

**LANDSPREADING ASH AND SLUDGE
AT THE OPERATIONS OF
SLAVE LAKE PULP CORPORATION**

1995

D. Thacker and T. Macyk
Environmental Research and Engineering Department
Alberta Research Council
250 Karl Clark Road
Edmonton, Alberta
T6H 5X2

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5320 - 122nd Street
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Land and Forest Services
Alberta Environmental Protection
10th Floor, Bramalea Building
9920 - 108th Street
Edmonton, Alberta
T5K 2M4
Telephone: (403) 427 - 3551

ABSTRACT

In 1992, the Alberta Research Council established field plots to evaluate the impact of land application of sludge and ash materials from the operations of Slave Lake Pulp Corporation (SLPC) on soils and vegetation. Six treatments include control (0 cm sludge), 1 cm sludge (about 16 dry t/ha), 3 cm sludge, 5 cm sludge, 5 cm sludge annually and a combination of 5 cm sludge and 0.5 cm wood ash (about 50 t/ha). The sludge was incorporated by rototilling and the plots seeded to brome grass. After two growing seasons yields for the 3 cm sludge and 5 cm sludge treatments were three and five times greater than the control treatments respectively. Soil sampling and analysis to determine pH, carbon, nitrogen, CaCO_3 equivalent, saturated paste extract properties (EC, SAR, soluble ions), DTPA extractable elements, and total elements indicate that the soil-sludge mixtures rate fair to good relative to soil quality criteria guidelines for Alberta. The sludge generally had no measurable impact on the tissue concentration of some elements, however for others the impact was favourable in raising below normal to normal levels. Results to date indicate that the sludge landspreading results in increased plant (crop) yields and does not have a negative impact on soil quality.

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EXECUTIVE SUMMARY

This research project was designed to determine the impact of landspreading pulp sludge and a sludge-ash mixture on soils and plants in research plots located at the Slave Lake Pulp Corporation millsite. Sludge was spread on selected plots on June 10, 1992, and again on selected plots on June 1, 1993. This report describes the results to the end of the 1993 growing season.

Six treatments were replicated three times using individual plots 6 m x 12 m in size. The treatments included control, 1 cm sludge layer (approx. 16 dry tonnes/ha), 3 cm sludge layer (48 t/ha), 5 cm sludge layer (80 t/ha), 5 cm sludge layer each year (80 t/ha), and a combination of 5 cm sludge (80 t/ha) and 0.5 cm wood ash (approx. 50 t/ha). The sludge was incorporated by rototilling to 15 cm depth and the plots were seeded to brome grass except for the 5 cm/yr treatment which was not seeded and is rototilled each spring. In 1993 grass yields were determined in June and August, and grass tissue samples for elemental analysis were collected with the June harvest. Soil samples were collected at the time of the August harvest.

After two growing seasons the sludge still had a strong fertilizing effect on the brome grass at the 3 cm and 5 cm sludge application rates. June yields were about double those of the controls with these two treatments, and August yields were three times those of the controls with 3 cm sludge, and five times with 5 cm sludge. Yields with 1 cm sludge have never shown a significant difference from those of the control plots.

Soil pH values in the amended plots have declined from those measured immediately following sludge application. The sludge plus ash treatment is the only one that has a pH more than one half unit higher than the control plots (7.0 vs. 7.8). According to the Alberta Soils Advisory Committee guidelines (ASAC 1987), the incorporation zone of all treatments receive a good rating for pH (measured in a calcium chloride solution), organic carbon content, and calcium carbonate equivalent, except for the ash treatment which is rated fair with respect to pH.

Both SAR and EC values have improved from those measured shortly after sludge incorporation. The SAR was identified previously as the main potential chemical limitation to the land application of these sludges. SAR values in 1992 were considered poor for all treatments using 5 cm of sludge, fair for treatments using 1 cm or 3 cm of sludge, and good only in the control plots, according to the ASAC guidelines. At the end of the 1993 growing season the control and 1 cm treatments are rated as good and all other treatments are rated as fair except for the treatment using annual additions of sludge which continues to be rated as poor.

Soils in the plots receiving 5 cm sludge in 1992 now have EC values in the incorporation zone of about 1.1 dS/m, compared to 2.0 dS/m shortly after incorporation. In the plots receiving annual additions of sludge the EC is about 1.6 dS/m. The 1993 values would all meet the ASAC requirement for a good rating (EC less than 2.0 dS/m).

Soluble ions and plant available element levels in saturation extracts and in DTPA extracts increase as the rate of sludge increases. Nitrate may be of some concern because of the potential

for it to leach to groundwater, but the data indicate that elevated nitrate and nitrite levels in saturation extracts are restricted to the upper 45 cm of the soil profile. In the incorporation layer there are less than 0.1 mg/L of nitrate and nitrite with the control and 1 cm sludge treatments, and about 50 mg/L with the 5 cm sludge treatments.

DTPA extractable trace elements are mostly unaffected by sludge or ash treatment, with the exception of increased boron with the ash treatment and increased sodium with all sludge and ash treatments. Sodium is four to five times higher in the plots receiving annual sludge additions than in the control plots, and two to three times higher in the treatments given 3 cm or 5 cm of sludge in 1992.

Compared to average values for soils the total elemental concentrations in the soils from all treatments are within the normal range and are generally very close to the average values for soils. There was approximately a fifty percent increase in phosphorus with the 5 cm sludge treatment and a similar increase in calcium with the ash treatment, but these increases are insignificant when compared to the normal range of these elements in soils.

The plant tissue from the various treatments was found to generally have normal or below normal elemental concentrations when compared to published values for brome grass, grass, or plants in general. The sludge had no impact on the tissue concentration of most elements, but when it does have an impact it is usually favourable in raising below normal values to those considered more normal.

One aspect of the sludge incorporation that appears very positive is that the measurable impact of the sludge is almost entirely restricted to the incorporation zone. Nitrate and nitrite are exceptions, but even at the highest rates of sludge application these have fallen to levels indistinguishable from those in the control plots below 45 cm depth.

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INTRODUCTION

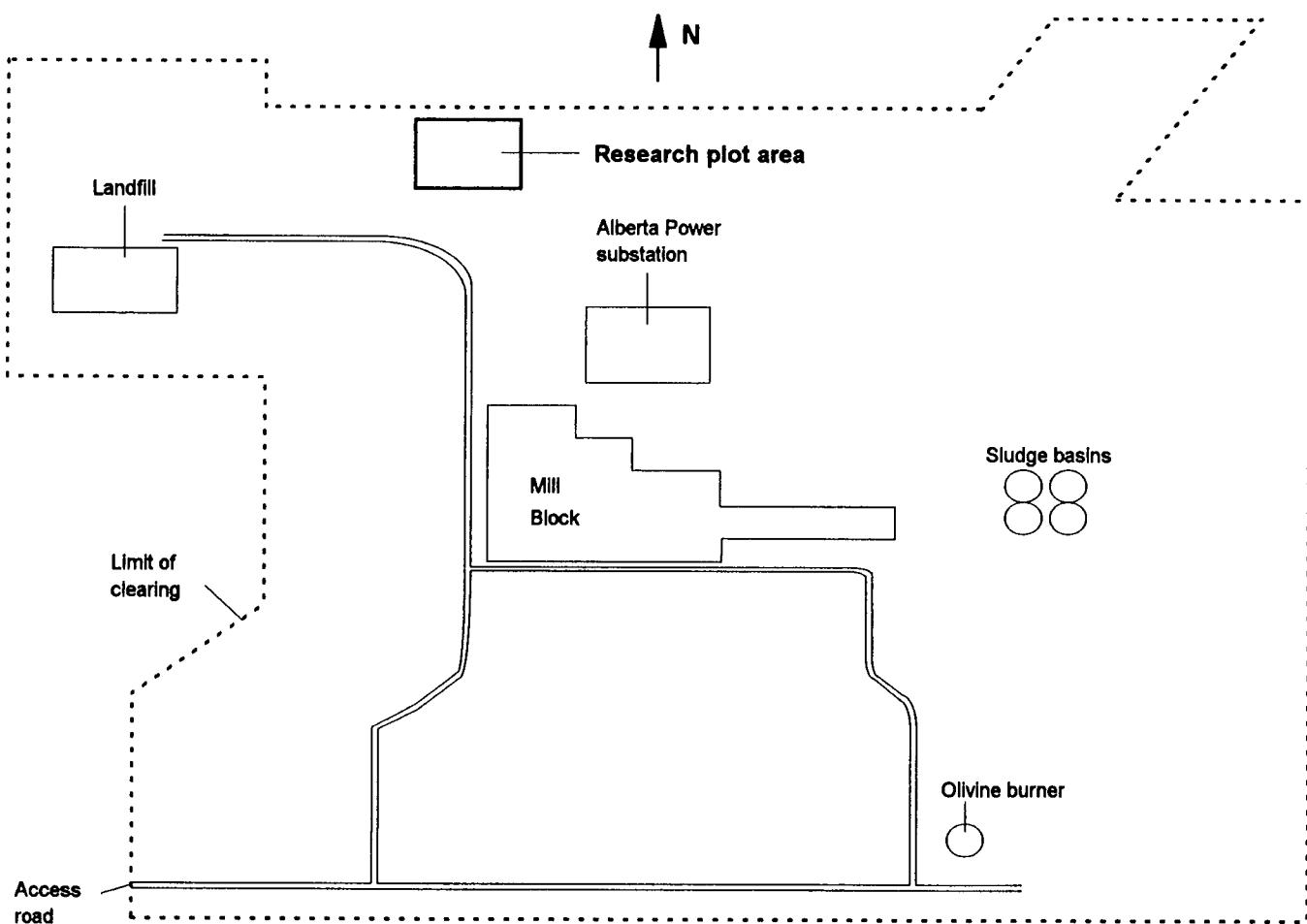
In 1992, the Alberta Research Council (ARC) established field plots to evaluate the impact of land application of sludge and ash materials from the operations of Slave Lake Pulp Corporation (SLPC) on soils and vegetation. Individual plots received applications of 0 cm (control), 1 cm, 3 cm, or 5 cm of sludge. In addition, one treatment combined 0.5 cm of ash with 5 cm of sludge, and one treatment was designated to receive annual applications of 5 cm of sludge. Each treatment was replicated three times on an area of disturbed Luvisolic soils located on SLPC millsite property (Figure 1). A previous report provides a more detailed description of the site and plot construction methods (Thacker and Macyk 1993).

The results of the first year of the study indicated that the sludge did not pose a risk of trace element contamination to soils or vegetation. However, the sludge and ash contain relatively high levels of sodium, which raised the concentration of sodium in the soil to levels that could potentially have an impact on soil quality or the ability of the soil to support plant growth with the highest rates of the amendments.

