand samples were digested by boiling 1g portions in 12 mls of a $HNO_3/HClO_4$ (2/1, v/v) mixture for 30 minutes.

SO_4 in saturated soil extracts was determined by $BaCl_2$ titration (Rasnick and Nakayama 1973), Cl by $AgNO_3$ titration and HCO_3 by H_2SO_4 titration (Bower and Wilcox 1965). Electrical Conductivity (EC) of the saturated extracts and pH of the saturated soil were determined as described by Bower and Wilcox (1965).

Ca, Mg, Fe, Mn, Cu and Zn, from various extracts, were determined by AAS and Na and K in these extracts were determined by AES. Phosphorus was determined colourimetrically (John 1970) and NO_3-N was determined colourimetrically by a phenoldisulfonic acid method (Bremner 1965).

Available phosphorus was extracted by the Miller and Axley (1965) procedure and NO_3-N was extracted by the ASFTL procedure. (Cameron and Toogood 1970).

Hot-water-soluble Boron was extracted and determined as described by Wear (1965). Total Kjeldahl Nitrogen was determined as described by Bremner (1965).

Five greenhouse experiments were conducted; details of materials used, treatments and crops grown are described in the section titled "Procedure" in each experiment.

Table 1 Chemical and Physical Analysis of some of the materials available for Reclamation

Material	pH	(mmhos/cm) E.C.	SAR	Ca	Mg	Na	SO_4	Cl	HCO_3	Total N	NO_3-N	P	K
				p.p.m. Saturation Extract							available		extractable
Soil Ae	6.0	0.17	0.2	10	4	3.0	7	3.5	30	400	1.5	16	31
Bf	6.4	0.10	0.4	4	2	3.9	15	0.7	30	200	1.5	7.5	16
C	6.6	0.10	0.5	4	1	4.6	3	trace	30	100	1.5	3.5	-
Peat GCOS	6.3	0.48	0.6	59	7	18	57	trace	189	9600	3.0	0.6	55
Syncrude	6.3	0.25	0.2	38	6	5.3	57	trace	85	11400	3.5	0.6	-
Raw Sedge	6.0	0.56	0.2	71	16	8.5	67	7.1	219	19700	13	36	-
Raw Sphagnum	4.1	0.40	0.9	5	25	9.2	20	12	0	7900	13	41	1800
Overburden GCOS Waste Dump # 5	6.3	5.06	7.0	266	164	591		3.5	-	600	4.8	4.8	-
Overburden GCOS Waste Dump # 7	6.3	3.14	1.3	273	145	103		-	-	500	1.3	1.4	-
Overburden Syncrude Till # 1	6.4	0.17	0.6	8	4	7.8	15	5.3	39	300	1.8	2.3	47
Overburden Syncrude Till # 2	6.2	0.30	0.5	18	8	9.2	13	1.8	122	300	1.5	13	-
Spent sand GCOS	6.6	0.70	0.9	47	27	32	177	trace	134	100	1.0	0.8	4.0
Lean Oil Sand	6.4	1.01	2.2	52	28	80	331	21	54	600	1.8	11	7.8

Note: Lack of numerical value refers to insufficient sample

Table 1 (cont'd)

Material	Texture (hydrometer) % Sand	% Clay	% Silt		Density (Disturbed sample)	Hydraulic conductivity (cm/hr.)	Field Capacity(%)*
Soil Ae	98	trace	2	S	1.5	80	12
Bf	98	1	1	S		250	10
C	99	0	1	S		280	8
Peat GCOS					0.25		130
Syncrude							250
Raw Sedge					0.1		310
Raw Sphagnum					0.05		570
Overburden GCOS Waste Dump #5	70	14	16	SL	1.3	30	30
GCOS Waste Dump #7	59	16	25	SL	1.4	13	25
Syncrude Till #1	62	16	22	SL		8	16
Syncrude Till #2	62	16	22	SL	1.5	6	19
Spent Sand GCOS	99	0	1	S	1.4	100	25
Pilot	97	1	2	S		150	
Lean oil sand						250	1.0