Brome grass vigour was much improved by the sludge and sludge/ash amendments. Dry matter yields from the 3 cm and 5 cm sludge and ash plots were two and one-half to three times that of the control plots. The yields with the 1 cm sludge treatment were not significantly different from the control plots.

This report describes the activities and results in 1993. This is the second year that the site has been monitored since sludge was applied so some of the longer term impacts of sludge landspreading can begin to be examined. The results from 1992 are discussed in detail in a previous report (Thacker and Macyk 1993).

Figure 1. Sketch of Slave Lake Pulp Corporation operations with research plot area indicated.



OBJECTIVE

The objective of this research is to determine the impact of land application of four rates of sludge, and a sludge-ash mixture on soil and grass grown thereon in a field experiment located on the SLPC millsite property. The project will be undertaken for a period of three years to assess the fate of the waste and its effect on soil characteristics and plant growth and tissue characteristics, and to permit the development of recommendations regarding environmentally acceptable rates of sludge and ash application.

STUDY DESIGN

The experiment consists of 18 plots within a 48 m x 41 m area with individual plots 6 m x 12 m in size. Six treatments are replicated three times in a completely randomized experimental design (Figure 2). The treatments are:

- 1) Control. No sludge application.
- 2) 1 cm wet sludge layer equivalent (0.75 m^3 per plot). Single application.
- 3) 3 cm wet sludge layer equivalent (2.25 m^3 per plot). Single application.
- 4) 5 cm wet sludge layer equivalent (3.75 m^3 per plot). Single application.
- 5) Multiple sludge treatment. 5 cm wet sludge layer equivalent (3.75 m^3 per plot) each year for 3 years.
- 6) 5 cm wet sludge layer equivalent (3.75 m^3 per plot) plus 0.5 cm dry ash layer equivalent (0.4 m^3 per plot). Single application.

This report refers to the plot treatments by the thickness of the sludge or ash layer that was applied. This is based on the volume of material required to produce a layer of the specified thickness. Determining the sludge density (and therefore the mass of material applied) can result in a range of values because the sludge is easily compacted. The density of sludge can be increased by a factor of two by moderate to firm hand pressure (unpublished ARC data). A previous report by Thacker and Macyk (1993) provided estimates of the mass of sludge applied to the plots which were based on the density of moderately packed sludge. Subsequent investigation suggests that lower densities are more appropriate given the sludge handling operations involved in applying sludge to the research plots. Based on our (the authors) current understanding the following conversions represent the best estimates of the mass of material applied to the plots:

1 cm sludge = 16 dry tonnes per hectare
3 cm sludge = 48 dry tonnes per hectare
5 m sludge = 80 dry tonnes per hectare
05 cm ash = 50 dry tonnes per hectare

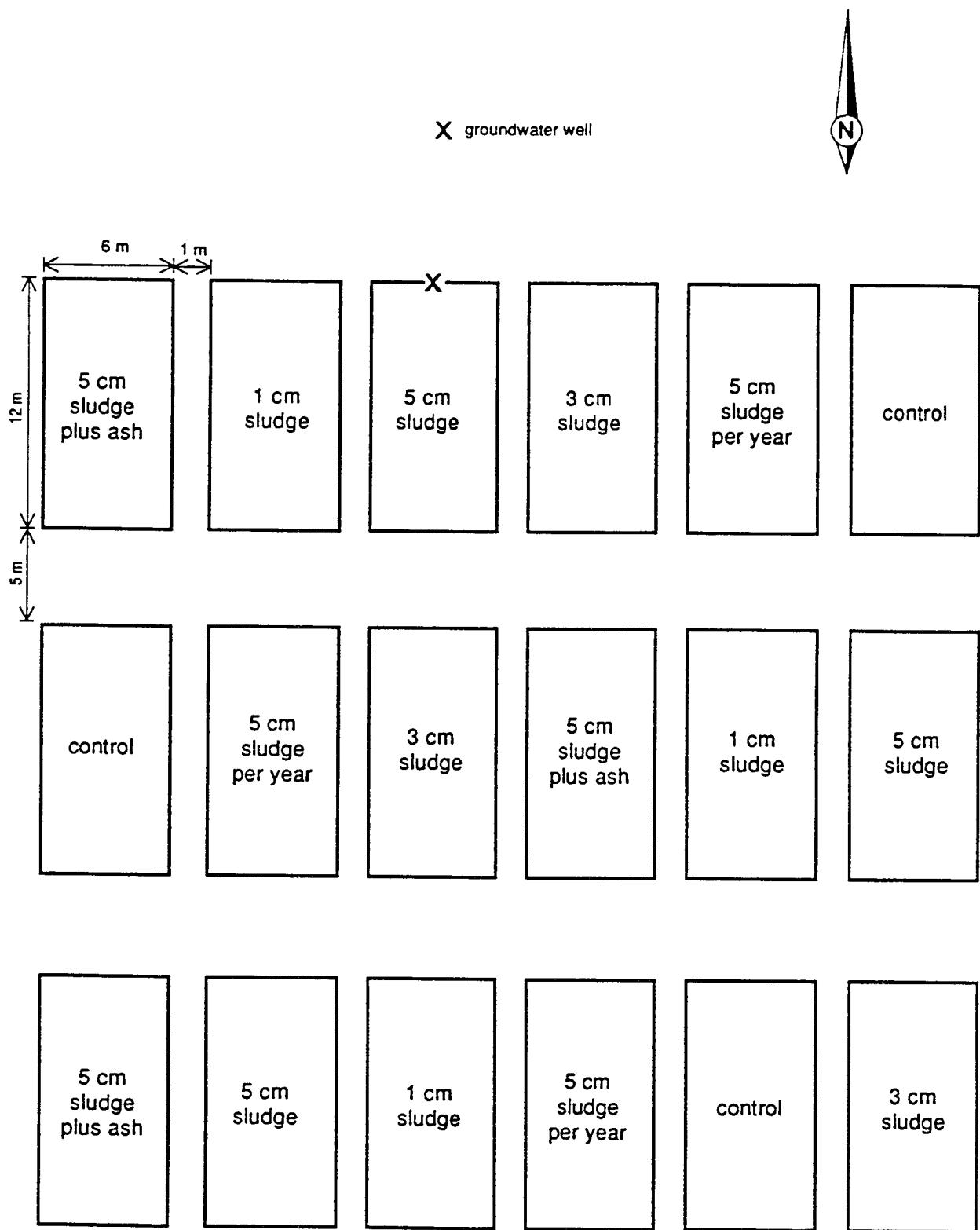


Figure 2. Research Plot Layout

X

The sludge was applied to the plots on June 10, 1992. All plots were treated in an identical manner, with the exception of the multiple sludge treatment which was not seeded and is rototilled following sludge application each spring. This latter treatment was given the second 5 cm application of sludge on June 1, 1993, as described in the following sections. All plots have a brome grass (*Bromus inermis*) cover with the exception of the multiple sludge treatment.

ACTIVITIES IN 1993

The major field activities undertaken in 1993 were sludge application to the three plots selected for annual additions of sludge, two yield assessments (June and August), and sampling of the sludge, soil, and brome grass tissue.

SLUDGE SPREADING AND INCORPORATION

One treatment (three plots) was designated to receive annual additions of 5 cm of sludge; 1993 is the second year of sludge application to these plots.

Fresh sludge was taken directly from the mill's sludge bunker during the production run of May 11 and moved to a stockpile area near the plots. Samples of the sludge were collected on May 12 (six samples, combined into one composite sample). Wet soil conditions prevented spreading and incorporating the sludge until June 1. Sludge loads were dumped on the plots and back-bladed with a bobcat. Rakes were used to finish spreading the sludge to uniform depth.

The sludge was incorporated using a garden tractor equipped with a rototiller unit with tiller blades set to a depth of 15 cm. Excellent incorporation was achieved by completing two passes with the rototiller.

SOIL SAMPLING

Sampling following the June sludge application

Soil samples were collected on June 9 from the three plots given annual sludge applications. Post-incorporation samples were collected from the 0 to 15 cm and 15 to 30 cm depths, with each sample representing a composite from five sampling locations.

Soil sampling following the August harvest

Soil samples were collected from all plots on August 19. Samples from 0 to 15 cm and 15 to 30 cm depth were obtained by using a shovel to dig soil from five locations in each plot and combine them into one composite sample. A hand auger was used to obtain samples from one location for the following depths in each plot: 30 to 45 cm, 45 to 60 cm, 60 to 75 cm, 75 to 90 cm, and 90 to 105 cm. Cores were sealed in two layers of plastic bag and transported to the laboratory for air-drying and crushing to 2 mm prior to analysis.

FERTILIZING

One of the critical factors being investigated in this study is the fertilizing value of the sludge material. Total chemical analysis indicates that the sludge contains substantial quantities of nitrogen (3%) and phosphorus (0.5%) (Thacker and Macyk 1993), but the time required for these nutrients to be liberated is unknown. Chemical fertilizers were added at low rates in 1992 to help establish vegetation on the plots. In 1993 no fertilizer was added to prevent masking any fertilizing effect of the sludge when compared to the control plots.

METEOROLOGICAL DATA COLLECTION

A rain gauge was installed in the plot area in 1992 to monitor cumulative precipitation between visits to the site. The gauge was emptied of fall/winter/early spring precipitation on May 12, and was checked periodically until August 26.

TISSUE SAMPLING AND YIELD ASSESSMENT

Yield assessment was conducted on June 8 and 9, shortly after the brome grass began to produce flower heads, and again on August 17 and 18 when the grass had regrown but had not yet produced flower heads. Weed growth in the plots was negligible at the time of both harvests. Photographs were taken of each plot immediately prior to the harvests. Photographs were also taken on May 12 before vigorous growth had commenced in the spring, and on June 1 when growth was vigorous but before heading had occurred.

The grass was harvested with a lawnmower equipped with a grass-catcher to cut the brome grass to approximately 5 cm height over the entire area of each plot. The grass was weighed immediately at the site and subsamples (1 to 2 kg) were returned to the laboratory where they were air dried for determination of moisture content and ultimately dry weight of the harvest. Statistical analysis of the dry yield data was performed using a microcomputer Statistical Analysis System (SAS) package (SAS Institute Inc. 1985).

Tissue samples for chemical analysis were collected during the June harvest. Tissue samples were obtained from six or more randomly selected locations in each plot, until approximately 500 g of moist vegetation was collected. Seed stalks were excluded from sampling. The tissue samples were transported to the laboratory in paper bags, washed, oven dried (70°C), and ground prior to analysis.