* Gravimetric method

Table 2 — Chemical Analysis of Spent Sand used in Greenhouse Experiments #1, #2 & #3

	Mean*	SD	
pH	7.2	-	(saturated soil)
EC mmhos/cm	0.25	0.06	saturated soil extract (30 mls per 100 g soil)
Na mg/l	30	17	saturated soil extract (30 mls per 100 g soil)
K mg/l	5.5	0.7	saturated soil extract (30 mls per 100 g soil)
Ca mg/l	4.3	1.1	saturated soil extract (30 mls per 100 g soil)
Mg mg/l	3.3	0.6	saturated soil extract (30 mls per 100 g soil)
Na me/100g	0.24	0.10	1N NH_4OAC Extractable
K me/100g	0.04	0.01	1N NH_4OAC Extractable
Ca me/100g	0.38	0.15	1N NH_4OAC Extractable
Mg me/100g	0.07	0.02	1N NH_4OAC Extractable
NO_3-N/mg/Kg	2.4	0.5	(0.02N $CuSO_4$, 0.007 N Ag_2SO_4 Extractable)
P mg/Kg	1.9	0.2	(0.03N H_2SO_4, 0.03 N NH_4F Extractable)
Fe mg/Kg	6.5	1.3	"DTPA" Extractable
Cu mg/Kg	0.2	0.0	"DTPA" Extractable
Zn mg/Kg	0.3	0.2	"DTPA" Extractable
Mn mg/Kg	0.6	0.2	"DTPA" Extractable
B mg/Kg	0.9	-	Hot Water Soluble

* All parameters, except B, based on determination of 5 subsamples.

Table 2 continued

	Mean*	SD	
Na mg/Kg	76	5.0	$HClO_4/HNO_3$ Digestible
K mg/Kg	49	1.9	$HClO_4/HNO_3$ Digestible
Ca mg/Kg	110	15	$HClO_4/HNO_3$ Digestible
Mg mg/Kg	53	1.1	$HClO_4/HNO_3$ Digestible
Fe mg/Kg	420	44	$HClO_4/HNO_3$ Digestible
Cu mg/Kg	5.0	0.0	$HClO_4/HNO_3$ Digestible
Zn mg/Kg	3.2	0.3	$HClO_4/HNO_3$ Digestible
Mn mg/Kg	11	1.6	$HClO_4/HNO_3$ Digestible
P mg/Kg	7.7	0.9	$HClO_4/HNO_3$ Digestible
CEC me/100 gms	.73		(NaOAC, pH 8.2)

* All parameters, except B, based on determination of 5 subsamples.

RESULTS AND DISCUSSION - Material Analyses

Physical analyses of the spent sand (Table 1) indicate that this material contains negligible amounts of clay and silt, being predominately comprised of fine sands of a uniform grain size.

Chemical analyses of several spent sands samples (Tables 1 and 2) indicate that they are inherently infertile. Of the macronutrients (as defined by Buckman and Brady 1969) only sulfur may be present in sufficient quantities to enhance plant growth. Nitrogen (total N and available NO_3) phosphorus ($HClO_4/HNO_3$ digestible and H_2SO_4/NH_4F extractable) potassium, calcium and magnesium (saturated extract, NH_4OAC extractable and $HClO_4/HNO_3$ digested) contents are very low. DTPA extractable Mn and Zn concentrations in the spent sand are in a range considered "deficient", DTPA extractable Cu concentration is "marginal" and DTPA Fe is "adequate" for plant growth (Table 2) according to the criteria described by Viets and Lindsay (1973).

The spent sand samples analysed were non-saline and had pH values ranging from 6.6 - 7.2 (Tables 1 and 2). Analyses of soil (Ae, Bf and C horizons) taken from an aeolian sand ridge in the area indicate that these materials have similar textural class and chemical properties to the spent sand.