SOIL CHEMICAL PROPERTIES

The following analyses were performed on all soil samples to 105 cm depth:

- i) pH (in both water and calcium chloride).
- ii) Total nitrogen content.
- iii) Total carbon, inorganic carbon, organic carbon content.
- iv) Carbon:Nitrogen (C/N) ratio.

- v) Calcium carbonate equivalent.
- vi) Exchangeable cations (Ca, Mg, Na, K) and cation exchange capacity.
- vii) Saturated paste extract, including pH, electrical conductivity, sodium adsorption ratio, and soluble ions (HCO_3 , CO_3 , Cl, NO_2 , NO_3 , NH_4 , Sr, Ba, P, S, Mg, As, Si, V, Na, Mo, Se, Al, Ca, Zn, Cu, Pb, Li, Ti, Cd, Co, Ni, B, K, Mn, Fe, Cr).
- viii) DTPA (plant-available) elements (P, Mg, Na, Mo, Se, Ca, Zn, Cu, Pb, Cd, Ni, B, K, Mn, Fe).
- ix) Total elemental analysis (Zr, Sr, Ba, P, Mg, V, Na, Mo, Al, Ca, Zn, Cu, Pb, Li, Ti, Cd, Co, Ni, K, Mn, Fe, Cr).

Baseline monitoring in 1992 also included measurement of particle size distribution on all pre-incorporation soil cores to 105 cm depth as part of the soil characterization. Particle size distribution is not expected to change during the course of the experiment so was not included in the 1993 analyses. The data from the pre-incorporation soil cores were presented in an earlier report (Thacker and Macyk 1993).

VEGETATION TISSUE ANALYSIS

The tissue samples from each plot were analyzed for Sr, Ba, P, S, Mg, As, Si, V, Na, Mo, Se, Al, Ca, Zn, Cu, Pb, Li, Ti, Cd, Co, B, K, Mn, Fe, Cr, and Cl.

LABORATORY METHODS

Soil chemical properties

The pH in a water paste was determined according to Doughty (1941) and in a 0.01 M CaCl_2 according to Peech (1965). Total nitrogen was determined by the Kjeldahl method; the samples were acid digested and nitrogen measured by a Tecator Kjeltec Auto 1030 Analyser. Calcium carbonate equivalent (inorganic carbon) was determined by acid dissolution (Bascomb 1961). Total carbon was measured with a CR12 carbon analyser (Leco Corporation 1979), and organic carbon was calculated as the difference between total and inorganic carbon. Cation exchange capacity (CEC) and extractable cations were measured by extraction with a normal (1 M at pH 7.0) ammonium acetate solution (Holmgren et al. 1977), where ammonium ions were determined by a Tecator Kjeltec Auto 1030 Analyser distillation and titration unit, and the extractable ions using an ARL Model 3680 Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES).

Saturated paste extracts

Saturated pastes were prepared using the method of the United States Department of Agriculture (USDA) Soil Salinity Laboratory (USDA 1954). Extracts were filtered through a 0.45 μm filter and analyzed for electrical conductivity using a Yellow Springs Instruments conductivity cell and model 32 conductance meter. Alkalinity was determined by Environmental Protection Agency (EPA) method 310.2, chloride by EPA method 325.2 with a Lachat flow injection analysis (FIA) instrument (EPA 1983), and the soluble ions (Sr, Ba, P, S, Mg, As, Si,

V, Na, Mo, Se, Al, Ca, Zn, Cu, Pb, Li, Ti, Cd, Co, Ni, B, K, Mn, Fe, Cr) using ICP-AES. The sodium adsorption ratio was calculated from the soluble ion data.

DTPA extractable elements

DTPA-NH₄HCO₃ extractable elements were determined by the method of Soltanpour and Workman (1981), with the elements (P, Mg, Na, Mo, Se, Ca, Zn, Cu, Pb, Cd, Ni, B, K, Mn, Fe) determined by ICP-AES.

Total elemental analysis

Total elemental analysis was done by digestion in a CEM microwave digestion system. The material was ashed overnight at 425°C, digested in a teflon bomb in the microwave oven with 1.5 mL HNO₃, 4.5 mL HCl and 10 mL HF for 10 minutes at 100 percent power. The digested solutions were made up with saturated H₃BO₃ to 50 mL, and the elements (Zr, Sr, P, Mg, V, Na, Mo, Al, Ca, Zn, Cu, Pb, Li, Ti, Cd, Co, Ni, K, Mn, Fe, Cr) were measured using ICP-AES.

Tissue analysis

The vegetation samples were digested with a concentrated HNO₃-HClO₄ acid mixture in a teflon bomb heated in a CEM microwave digestion unit and the elements (Sr, Ba, P, S, Mg, As, Si, V, Na, Mo, Se, Al, Ca, Zn, Cu, Li, Ti, Co, Ni, B, K, Mn, Fe, Cr) were measured by ICP-AES. Cadmium and Pb were determined by graphite furnace atomic absorption, and chloride was determined by the sodium nitrate extraction method of Gaines et al. (1984).

RESULTS

GRASS YIELDS

The yields obtained in August 1992, June 1993, and August 1993 are shown in Table 1 and in Figures 3 through 5. With moist growing conditions and a well established brome grass cover the yields in June and August 1993 were approximately four times higher than in August 1992.

In August 1992 the mean yields with a 1 cm layer of sludge were about 1.5 times that of the control plots, but this difference was not statistically significant. The 3 cm sludge, 5 cm sludge, and 5 cm sludge plus ash plots yielded 2.5 to 3 times the dry matter of the control plots.

For the June 1993 harvest the mean yields with a 1 cm layer of sludge were about 40% higher than the control plots, but again this was not statistically significant. The 3 cm sludge, 5 cm sludge, and 5 cm sludge plus ash plots produced almost twice as much dry matter as the control plots.

For the August 1993 harvest the yield in the control and 1 cm plots was about one half the June

yields for those treatments. However, the 3 cm sludge plots had almost the same yield as in June, and the 5 cm sludge and 5 cm sludge plus ash plots had higher yields than in June. This made the yield with 3 cm of sludge almost three times that of the control plots, and with the two 5 cm sludge treatments almost five times that of the control plots.

The August 1993 harvest was the first time that a statistical difference between the 3 cm and 5 cm sludge treatments was evident. The mean yield of the control plots has consistently been less than the 1 cm sludge treatment.

Plates 1 through 5 show the brome grass growth just prior to the August harvest in the middle row of plots at the research site which includes one plot of each treatment.

Table 1. Mean yield by treatment for each harvest.

Treatment	Mean yield (air dry weight)*	
	Kg/plot	Tonnes/ha
AUGUST 1992 HARVEST		
Control	3.3 c	0.46
1 cm sludge	5.0 bc	0.69
3 cm sludge	9.8 a	1.36
5 cm sludge	8.7 ab	1.21
5 cm sludge & ash	8.7 ab	1.21
JUNE 1993 HARVEST		
Control	17.1 c	2.38
1 cm sludge	23.3 bc	3.24
3 cm sludge	31.4 ab	4.36
5 cm sludge	32.2 a	4.47
5 cm sludge & ash	33.7 a	4.68
AUGUST 1993 HARVEST		
Control	8.3 c	1.15
1 cm sludge	11.1 c	1.54
3 cm sludge	30.6 b	4.25
5 cm sludge	40.6 a	5.64
5 cm sludge & ash	39.4 a	5.47

* Treatment means for each harvest not followed by a common letter are significantly different at 0.05 probability by Tukey's Studentized Range (HSD) Test.

Effect of pulp sludge on grass yield
(First cut, August of year 1)

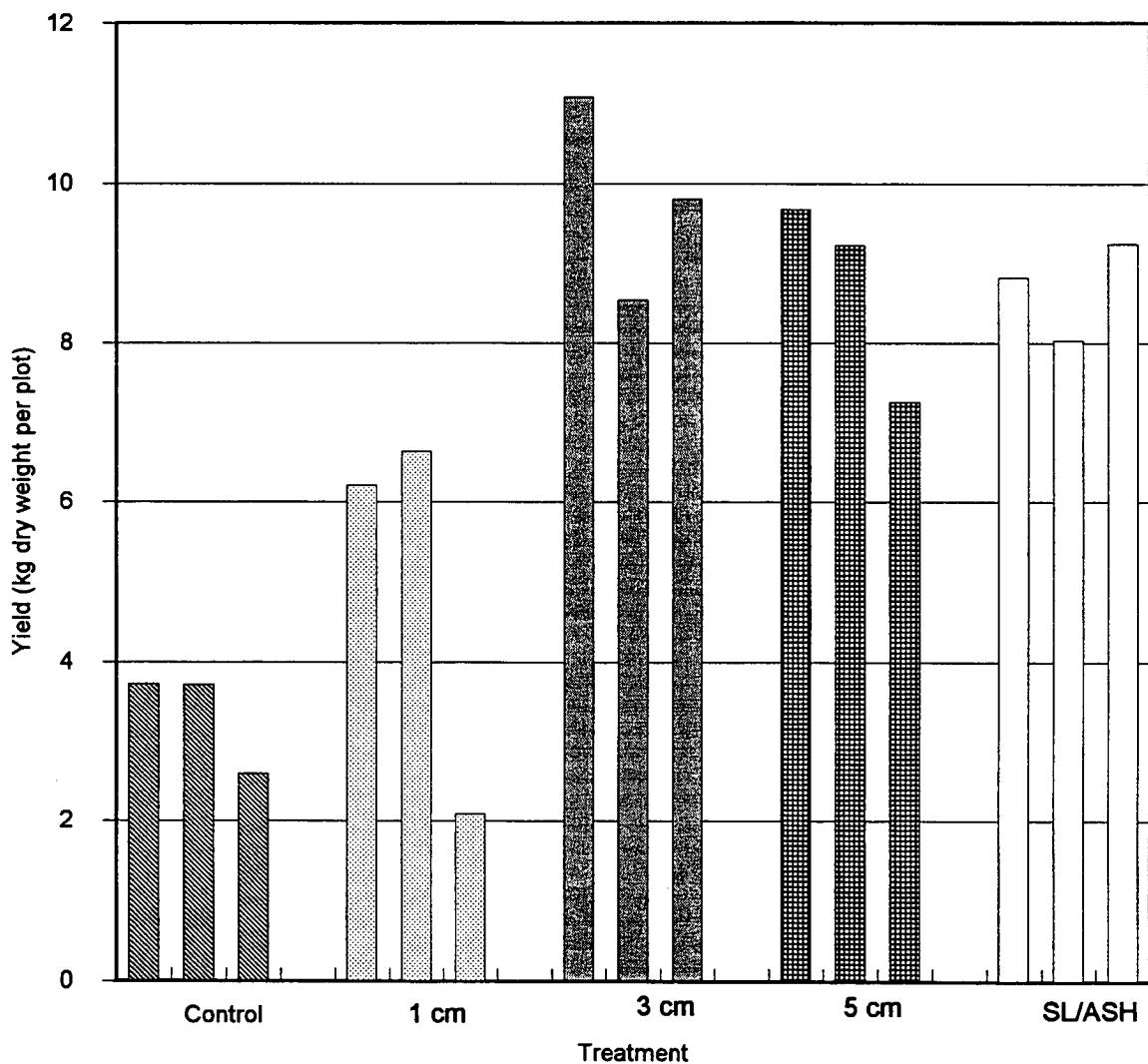


Figure 3. August 1992 grass yield for each plot by treatment (three plots per treatment). Treatments are indicated by the depth of sludge applied, with SL/ASH referring to the 5 cm sludge plus 0.5 cm ash treatment.