Analyses of overburden samples from four dump-sites (two from G.C.O.S. and two from Syncrude) indicate that these materials are in the sandy loam textural class, have a low total N content and low contents of both NO_3-N and extractable phosphorus. The pH range of these materials was 6.2 - 6.4. The two overburden samples from the G.C.O.S. site were more saline (EC 5.06, 3.14) than those from the Syncrude site (EC 0.17, 0.30). This distinction in salinity suggests that the overburden in the mined areas is probably quite variable in salinity but should not be interpreted as implying that all overburden material from the Syncrude site is less saline than that from the G.C.O.S. site. Analyses of decomposed peat, raw sphagnum and raw sedge samples indicate that these materials have a high total N and low NO_3 content. Decomposed peat has a low extractable phosphorus content but both the raw sedge and sphagnum have relatively large extractable phosphorus contents. The raw sphagnum samples had a pH of 4.1: This material could result in soil acidity problems if it were used disproportionately in a reclamation program.

These data suggest that both the overburden materials and the organic materials (decomposed peat, raw sphagnum and raw sedge) may be of considerable use in aiding revegetation of the spent sands. Their incorporation should aid in moisture and applied nutrient retention. Furthermore, if mineralization occurs, the organic materials should provide a supply of available nitrogen. The variability in salinity of the four overburden samples analysed suggests a need for extensive sampling and analyses of these materials prior to their inclusion in a reclamation program.

Experiment 1

Objective

To determine the effects of additions of some essential nutrients to spent sands on plant yield.

Experimental Design

Randomized block, three replicates, eleven treatments.

Procedure

1600 g of air-dry spent sand were transfered to sealed pots and saturated using distilled water. These were dried at room temperature to reduce the moisture content to less than "Field Capacity". This presaturation and drying technique was employed to attempt to ensure an even distribution of moisture throughout the pots. (It had been observed that air-dry spent sand is hydrophobic and does not wet evenly.) Treatments were applied to the spent sands at the following rates and, with the exception of P and K which were "banded" 2 cm below the seed, were mixed throughout the pot.

N	100 mg/Kg	as NH_4NO_3
P	60 mg/Kg	as KH_2PO_4
K	76 mg/Kg	as KH_2PO_4
S	5 mg/Kg	as $Na_2SO_4 \cdot 10H_2O$
Cu	10 mg/Kg	as $CuSO_4 \cdot 5H_2O$
Zn	10 mg/Kg	as $ZnCl_2$
Fe	10 mg/Kg	as Fe EDTA
Mn	5 mg/Kg	as $MnCl_2 \cdot 4H_2O$
Mo	5 mg/Kg	as $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$
B	2 mg/Kg	as H_3BO_3
Ca	30 mg/Kg	as $CaCl_2 \cdot 2H_2O$
Mg	20 mg/Kg	as $MgSO_4 \cdot 7H_2O$

Table 3 Mean Barley Yields g (dry matter content) from Spent Sands Greenhouse Experiment # 1

	Treatment	Mean Yield g
1	NPK + S	1.8 a[3]
2	NPK	1.6 a
3	NPK + Tr[1]	0.7 d
4	NPK + (Tr - B)[2]	1.6 a
5	NPK + (Tr - Zn)	1.2 bc
6	NPK + (Tr - Cu)	1.2 bc
7	NPK + (Tr - Mg)	1.1 c
8	NPK + (Tr - Mn)	1.1 c
9	NPK + (Tr - Mo)	1.1 c
10	NPK + (Tr - Ca)	1.0 c
11	NPK + (Tr - Fe)	1.0 c

1 Tr = B + Zn + Cu + Mg + Mn + Mo + Ca + Fe

2 Tr - B = Zn + Cu + Mg + Mn + Mo + Ca + Fe

3 Means followed by the same letter do not differ significantly from one another (P = 0.05). Duncan's New Multiple Range Test.

Six barley seeds (Galt) were planted in each pot but following germination each pot was "thinned" to four seedlings. The pots were weighed frequently and watered with distilled water to maintain a moisture content of approximately 1/3 bar. The plants were harvested in the boot stage, dried at 40°C and weighed.