Effect of pulp sludge on grass yield
(Second cut, June of year 2)

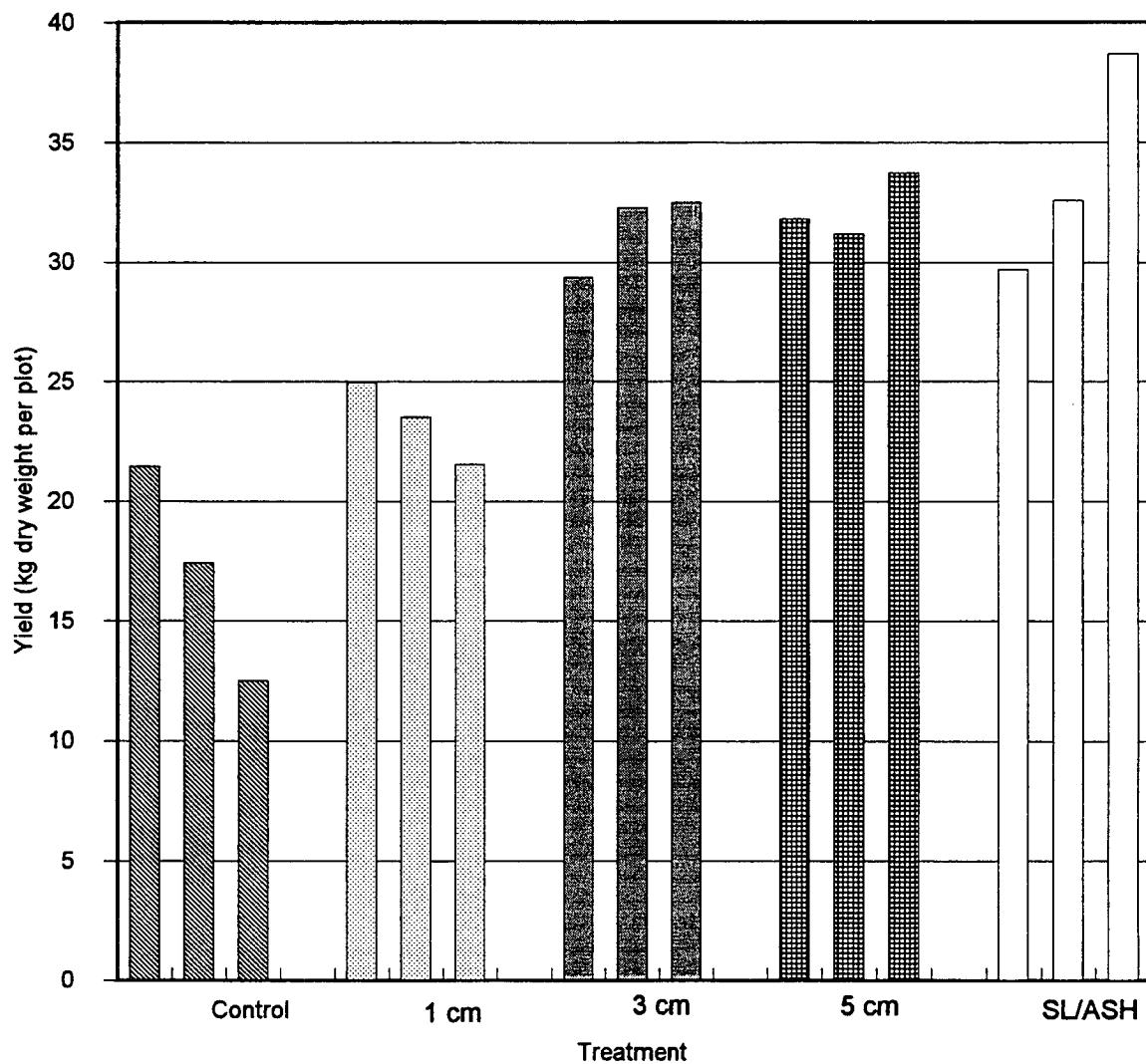


Figure 4. June 1993 grass yield for each plot by treatment (three plots per treatment). Treatments are indicated by the depth of sludge applied, with SL/ASH referring to the 5 cm sludge plus 0.5 cm ash treatment.

Effect of pulp sludge on grass yield
(Third cut, August of year 2)

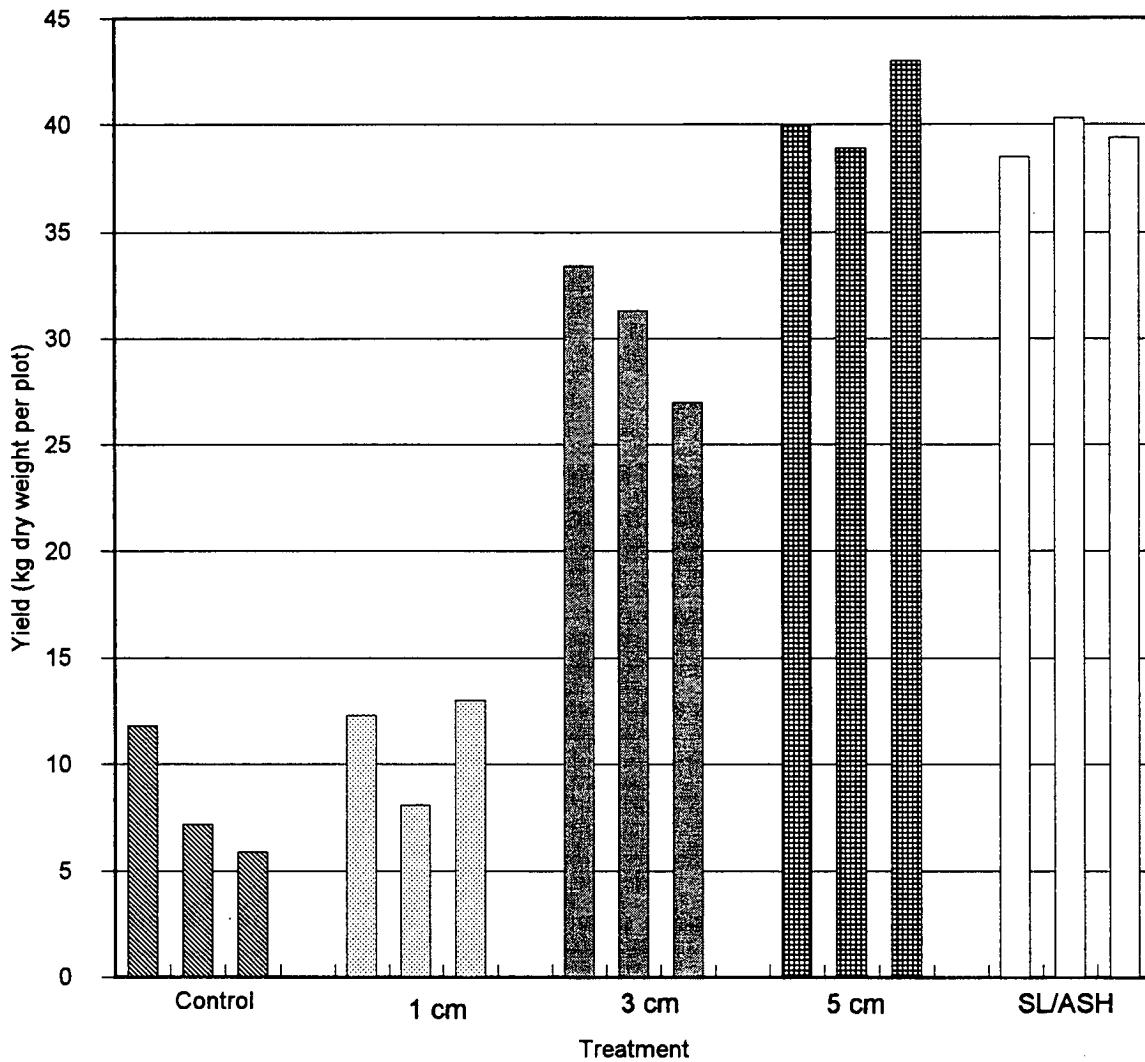


Figure 5. August 1993 grass yield for each plot by treatment (three plots per treatment). Treatments are indicated by the depth of sludge applied, with SL/ASH referring to the 5 cm sludge plus 0.5 cm ash treatment.



Plate 1. Brome grass in Plot 7 on August 17, plot not amended with sludge (control treatment).



Plate 2. Brome grass in Plot 11 on August 17, plot amended with 1 cm of sludge.



Plate 3. Brome grass in Plot 9 on August 17, plot amended with 3 cm of sludge. *do to me 2.0*



Plate 4. Brome grass in Plot 12 on August 17, plot amended with 5 cm of sludge.



Plate 5. Brome grass in Plot 10 on August 17, plot amended with 5 cm of sludge plus ~~ash~~
0.5 cm of ash.

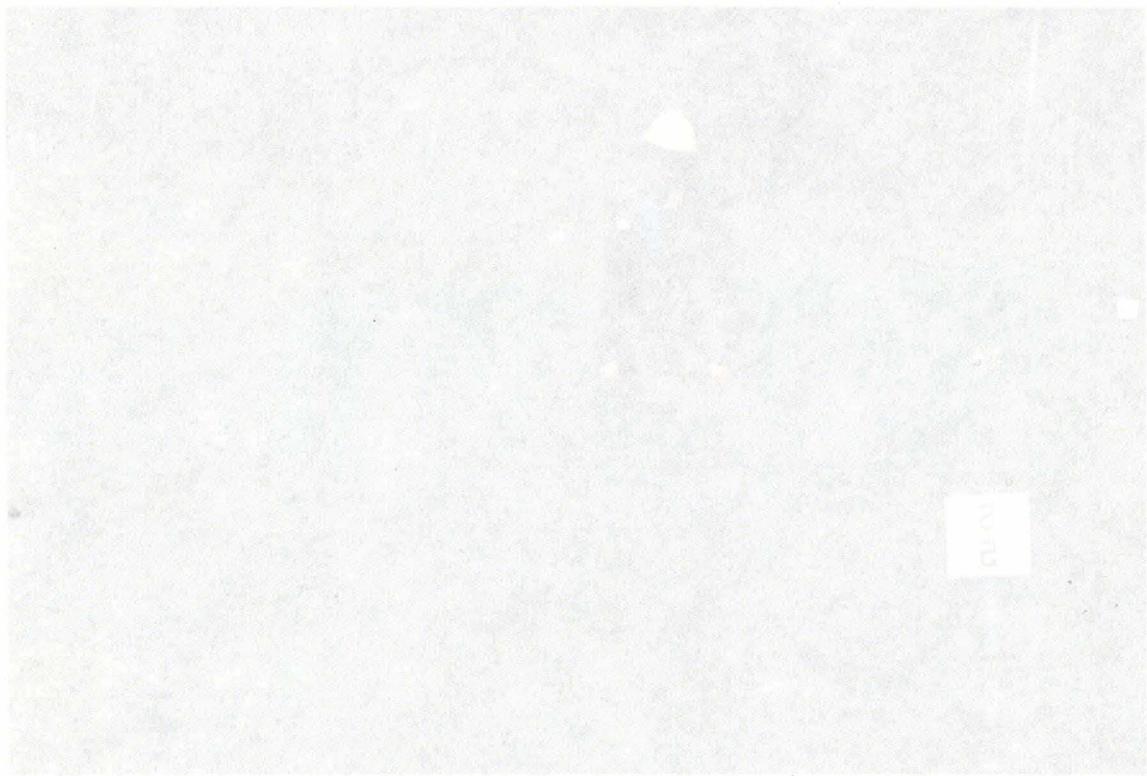


Figure 10. no 2 diw bosome wdg, SI nagaA no S1 wdg in seky emoy. A wdg

PRECIPITATION

The rainfall recorded during the period from May 12 to August 26 at the study site is as follows:

May 12 to June 1	4.0 mm
June 1 to June 8	0.0 mm
June 8 to August 17	219.8 mm
August 17 to August 26	44.3 mm
Total	268.1 mm

The site had substantially more precipitation in 1993 than in 1992. In 1992 rainfall was recorded from June 10 to August 20 and totalled 97.8 mm. For almost the same period in 1993 (June 8 to August 17) rainfall totalled 219.8 mm.

SOIL CHEMICAL AND PHYSICAL PROPERTIES

The data for the soil chemical properties at the end of the second growing season are provided in Appendix 1. For the 5 cm of sludge per year treatment there is an additional row of data designated in the depth column by "0-15, June" indicating that the samples were collected in June 1993, shortly after sludge application to these plots. Table 2 provides mean values for the various parameters for each treatment, and Table 3 shows the trend of these properties over time.

Almost all pH values in the calcium chloride solution are between 7.0 and 7.5; the pH values in the water extracts are about one half unit higher. In the zone of sludge incorporation (0 to 15 cm) the largest difference from the control treatment (mean CaCl_2 pH of 7.0) is the sludge plus ash treatment which has a pH of 7.8. The treatment receiving annual sludge applications has a mean pH of 7.4, the 1 cm and 3 cm sludge treatments have a mean pH of 7.1, and the 5 cm sludge treatment has a pH of 7.2. These differences are restricted to the zone of incorporation, but even in this zone the pH values are very small except for the treatment including ash. The pH increase associated with the ash can be considered a negative impact in these soils because of their initial pH, but could prove beneficial if the ash were used to treat acidic soils.

Immediately following sludge application in 1992 the CaCl_2 pH values in the incorporation zone for the control, 1 cm, 3 cm, 5 cm, 5 cm/yr, and 5 cm sludge plus ash treatments were 7.0, 7.2, 7.3, 7.5, 7.6, and 8.2, respectively (Thacker and Macyk 1993). As noted previously, these values have all decreased in 1993 with the exception of the control treatment. The greatest decrease occurred with the sludge plus ash treatment (0.4 pH units).

The carbon and nitrogen content of these soils tends to be quite variable within any given treatment, and this variability masks any clear trend with respect to the soil amendments.

There is also no clear pattern in the data for the C/N ratio. The variability of these properties masks any impact from the sludge.

Table 2 . Mean Chemical and Physical Properties of Sludge and Ash Amended Soils in 1993 .

Treatment	Depth (cm)	pH H ₂ O	pH CaCl ₂	Total N (%)	Total C (%)	Organic C (%)	C/N Ratio	CaCO ₃ Eq. (%)	Extractable Cations				CEC
									Na	K	Ca	Mg	
												cmol(+) /Kg	
control	0-15	7.4	7.0	0.53	7.21	7.17	13.8	0.4	1.15	0.34	61.0	10.05	75.6
control	15-30	7.4	7.0	0.49	7.52	7.48	15.4	0.3	1.38	0.35	60.2	10.05	74.6
control	30-45	7.5	7.2	0.24	3.40	3.33	14.0	0.7	0.88	0.38	34.7	6.63	38.4
control	45-60	7.6	7.2	0.15	2.36	2.25	14.4	0.8	0.69	0.36	30.3	5.52	29.1
control	60-75	7.6	7.3	0.17	2.50	2.41	14.7	0.8	0.70	0.36	29.5	5.67	30.7
control	75-90	7.7	7.3	0.17	3.19	3.09	17.5	0.8	0.88	0.38	30.6	5.72	32.2
control	90-105	7.6	7.2	0.21	3.17	3.01	14.5	1.3	1.22	0.40	36.0	6.37	38.0
1 cm sludge	0-15	7.5	7.1	0.40	5.67	5.61	14.0	0.4	1.11	0.33	47.5	7.88	56.7
1 cm sludge	15-30	7.5	7.1	0.33	4.89	4.85	14.6	0.3	1.21	0.29	46.9	7.67	51.7
1 cm sludge	30-45	7.6	7.3	0.27	4.78	4.66	17.2	1.0	1.07	0.39	45.8	8.18	47.9
1 cm sludge	45-60	7.7	7.3	0.26	3.98	3.89	15.0	0.8	0.71	0.36	40.8	7.40	43.9
1 cm sludge	60-75	7.6	7.2	0.29	4.27	4.20	13.9	0.7	0.81	0.39	45.7	8.61	53.7
1 cm sludge	75-90	7.5	7.1	0.28	1.99	1.94	7.6	0.4	0.78	0.33	40.8	7.54	49.8
1 cm sludge	90-105	7.8	7.4	0.16	1.59	1.49	10.9	0.8	0.67	0.33	29.4	5.72	31.5
3 cm sludge	0-15	7.5	7.1	0.58	9.18	9.15	15.7	0.2	2.25	0.29	63.6	10.30	78.4
3 cm sludge	15-30	7.4	7.0	0.52	7.98	7.93	15.3	0.4	1.94	0.27	61.0	9.98	76.0
3 cm sludge	30-45	7.4	7.0	0.29	4.54	4.51	15.4	0.2	0.82	0.33	39.3	7.02	45.7
3 cm sludge	45-60	7.5	7.1	0.22	3.13	3.05	13.5	0.7	0.72	0.40	34.1	6.82	38.7
3 cm sludge	60-75	7.5	7.2	0.21	3.26	3.20	14.6	0.5	0.69	0.42	34.3	6.91	38.5
3 cm sludge	75-90	7.4	7.1	0.23	3.89	3.83	17.0	0.5	0.71	0.33	36.1	6.12	39.7
3 cm sludge	90-105	7.5	7.2	0.21	3.30	3.12	13.4	1.5	0.70	0.37	37.2	6.22	37.8
5 cm sludge	0-15	7.7	7.2	0.67	10.02	9.97	14.9	0.4	3.80	0.28	64.7	10.22	80.4
5 cm sludge	15-30	7.7	7.2	0.36	4.44	4.38	12.4	0.5	2.10	0.28	45.7	7.74	53.1
5 cm sludge	30-45	7.6	7.2	0.23	3.27	3.19	14.0	0.7	1.08	0.34	34.9	6.59	38.5
5 cm sludge	45-60	7.6	7.3	0.15	2.04	1.91	12.7	1.0	0.73	0.35	29.3	5.78	28.8
5 cm sludge	60-75	7.6	7.3	0.15	2.45	2.29	15.5	1.3	0.76	0.35	31.4	5.67	29.7
5 cm sludge	75-90	7.8	7.4	0.16	1.75	1.56	11.8	1.6	0.92	0.42	31.1	5.88	28.7
5 cm sludge	90-105	7.8	7.3	0.14	1.70	1.54	11.1	1.3	0.76	0.34	30.3	5.13	27.5
5 cm sludge&ash	0-15	8.2	7.8	0.56	7.36	7.13	12.7	1.9	2.62	0.82	77.1	11.24	58.3
5 cm sludge&ash	15-30	7.8	7.4	0.44	7.10	7.03	16.0	0.6	2.96	0.38	56.4	8.74	58.8
5 cm sludge&ash	30-45	7.6	7.2	0.26	4.51	4.45	16.7	0.5	0.93	0.34	36.8	6.68	40.6
5 cm sludge&ash	45-60	7.6	7.2	0.25	4.57	4.50	17.8	0.5	0.72	0.33	37.1	6.82	40.7
5 cm sludge&ash	60-75	7.5	7.1	0.29	4.48	4.41	15.3	0.6	0.72	0.34	41.5	7.40	46.6
5 cm sludge&ash	75-90	7.5	7.1	0.33	4.79	4.71	14.3	0.7	0.88	0.36	45.8	8.09	52.4
5 cm sludge&ash	90-105	7.6	7.2	0.28	3.63	3.54	12.0	0.8	0.89	0.38	41.9	7.48	46.5
5 cm sludge/yr	0-15	7.7	7.4	0.65	8.74	8.68	13.3	0.5	5.21	0.49	57.5	9.47	69.3
5 cm sludge/yr	15-30	7.7	7.3	0.43	6.10	6.05	14.2	0.4	3.02	0.46	49.2	8.31	55.8
5 cm sludge/yr	30-45	7.6	7.3	0.26	4.36	4.28	16.9	0.6	1.19	0.38	37.3	6.78	40.4
5 cm sludge/yr	45-60	7.7	7.3	0.25	4.43	4.36	17.0	0.6	0.92	0.35	38.4	6.99	42.5
5 cm sludge/yr	60-75	7.7	7.3	0.19	2.66	2.54	14.1	1.0	0.84	0.40	32.9	6.61	34.8
5 cm sludge/yr	75-90	7.6	7.2	0.26	4.32	4.19	15.9	1.1	1.04	0.37	39.6	6.75	43.2
5 cm sludge/yr	90-105	7.5	7.2	0.24	4.01	3.88	15.9	1.1	1.20	0.41	38.2	6.92	41.7

Table 3. Selected mean chemical properties for the zone of sludge incorporation on three sampling dates.