Results (Table 3)

Those treatments which did not include an addition of boron (treatment 1, 2 and 4) had a significantly higher yield than those which did. (Table 3) The "hot-water-soluble boron content" (Wear 1965) of the spent sand (Table 2) used in the experiment was 0.9 mg/Kg which is regarded as low (Reisenauer et al 1973). However applied boron is more readily available to plants in coarse textured soils (Rogers 1947, Wear and Patterson 1962). Treatments which did not contain boron (treatments 1, 2 and 4) did not differ significantly in yield.

On treatments containing boron (treatments 3, 5, 6, 7, 8, 9, 10 and 11) the treatment which contained all other micronutrients (treatment 3) was significantly lower than the others. (Table 3)

Experiments #2 & #3

Objective

To determine plant response to the addition of some essential nutrients to spent sands.

Experimental Design

Randomized block, three replicates, twenty treatments.

Procedure

Greenhouse pots containing 1600 g of spent sand were prepared as described in Experiment 1. Treatments were applied at rates described below and, with the exception of P and K, which were "banded" 2 cm below the seed, were mixed throughout the pot. Chemical compounds used to prepare the treatments were identical to those used in Experiment 1. Boron was excluded from the composite treatment (Tr) but was included in combination with NPKS at concentrations of 0.5, 1.0 and 2.0 mg/Kg B and in combination with NPKS + Tr at a concentration of 2.0 mg/Kg (Tables 4 and 5). Concentrations of Cu and Zn were reduced to 5 mg/Kg of soil.

	N	100	mg/Kg	(Experiment 2) · 30 mg/Kg (Experiment 3)
	P	60	mg/Kg	Experiment 2 & 3
	K	76	mg/Kg	Experiment 2 & 3
	S	5	mg/Kg	Experiment 2 & 3
Tr	Cu	5	mg/Kg	Experiment 2 & 3
Tr	Zn	5	mg/Kg	Experiment 2 & 3
Tr	Fe	10	mg/Kg	Experiment 2 & 3
Tr	Mn	5	mg/Kg	Experiment 2 & 3
Tr	Mo	5	mg/Kg	Experiment 2 & 3
Tr	Ca	30	mg/Kg	Experiment 2 & 3
Tr	Mg	20	mg/Kg	Experiment 2 & 3
	B_3	2	mg/Kg	Experiment 2 & 3
	B_2	1	mg/Kg	Experiment 2 & 3
	B_1	0.5	mg/Kg	Experiment 2 & 3

Experiment 2 employed barley plants as an indicator crop and planting, watering and harvesting were conducted as described in Experiment 1. In Experiment 3, alfalfa (vernal) seedlings were allowed to germinate on moistened filter paper in the presence of alfalfa innoculant (Rhizobia Meliloti). Four of these seedlings were planted in each pot and watered with distilled water to maintain a moisture content of approximately 1/3 bar. The plants were harvested four weeks after planting, dried at 40°C and weighed.

Table 4 Mean Barley Yields g (dry matter content) from Spent Sands Greenhouse Experiment # 2

	Treatment	Yield (g)	
1	NPKS	3.1	bcd[2]
2	NPKS + Ca	3.8	a
3	NPKS + Fe	3.5	ab
4	NPKS + Mg	3.4	ab
5	NPKS + Zn	3.4	ab
6	NPKS + B_1	3.3	abc
7	NPKS + Cu	3.3	abc
8	NPKS + Mn	3.2	bcd
9	NPKS + B_2	2.8	cde
10	NPKS + Mo	2.7	de
11	NPKS + B_3	2.5	e
12	NPKS + Tr[1]	3.2	bcd
13	NPKS + (Tr - Mg)	3.7	a
14	NPKS + (Tr - Cu)	3.7	a
15	NPKS + (Tr - Mn)	3.7	a
16	NPKS + (Tr - Zn)	3.7	a
17	NPKS + (Tr - Mo)	3.6	ab
18	NPKS + (Tr - Fe)	3.2	bcd
19	NPKS + (Tr - Ca)	3.1	bcd
20	NPKS + Tr + B_3	2.0	f

1. Tr = Zn + Cu + Mg + Mn + Mo + Ca + Fe
2. Means followed by the same letter do not differ significantly (P=0.05). Duncan's New Multiple Range Test.