Treatment	pH (CaCl ₂)			CaCO ₃ equivalent (%)		
	Baseline	June 92	August 93	Baseline	June 92	August 93
Control	7.1	7.0	7.0	0.2	0.2	0.4
1 cm sludge	7.2	7.2	7.1	0.4	0.2	0.4
3 cm sludge	7.1	7.3	7.1	0.3	0.4	0.2
5 cm sludge	7.2	7.5	7.2	0.5	0.5	0.4
5 cm sludge and ash	7.1	8.2	7.8	0.2	1.6	1.9
5 cm sludge/yr.	7.3	7.6	7.4	0.5	0.4	0.53

The calcium carbonate equivalent in the incorporation zone has been increased by the sludge plus ash treatment. The level of about 2% for this treatment is four to five times higher than the other treatments. There are no apparent differences between the treatments receiving sludge only.

Any change in extractable cations or the cation capacity is minor compared to the natural variability of these properties, and is not discernable in the data.

The Alberta Soils Advisory Committee has provided guidelines for rating the suitability of soils in Alberta for plant growth (ASAC 1987). For topsoils in the Plains Region of Alberta, or where the vegetation can include grass, some of the relevant ratings are shown in Table 4.

Using the ASAC guidelines to rate the incorporation zone, the soils in the study area would receive a good rating with respect to pH, organic carbon, and CaCO₃ equivalent. The exception to this are the soils receiving the sludge plus ash treatment where pH would be given a fair rating. This treatment barely meets the requirement for a good rating with regard to CaCO₃ equivalent. For the northern forested region the ratings are similar, except that there is no rating for organic carbon, and the ratings for pH are good (5.0 to 6.5), fair (4.0 to 5.0 and 6.5 to 7.5), poor (3.5 to 4.0 and 7.5 to 9.0), and unsuitable (<3.5 and >9.0). Because the plots are vegetated with grass the Plains ratings were used to rate these soils.

SATURATED PASTE EXTRACT DATA

The saturated paste extract data for each plot are presented in Appendix 2. Table 5 provides the mean values for each treatment, and Table 6 shows the trend of these values over time. A saturated paste extract approximates the soil solution and provides a consistent condition with which to compare any changes over time.

Table 4. Some criteria for evaluating the suitability of topsoil in the Plains Region or where the vegetation is grass. Adapted from ASAC (1987).

	Good	Fair	Poor	Unsuitable
pH	6.5 to 7.5	5.5 to 6.4 7.6 to 8.4	4.5 to 5.4 8.5 to 9.0	<4.5 and >9.0
Salinity (EC) dS/m	<2	2 to 4	4 to 8	>8
Sodicity (SAR)	<4	4 to 8	8 to 12	>12
Organic Carbon (%)	>2	1 to 2	<1	
CaCO ₃ Equivalent (%)	<2	2 to 20	20 to 70	>70

Compared to the soils the sludge has higher saturation percent, EC, SAR, chloride, ammonium-nitrogen, silicon, sodium, zinc, copper, potassium, manganese, and chromium. The ash has higher EC, SAR, pH, strontium, sulfur, sodium, aluminum, copper, boron, potassium, and chromium (Thacker and Macyk 1993). In 1992 this resulted in higher phosphorus, potassium, ammonium nitrogen, EC and SAR in the plots treated with high rates of sludge and/or ash. Increased levels of several trace elements occurred in the sludge treated plots (Cl, Al, Zn, Cu, Ti, Cd, Co, Ni, Mn, Fe, and in the ash treated plots only, Si and Mo).

In 1993 the soils treated with the high rates of sludge and/or ash still have several times more ammonium-nitrogen and phosphorus in the incorporation zone than the control soils (except for ammonium in the ash treated plots). Potassium in the 5 cm sludge plots has decreased to levels comparable to the control plots, but remains elevated in the plots receiving ash and the plots given additional sludge in 1993.

There is a substantial increase in nitrite and nitrate concentrations in the plots receiving 3 cm or 5 cm of sludge, which is apparent in the 1993 data but not the data from 1992. The increase in nitrate results from the gradual decomposition of the sludge. It was not apparent in 1992 because the soils were sampled shortly following sludge application and little decomposition would have occurred. Nitrate leaching to groundwater is a potential concern, but the data indicate that nitrate levels in the sludge treated plots are the same as in control plots below

Table 5. Mean Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Depth (cm)	pH	EC (dS/m)	%SAT	SAR	HCO ₃	CO ₃	Cl	NO ₂ -N	NO ₃ -N & NO ₂ -N	NH ₄ -N	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo	(mg/L)														
control	0-15	6.8	0.57	83.3	2.6	222	0.1	18.0	<0.1	<0.1	1.3	0.41	0.18	0.78	35.1	15.6	<0.15	4.45	<0.01	95.0	<0.03															
control	15-30	6.7	0.74	86.3	3.1	216	0.1	14.2	<0.1	<0.1	0.5	0.50	0.17	0.72	75.9	19.7	<0.15	4.61	<0.01	126.1	<0.03															
control	30-45	7.2	0.86	57.7	2.9	189	0.3	11.1	0.5	0.8	0.4	0.63	0.17	0.31	124.6	23.4	<0.15	3.08	<0.01	133.2	<0.03															
control	45-60	7.3	0.72	50.1	3.0	156	0.3	10.4	1.0	1.3	<0.3	0.51	0.12	0.33	95.0	16.5	<0.15	2.93	<0.01	113.7	<0.03															
control	60-75	7.3	0.60	51.4	3.1	175	0.4	10.9	0.7	1.0	<0.3	0.44	0.13	0.38	65.9	14.0	<0.15	3.06	<0.01	101.9	<0.03															
control	75-90	7.4	0.59	53.4	3.8	211	0.5	12.4	1.2	1.4	<0.3	0.41	0.16	0.37	48.9	12.2	<0.15	2.87	<0.01	113.1	<0.03															
control	90-105	7.5	0.60	54.1	5.4	249	0.8	13.7	0.5	0.6	1.1	0.37	0.17	0.52	49.8	10.9	<0.15	3.34	<0.01	143.4	<0.03															
1 cm sludge	0-15	6.6	0.56	72.0	2.9	225	0.1	18.8	<0.1	<0.1	<0.3	0.40	0.20	1.00	28.4	15.0	<0.15	4.28	<0.01	104.4	<0.03															
1 cm sludge	15-30	6.9	0.80	65.5	3.1	200	0.2	10.0	<0.1	0.1	<0.3	0.50	0.15	0.51	97.2	20.4	<0.15	3.51	<0.01	130.2	<0.03															
1 cm sludge	30-45	7.2	0.87	66.1	3.0	182	0.3	8.3	0.5	0.5	<0.3	0.71	0.11	0.41	122.5	23.4	<0.15	2.44	<0.01	132.8	<0.03															
1 cm sludge	45-60	7.4	0.58	60.1	2.2	189	0.5	9.8	0.8	0.9	<0.3	0.47	0.13	0.32	53.6	16.5	<0.15	2.66	<0.01	78.7	<0.03															
1 cm sludge	60-75	7.3	0.58	65.7	2.2	195	0.4	11.8	0.7	1.2	1.4	0.48	0.16	0.34	49.5	16.7	<0.15	3.06	<0.01	79.5	<0.03															
1 cm sludge	75-90	7.4	0.51	60.6	2.3	212	0.5	14.0	0.5	0.5	0.9	0.36	0.16	0.34	29.6	14.1	<0.15	4.27	<0.01	77.4	<0.03															
1 cm sludge	90-105	7.6	0.42	48.7	2.6	189	0.7	13.1	0.7	0.7	<0.3	0.26	0.12	0.32	17.9	9.1	<0.15	3.70	<0.01	72.8	<0.03															
3 cm sludge	0-15	6.9	0.70	93.9	4.5	385	0.3	15.3	9.4	7.8	3.1	0.41	0.19	1.95	40.3	15.1	<0.15	4.71	<0.01	168.3	<0.03															
3 cm sludge	15-30	6.8	0.80	86.8	4.0	242	0.2	9.8	4.7	5.8	0.9	0.50	0.18	0.85	103.4	20.0	<0.15	3.90	<0.01	166.2	<0.03															
3 cm sludge	30-45	7.1	0.67	63.0	2.7	148	0.2	7.2	1.0	1.0	<0.3	0.46	0.15	0.49	103.7	19.4	<0.15	3.84	<0.01	108.4	<0.03															
3 cm sludge	45-60	7.1	0.62	58.4	2.4	161	0.2	10.4	0.6	0.8	<0.3	0.43	0.13	0.38	83.4	18.1	<0.15	3.42	<0.01	94.6	<0.03															
3 cm sludge	60-75	7.3	0.50	57.5	2.4	168	0.3	10.8	0.6	1.1	<0.3	0.38	0.14	0.39	57.4	14.8	<0.15	3.22	<0.01	83.3	<0.03															
3 cm sludge	75-90	7.3	0.57	56.0	2.4	200	0.4	13.3	1.6	2.2	0.8	0.44	0.18	0.36	49.4	15.4	<0.15	3.28	<0.01	86.1	<0.03															
3 cm sludge	90-105	7.2	0.47	57.2	2.5	179	0.3	13.4	0.3	0.4	1.6	0.33	0.14	0.41	35.9	11.4	<0.15	3.51	<0.01	77.1	<0.03															

continued...