Results (Table 4)

(a) Additions of some essential nutrients (singularily)- Treatments 1 - 11 inclusive. Table 4.

The addition of calcium (Treatment 2, Ca+NPKS) resulted in a significantly higher yield than was obtained by the addition of NPKS alone (Treatment 1). Conversely the addition of Boron at 2 mg/Kg (Treatment 11, NPKS+B_3) resulted in a significantly lower yield than Treatment 1. The singular addition of all other nutrients including the two lower boron concentrations resulted in yields which did not differ significantly from Treatment 1 (NPKS).

(b) Additions of some essential nutrients in combination - Treatments 12 - 20 inclusive. Table 4.

The exclusion of either Mg, Cu, Mn or Zn from the composite treatment resulted in a significantly higher yield than was obtained in Treatment 12 (NPKS+Tr) or Treatment 1 (NPKS) and the exclusion of either Mo, Fe or Ca (Treatments 17, 18 and 19) resulted in yields which did not differ significantly with Treatments 12 or 1. The addition of Boron (Treatment 20, NPKS+Tr+B_3) at 2 mg/Kg to the composite treatment did result in a significant yield decrease.

(c) Summary of Results of Greenhouse Experiment # 2

Most of the essential plant nutrients tested had no significant effects on the yield of barley. Ca however did significantly increase plant yield and Boron at 2 mg/Kg significantly decreased it.

Table 5 Mean Alfalfa Yield g (dry matter content) from Spent Sands Greenhouse Experiment # 3

	Treatment	Yield (g)	
1	NPKS	0.94	ab[2]
2	NPKS + Ca	0.88	ab
3	NPKS + Fe	0.99	ab
4	NPKS + Mg	1.06	a
5	NPKS + Zn	0.89	ab
6	NPKS + B_1	0.91	ab
7	NPKS + Cu	0.51	c
8	NPKS + Mn	0.92	ab
9	NPKS + B_2	0.99	ab
10	NPKS + Mo	0.78	b
11	NPKS + B_3	0.83	b
12	NPKS + Tr	0.43	c
13	NPKS + (Tr-Mg)	0.36	c
14	NPKS + (Tr-Cu)	0.85	b
15	NPKS + (Tr-Mn)	0.41	c
16	NPKS + (Tr-Zn)	0.43	c
17	NPKS + (Tr-Mo)	0.43	c
18	NPKS + (Tr-Fe)	0.08	d
19	NPKS + (Tr-Ca)	0.43	c
20	NPKS + Tr + B_3	0.46	c

1. Tr = Zn + Cu + Mg + Mn + Mo + Ca + Fe

2. Means followed by the same letter do not differ significantly (P = 0.05). Duncan's New Multiple Range Test.

Results (Table 5)

(a) Additions of some essential nutrients (singularily) - Treatments 1 - 11 inclusive. Table 5.

The addition of Cu (treatment 7, NPKS + Cu) resulted in a significantly lower yield of alfalfa than was obtained by the NPKS treatment. All other singular nutrient additions resulted in a yield which did not differ significantly from the NPKS treatment.

(b) Additions of some essential nutrients in combination - Treatments 12 - 20 inclusive. Table 5.

Treatments 12 - 19 inclusive resulted in alfalfa yields which were signigicantly lower than the NPKS treatment. The exclusion of Cu from the composite treatment (treatment 14, NPKS + (Tr - Cu)) resulted in a significantly higher yield than occurred when it was included (treatment 12, 13 and 15 - 20 inclusive). Conversely the exclusion of Fe (treatment 18) from the composite treatment resulted in significantly lower yield than occurred when it was included (treatment 12 - 17 and 18 - 20 inclusive).

(c) Summary of Results of Greenhouse Experiment # 3

None of the treatments resulted in yields of alfalfa significantly higher than the NPKS treatment and in many instances the yields obtained were significantly lower than the NPKS treatment.