Table 5 . (Continued) Mean Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Depth (cm)	pH	EC (dS/m)	%SAT	SAR	HCO ₃	CO ₃	Cl	NO ₂ -N	NO ₃ -N & NO ₂ -N	NH ₄ -N	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo
						(mg/L)															
5 cm sludge	0-15	7.0	1.15	83.9	6.6	520	0.5	16.0	24.3	56.4	7.0	0.48	0.20	3.27	40.3	17.5	<0.15	6.10	<0.01	265.4	<0.03
5 cm sludge	15-30	7.2	0.85	64.4	5.0	252	0.3	9.8	10.7	11.5	0.6	0.41	0.15	0.71	85.3	15.9	<0.15	3.50	<0.01	184.8	<0.03
5 cm sludge	30-45	7.2	0.80	59.5	3.4	197	0.3	7.7	2.3	3.0	<0.3	0.47	0.11	0.34	106.7	19.7	<0.15	3.19	<0.01	138.6	<0.03
5 cm sludge	45-60	7.4	0.76	53.7	2.8	159	0.3	9.0	0.9	1.6	<0.3	0.53	0.12	0.29	106.4	19.7	<0.15	2.95	<0.01	109.9	<0.03
5 cm sludge	60-75	7.4	0.63	51.4	2.8	167	0.4	11.2	0.8	1.6	<0.3	0.44	0.12	0.29	69.9	14.4	<0.15	2.90	<0.01	99.6	<0.03
5 cm sludge	75-90	7.5	0.59	53.2	3.1	180	0.5	12.0	0.9	1.3	1.7	0.40	0.13	0.27	60.7	11.9	<0.15	3.09	<0.01	104.1	<0.03
5 cm sludge	90-105	7.5	0.48	48.4	3.0	201	0.5	12.7	0.6	1.1	1.1	0.30	0.13	0.30	29.3	9.6	<0.15	3.36	<0.01	90.7	<0.03
5 cm sludge&ash	0-15	7.4	1.11	83.3	5.4	629	1.6	14.5	26.0	38.3	<0.3	0.61	0.21	2.74	35.3	25.9	<0.15	13.43	<0.01	237.0	<0.03
5 cm sludge&ash	15-30	7.2	1.08	77.1	6.2	390	0.7	12.7	5.9	7.6	<0.3	0.52	0.22	1.89	110.2	20.5	<0.15	4.60	<0.01	259.4	<0.03
5 cm sludge&ash	30-45	7.2	0.73	61.7	2.8	188	0.3	7.3	1.9	2.6	<0.3	0.51	0.13	0.42	94.4	20.4	<0.15	2.89	<0.01	113.8	<0.03
5 cm sludge&ash	45-60	7.2	0.69	60.4	2.3	189	0.3	9.6	1.7	2.2	<0.3	0.54	0.15	0.33	84.5	21.6	<0.15	2.80	<0.01	94.5	<0.03
5 cm sludge&ash	60-75	7.3	0.60	64.2	2.2	214	0.4	11.7	0.8	1.3	<0.3	0.50	0.17	0.39	51.3	18.6	<0.15	3.14	<0.01	84.1	<0.03
5 cm sludge&ash	75-90	7.3	0.57	66.4	2.4	226	0.4	13.6	0.5	0.8	<0.3	0.55	0.20	0.45	37.5	16.5	<0.15	3.32	<0.01	88.0	<0.03
5 cm sludge&ash	90-105	7.4	0.55	60.7	2.6	232	0.5	13.2	0.3	0.4	<0.3	0.53	0.18	0.43	33.3	15.4	<0.15	3.50	<0.01	91.6	<0.03
5 cm sludge/yr	0-15	7.1	1.60	86.9	10.3	632	0.7	20.3	65.8	122.1	5.2	0.59	0.31	4.99	69.8	22.0	<0.15	8.90	<0.01	460.6	<0.03
5 cm sludge/yr	15-30	7.3	1.12	68.5	7.3	418	0.8	18.8	27.6	41.0	0.9	0.45	0.17	1.24	78.1	17.5	<0.15	4.69	<0.01	287.8	<0.03
5 cm sludge/yr	30-45	7.2	0.70	58.7	3.7	214	0.4	15.7	9.4	11.3	<0.3	0.46	0.14	0.53	67.7	15.5	<0.15	3.11	<0.01	136.0	<0.03
5 cm sludge/yr	45-60	7.3	0.65	58.9	2.9	196	0.4	14.9	2.4	3.0	<0.3	0.50	0.15	0.45	63.7	16.5	<0.15	2.95	<0.01	108.7	<0.03
5 cm sludge/yr	60-75	7.5	0.56	54.3	3.0	200	0.6	12.9	1.8	2.7	0.7	0.45	0.14	0.33	50.5	13.6	<0.15	2.75	<0.01	100.4	<0.03
5 cm sludge/yr	75-90	7.4	0.53	57.3	3.3	266	0.6	15.3	0.9	0.7	1.8	0.44	0.20	0.75	29.9	13.1	<0.15	3.23	<0.01	111.1	<0.03
5 cm sludge/yr	90-105	7.4	0.63	58.4	3.8	221	0.6	16.3	0.6	0.9	3.1	0.55	0.20	0.49	71.4	14.9	<0.15	3.18	<0.01	137.8	<0.03

continued...

Table 5 . (Continued) Mean Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Depth (cm)	Se	Al	Ca	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	B	K	Mn	Fe	Cr
		(mg/L)															
control	0-15	<0.3	0.20	77.2	0.09	0.02	<0.15	0.02	0.03	<0.02	<0.04	0.09	<0.30	3.32	0.05	1.08	<0.03
control	15-30	<0.3	0.13	94.3	0.10	0.02	<0.15	0.02	<0.02	<0.02	<0.04	0.14	<0.30	3.94	0.05	0.45	<0.03
control	30-45	<0.3	<0.07	107.6	0.05	0.02	<0.15	0.03	<0.02	<0.02	<0.04	0.10	<0.30	7.10	0.06	0.11	<0.03
control	45-60	<0.3	<0.07	78.4	0.03	0.02	<0.15	0.04	<0.02	<0.02	<0.04	<0.05	<0.30	6.85	0.04	0.11	<0.03
control	60-75	<0.3	<0.07	67.2	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	5.53	0.07	0.17	<0.03
control	75-90	<0.3	0.09	59.7	0.04	0.03	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	0.35	6.32	0.18	0.30	<0.03
control	90-105	<0.3	<0.07	54.4	0.04	0.02	<0.15	0.04	<0.02	<0.02	<0.04	<0.05	0.42	7.89	0.26	0.17	<0.03
1 cm sludge	0-15	<0.3	0.21	75.1	0.10	0.02	<0.15	0.02	0.02	<0.02	<0.04	0.07	<0.30	3.15	0.08	0.99	<0.03
1 cm sludge	15-30	<0.3	0.09	96.3	0.05	0.02	<0.15	0.02	<0.02	<0.02	<0.04	0.11	<0.30	4.04	0.05	0.42	<0.03
1 cm sludge	30-45	<0.3	<0.07	98.5	0.04	0.02	<0.15	0.05	<0.02	<0.02	<0.04	0.06	<0.30	7.60	0.05	0.13	<0.03
1 cm sludge	45-60	<0.3	<0.07	73.5	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	6.38	0.05	0.11	<0.03
1 cm sludge	60-75	<0.3	<0.07	71.7	0.03	0.02	<0.15	0.04	<0.02	<0.02	<0.04	<0.05	0.33	7.05	0.14	0.14	<0.03
1 cm sludge	75-90	<0.3	<0.07	62.4	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	0.44	6.65	0.20	0.14	<0.03
1 cm sludge	90-105	<0.3	0.08	44.1	0.04	0.03	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	0.41	6.50	0.13	0.17	<0.03
3 cm sludge	0-15	<0.3	0.28	79.9	0.10	0.04	<0.15	0.01	0.07	<0.02	<0.04	0.14	<0.30	1.91	0.06	2.46	<0.03
3 cm sludge	15-30	<0.3	0.13	98.7	0.07	0.03	<0.15	0.02	<0.02	<0.02	<0.04	0.23	<0.30	2.09	0.16	0.70	<0.03
3 cm sludge	30-45	<0.3	0.09	92.6	0.04	0.02	<0.15	0.02	<0.02	<0.02	<0.04	0.07	<0.30	5.90	0.06	0.21	<0.03
3 cm sludge	45-60	<0.3	<0.07	83.6	0.05	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	6.06	0.05	0.10	<0.03
3 cm sludge	60-75	<0.3	<0.07	69.2	0.03	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	6.05	0.06	0.09	<0.03
3 cm sludge	75-90	<0.3	<0.07	74.8	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	6.42	0.11	0.14	<0.03
3 cm sludge	90-105	<0.3	0.10	57.2	0.03	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	0.37	6.21	0.10	0.23	<0.03

continued..

Table 5 . (Concluded) Mean Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Depth (cm)	Se	Al	Ca	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	B	K	Mn	Fe	Cr
		(mg/L)															
5 cm sludge	0-15	<0.3	0.24	91.6	0.08	0.04	<0.15	0.02	0.05	<0.02	<0.04	0.20	<0.30	1.92	0.06	1.38	<0.03
5 cm sludge	15-30	<0.3	0.14	79.4	0.06	0.04	<0.15	0.02	0.04	<0.02	<0.04	0.32	<0.30	3.62	0.05	1.53	<0.03
5 cm sludge	30-45	<0.3	<0.07	90.0	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	0.11	<0.30	5.94	0.05	0.18	<0.03
5 cm sludge	45-60	<0.3	<0.07	90.8	0.03	0.02	<0.15	0.04	<0.02	<0.02	<0.04	<0.05	<0.30	7.98	0.05	0.19	<0.03
5 cm sludge	60-75	<0.3	0.10	71.1	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	6.85	0.06	0.43	<0.03
5 cm sludge	75-90	<0.3	<0.07	58.9	0.03	0.02	<0.15	0.04	<0.02	<0.02	<0.04	<0.05	0.33	8.18	0.08	0.08	<0.03
5 cm sludge	90-105	<0.3	<0.07	50.3	0.03	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	0.48	6.46	0.17	0.16	<0.03
5 cm sludge&ash	0-15	<0.3	0.12	105.1	0.06	0.05	<0.15	0.02	<0.02	<0.02	<0.04	0.13	0.33	14.34	0.04	0.59	<0.03
5 cm sludge&ash	15-30	<0.3	0.22	101.1	0.09	0.04	<0.15	0.02	0.12	<0.02	<0.04	0.44	<0.30	4.65	0.04	2.07	<0.03
5 cm sludge&ash	30-45	<0.3	<0.07	91.8	0.04	0.03	<0.15	0.03	<0.02	<0.02	<0.04	0.12	<0.30	5.72	0.04	0.16	<0.03
5 cm sludge&ash	45-60	<0.3	<0.07	93.3	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	0.08	<0.30	6.40	0.05	0.09	<0.03
5 cm sludge&ash	60-75	<0.3	0.08	80.7	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	0.44	6.44	0.15	0.13	<0.03
5 cm sludge&ash	75-90	<0.3	0.08	72.8	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	0.52	6.37	0.31	0.21	<0.03
5 cm sludge&ash	90-105	<0.3	<0.07	68.7	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	0.40	7.41	0.49	0.15	<0.03
5 cm sludge/yr	0-15	<0.3	0.28	116.3	0.21	0.07	<0.15	0.02	0.06	0.02	<0.04	0.62	<0.30	6.12	0.09	2.01	<0.03
5 cm sludge/yr	15-30	<0.3	0.14	86.6	0.10	0.04	<0.15	0.02	0.02	<0.02	<0.04	0.44	<0.30	6.72	0.11	0.98	<0.03
5 cm sludge/yr	30-45	<0.3	0.14	74.1	0.05	0.03	<0.15	0.03	<0.02	<0.02	<0.04	0.12	<0.30	5.53	0.07	0.50	<0.03
5 cm sludge/yr	45-60	<0.3	<0.07	75.7	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	0.09	<0.30	6.04	0.13	0.20	<0.03
5 cm sludge/yr	60-75	<0.3	<0.07	62.0	0.04	0.02	<0.15	0.04	<0.02	<0.02	<0.04	0.06	0.38	7.25	0.12	0.15	<0.03
5 cm sludge/yr	75-90	<0.3	0.09	63.1	0.05	0.04	<0.15	0.03	<0.02	<0.02	<0.04	0.06	0.44	7.04	0.44	0.28	<0.03
5 cm sludge/yr	90-105	<0.3	0.08	68.3	0.04	0.02	<0.15	0.04	<0.02	<0.02	<0.04	<0.05	0.54	8.39	0.30	0.19	<0.03

Table 6. Selected mean saturated paste data for the zone of sludge incorporation on three sampling dates.