Experiment 4

Objective

To determine the effect of additions of overburden and peat to spent sand on plant yield.

Experimental Design

Randomized block, three replicates, twenty-three treatments.

Procedure

Two mixtures of spent sand and overburden were prepared; one containing 20% spent sand and 80% overburden and the other 80% spent sand and 20% overburden (weight/weight basis). 1400 g portions of these two mixtures and 1400 g portions of either spent sand or overburden were transferred to sealed greenhouse pots. Decomposed peat was added to some of these pots at a rate sufficient to increase the volume by either 20% or 40%. The materials in each pot were mixed thoroughly, and wetted to approximately field capacity moisture content. The treatments employed are shown in Table 3. Chemical compounds used to prepare fertilizer treatments and method of application were identical to those described in Experiment 1. Barley seeds were planted, thinned, watered and harvested as described in Experiment 1.

Results (Table 6)

Nitrogen, phosphorus and potassium addition resulted in substantial increase in plant yield. The highest yields obtained on the four media (spent sands, overburden and two mixtures of these) occurred on the highest fertilizer application (F_2). Addition of peat alone to the four media resulted in yields similar to those obtained on the untreated media. Peat addition, in combination with NPK, resulted in higher yields than NPK addition alone. This may be due to nutrient release, from the peat, during the

Table 6 Mean Barley Yields g (dry matter content) from Greenhouse Experiment # 4

Spent Sand

	0	P_1	P_2
0	0.2	0.7	0.8
F_1		4.3	6.5
F_2		7.3	10.4

Overburden (Waste dump)

	0	P_1
0	0.5	0.5
F_1		4.7
F_2		8.5

80% Spent Sand and 20% Overburden

	0	P_1
0	0.6	0.6
F_1	4.8	5.3
F_2	6.1	7.9

20% Spent Sand and 80% Overburden

	0	P_1
0	0.5	0.5
F_1	4.5	5.5
F_2	7.8	9.0

P_1 Decomposed Peat 20% by volume

P_2 Decomposed Peat 40% by volume

F_1* 50 mg/Kg N, 30 mg/Kg P, 38 mg/Kg K

F_2 100 mg/Kg N, 60 mg/Kg P, 76 mg/Kg K

* Fertilizer application rates based on mineral portion (1400 g)

growth period and/or the increase in volume of rooting space due to peat addition. Peat addition has been recommended by Massey (1972) to aid in "reducing the alkalinity of the sand and increasing the nutrient-supplying power and water-holding capacity of the sand", however the pH of materials used in this experiment was less than 7 and moisture conditions were kept close to optimum in sealed pots. Under field conditions, however, peat addition to spent sand would undoubtedly improve moisture retention and aid in lowering pH if the spend sand were alkaline. (Lesko (1974) reported that spent sand is alkaline immediately following the production process but that the pH falls to neutral or slightly acidic within a few years.)

The order of productivity of the four media used in this experiment with equal additions of peat (P_1) and two fertilizer rates were as follows.

		Yield (g)	
		F_1	F_2
(a)	Spent Sand	4.3	7.3
(b)	80% Spent Sand 20% Overburden	5.3	7.9
(c)	Overburden	4.7	8.5
(d)	20% Spent Sand 80% Overburden	5.5	9.0

In view of the relative abundance of the materials only (a) or (b) would be practical on a large-scale reclamation project.

Experiment # 5

Objective

To determine plant response to the addition of peat materials (decomposed, undecomposed sphagnum and sedge) and digested sewage sludge to spent sand.

Experiment Design

Randomized block, three replicates, nine treatments.

Procedure

Mixtures of spent sand and either sewage sludge, sedge, peat or sphagnum were prepared and transferred to sealed greenhouse pots. The volume of material used in each pot was identical (Table 7) and an identical amount of fertilzer (NPK) was applied to treatments (a) to (h) inclusive (Table 7). The amount of nitrogen applied on treatment (c) was double that applied on other treatments. Compounds used to prepare fertilizer treatments were the same as those described in Experiment 1 and planting, watering and harvesting were conducted as described in Experiment 1. The materials were removed from the pots after the first harvest (crop $_1$) mixed and reseeded.

Results (Table 7)

(a) Crop $_1$

Mixtures of spent sand and either sewage sludge or sedge (treatments a and b) resulted in crop yields which were significantly higher than those from other treatments. The spent sand-peat mixture (treatment c) had a yield significantly greater than those obtained using spent sand alone (treatments h and c). Conversely the spent sand-sphagnum treatment (d) and sphagnum

Table 7 Mean Barley Yield g (dry matter content) from Spent Sands Greenhouse Experiment # 5

	Treatment	Mean Yield Crop 1	Mean Yield Crop 2
(a)	Spent Sand (1210g) + Sludge[4](130g) + NPK[2]	5.0 a *1	3.3 a
(b)	Spent Sand (1210g) + Sedge (50g) + NPK	4.8 a	1.1 c
(c)	Spent Sand (1210g) + Peat (160g) + NPK	3.3 c	1.5 c
(d)	Spent Sand (1210g) + Sphagnum (30g) + NPK	1.1 e	1.3 c
(e)	Sedge (255g) + NPK	2.2 d	0.9 c
(f)	Peat (450g) + NPK	3.9 b	2.4 b
(g)	Sphagnum (105g) + NPK	0.5 f	1.2 c
(h)	Spent Sand (2100g) + NPK	2.4 d	1.3 c
(i)	Spent Sand (2100g) + N_2PK[3]	2.6 d	2.2 b

* 1 Means, in each column, followed by the same letter do not differ significantly (P = 0.05). Duncan's New Multiple Range Test.

2 NPK rates (Kg/ha) 150 N, 100 P, 126 K

3 N_2PK rates (Kg/ha) 300 N, 100 P, 126 K

4 The sewage sludge used had a nitrogen content of 2.44% (approximately 30% of which was in a readily available NH_4-N form), a phosphorus content of 0.21% (approximately 70% of which was in an orthophosphate form) and a potassium content of 0.23%

treatment (g) had yields significantly lower than treatments h and i.

(b) Crop $_2$

Yields produced in the second crop were, on average, significantly lower than those produced in crop $_1$ (paired t test p = 0.05). The sludge treatment (a), the treatment with the higher N application (i) and the peat treatment (f) resulted in yields significantly greater than all other treatments. The higher yield in these three treatments (a, f and i) was probably due to a greater nitrogen supply than was available in other treatments.

CONCLUSIONS

1. Material Analyses

Analyses of spent sand indicate that this material is very infertile. Mineral overburden-material varied considerably in soluble salt content and should be sampled and analysed before inclusion in a reclamation program. These materials, if not highly saline, should aid in seedbed preparation. Their inclusion should aid moisture and nutrient retention.

Organic overburden-materials (decomposed peat, undecomposed sedge and sphagnum) should also aid in moisture and nutrient retention. Some nutrient supply may result from their inclusion. Undecomposed sphagnum had a low pH (4.1) and may cause acidity if used disproportionately in seedbed preparation.

2. Greenhouse Experiments

In greenhouse experiments, involving singular additions of Cu, Zn, Fe, Mn, Mo, Ca, Mg and B to spent sand (adequately supplied with NPKS) there were few significant effects on the yield of barley or alfalfa.

Exceptions were:

(a) Boron addition (2mg/Kg) adversely affected barley yield.
(b) Calcium addition (30 mg/Kg) beneficially affected barley yield.
(c) Copper addition (5 mg/Kg) adversely affected alfalfa yield.

In a greenhouse experiment involving growth of barley on media comprised of spent sand, overburden and peat, barley yield was primarily governed by NPK addition but peat and overburden addition did result in growth increase.

Barley yield was significantly increased by addition of sewage sludge, decomposed peat and undecomposed sedge to spent sand. Addition of undecomposed sphagnum significantly decreased barley yield.

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