Treatment	NO ₃ -N and NO ₂ -N mg/L			EC dS/m			SAR		
	Baseline	June 92	August 93	Baseline	June 92	August 93	Baseline	June 92	August 93
Control	<0.1	13.7	<0.1	0.77	0.90	0.57	3.1	2.4	2.6
1 cm sludge	2.4	0.1	<0.1	0.69	1.07	0.56	2.4	5.1	2.9
3 cm sludge	10.2	0.1	7.8	0.68	1.36	0.70	2.3	7.4	4.5
5 cm sludge	2.5	0.2	56.4	0.68	1.69	1.15	2.6	10.6	6.6
5 cm sludge and ash	1.8	0.2	38.3	0.68	2.02	1.11	2.3	11.4	5.4
5 cm sludge/yr.	1.5	0.2	122.1	0.86	2.00	1.60	3.4	12.4	10.3

45 cm depth. It seems probable that the brome grass is capable of using all the available nitrogen before it leaches below the root zone. It is also possible that there has been insufficient time for leaching to move the nitrates below 45 cm depth, although this seems unlikely considering the precipitation that has occurred. Data collected in 1994 should assist in determining which of these scenarios is occurring.

The highest EC values in the incorporation zone occur in the treatment receiving annual applications of sludge (EC of 1.6 dS/m). The 5 cm sludge and sludge plus ash treatments both have an EC of about 1.1 dS/m. Shortly following sludge application in 1992 these three treatments had mean EC values of 2.0, 1.7 and 2.0 dS/m, respectively. The reduced EC values by the end of the 1993 growing season indicate that salts are being removed from the incorporation zone. There does not appear to be an identifiable increase in EC below 30 cm depth in these treatments, so the leached salts must be spread over a considerable depth. The EC values in the 15-30 cm depth interval were also higher in 1992 than in 1993 because some sludge was incorporated into this zone during the application/ incorporation process.

The SAR values in the incorporation zone increase with increasing application rate of sludge. The mean values for the control, 1 cm, 3 cm, 5 cm, 5 cm sludge plus ash, and 5 cm/yr treatments were 2.6, 2.9, 4.5, 6.6, 5.4, and 10.3, respectively, in August 1993. Shortly after sludge application in 1992 these values were 2.4, 5.1, 7.4, 10.6, 11.4, and 12.4, respectively. There has been a major reduction in SAR in 1993 with the exception of the treatment receiving annual applications of sludge because this treatment received a new layer of sludge in 1993. The high SAR in 1992 was considered the main chemical limitation to land application of these sludges; the fact that it is a very temporary condition is of considerable importance. The leaching of sodium has not produced elevated sodium levels below 30 cm. The high values in the 15-30 cm zone are explained in the same manner as for EC described previously.

Using the ASAC (1987) guidelines to rate the incorporation zone of these soils all soils would be rated good for EC. In 1992 the 5 cm sludge per year and 5 cm sludge plus ash treatments just failed to meet the requirements for a good rating, and were rated fair.

In 1993 the control and 1 cm sludge treatments are rated good for SAR, the 3 cm, 5 cm, 5 cm ash and sludge treatments are rated fair, and the 5 cm sludge per year treatment rated poor. In 1992 only the control treatment was rated as good, the 1 cm and 3 cm sludge treatments rated fair, and the 5 cm sludge, 5 cm sludge plus ash, and 5 cm per year treatments all rated poor. Thus there has been a marked improvement in the ability of these soils to support and maintain healthy plant growth.

After sludge incorporation in 1992 some trace elements showed small but identifiable increases in saturation extracts from sludge and sludge/ash treated soils, as noted previously. Most of these could be related to the presence of these elements in the sludge and/or ash, but in the case of Ti, Cd, Co, and Ni the elevated levels were unusual because these elements were not present in higher concentration in the sludge or ash than in the soils. In the 1993 results these differences are no longer present for Cl, Al, Ti, Cd, Co, Mn, Fe, Si, and Mo. The differences remain for Zn and Cu, but only for the soils receiving fresh sludge in 1993.

DTPA EXTRACTABLE ELEMENT DATA

DTPA (diethylene triamine pentaacetic acid) extraction provides an approximation of the plant-available fraction of soil constituents. The data for the DTPA extractable elements from each plot are presented in Appendix 3. The mean values for each treatment are presented in Table 7, and Table 8 shows the trend of these values over time.

Shortly after sludge application in 1992 the plots receiving the highest rates of sludge and ash were found to have twice as much DTPA extractable phosphorus and potassium (three to four times with the ash treatment), approximately four times more extractable sodium, a slight elevation in manganese, and two to three times more boron with the ash treatment only. The increases in phosphorus and potassium are beneficial as these are important plant nutrients. The increase in sodium, boron, and manganese may not be desirable, but did not affect plant tissue levels of these elements.

At the end of the 1993 growing season these differences remain. DTPA available phosphorus is approximately three times higher in the plots treated with 5 cm of sludge than in the control plots, approximately five times higher in the plots given annual applications of sludge, and seven times higher in the plots receiving ash. The 1 cm and 3 cm treatments have intermediate levels, depending on the application rate. The actual amounts of DTPA extractable phosphorus in the plots receiving the annual sludge application have not changed much from the previous year, but the amount of available phosphorus has decreased in the other plots and in the control treatments, due largely to the fact that no fertilizer was applied in 1993.

Levels of DTPA extractable potassium are approximately fifty percent higher in the plots receiving annual additions of sludge than in the control plots, and two to three times higher with the ash treatment. Other treatments do not differ from the controls. In absolute terms the levels of DTPA extractable potassium have remained almost unchanged from the previous year in the control plots only, but has declined for all other treatments, in part because fertilizer was not applied in 1993. Potassium is an important plant nutrient so the increase noted for two of the treatments should have a positive impact on plant growth.

DTPA extractable sodium is four to five times higher in the plots receiving annual applications of sludge than in the controls, two to three times higher in the 3 cm and 5 cm sludge and sludge/ash treatments, and no different with the 1 cm sludge rate. In absolute terms the control plots and the plots receiving annual applications of sludge have not changed from the previous year; plant available sodium has decreased with all other treatments.

Boron remains somewhat elevated in two of the three plots where ash was applied. Manganese remains slightly elevated in the plots with the ash treatment.

TOTAL ELEMENTAL ANALYSIS

The data for the total elemental composition of the soils from each plot are presented in Appendix 4. The mean values for each treatment are presented in Table 9, and the trend of

Table 7. Mean DTPA-NHCO₃ Extract Data of Sludge and Ash Amended Soils.

Treatment	Depth (cm)	P	Mg	Na	Mo	Se	Ca	Zn	Cu	Pb	Cd	Ni	B	K	Mn	Fe
		ug/g														
control	0-15	5.84	284	252	<0.08	<0.80	611	9.16	3.04	1.44	0.41	3.17	0.26	91.3	10.25	292
control	15-30	5.69	284	292	<0.08	<0.80	591	9.79	3.16	1.52	0.35	3.26	0.26	91.2	14.84	301
control	30-45	3.72	277	217	<0.08	<0.80	393	3.81	4.17	1.78	0.23	3.14	0.32	123.2	14.44	266
control	45-60	2.66	276	183	<0.08	<0.80	409	2.78	3.68	1.70	0.18	2.90	0.27	124.8	15.19	193
control	60-75	2.89	271	187	0.10	<0.80	424	2.96	3.86	1.78	0.18	2.69	0.26	124.0	25.10	180
control	75-90	3.09	216	189	<0.08	<0.80	351	2.66	4.47	2.02	0.17	3.04	0.29	118.6	50.06	215
control	90-105	3.66	239	298	0.09	<0.80	324	4.14	5.70	2.34	0.19	3.29	0.49	131.0	83.66	259
1 cm sludge	0-15	6.98	286	251	<0.08	<0.80	592	6.21	2.76	1.35	0.31	2.52	0.25	108.1	9.75	251
1 cm sludge	15-30	4.79	286	275	<0.08	<0.80	526	6.14	2.87	1.45	0.30	2.88	0.29	96.3	10.80	284
1 cm sludge	30-45	3.48	311	248	<0.08	<0.80	400	5.33	4.50	1.98	0.27	3.08	0.41	129.9	18.66	292
1 cm sludge	45-60	3.22	291	163	<0.08	<0.80	412	4.72	4.57	2.25	0.27	3.37	0.40	121.9	26.72	288
1 cm sludge	60-75	3.32	305	179	<0.08	<0.80	375	5.47	5.49	2.65	0.28	3.91	0.47	127.4	61.27	315
1 cm sludge	75-90	3.51	273	177	0.09	<0.80	339	5.23	4.74	2.37	0.24	3.52	0.51	106.8	83.40	331
1 cm sludge	90-105	2.45	261	158	<0.08	<0.80	376	2.68	4.11	1.84	0.16	2.87	0.36	119.7	70.72	173
3 cm sludge	0-15	10.67	285	494	<0.08	<0.80	640	8.85	3.09	1.48	0.40	2.96	0.26	85.3	11.89	303
3 cm sludge	15-30	6.30	288	437	<0.08	<0.80	587	9.53	3.25	1.65	0.40	3.58	0.30	78.5	16.35	337
3 cm sludge	30-45	4.25	270	200	<0.08	<0.80	447	5.25	3.40	1.71	0.27	2.66	0.26	105.9	11.38	277
3 cm sludge	45-60	3.32	312	184	<0.08	<0.80	406	3.50	3.62	1.75	0.22	2.75	0.24	130.0	12.56	241
3 cm sludge	60-75	2.92	309	176	<0.08	<0.80	389	3.52	3.94	1.96	0.22	2.94	0.25	136.9	16.32	241
3 cm sludge	75-90	3.26	248	161	<0.08	<0.80	393	4.06	4.52	2.20	0.24	3.50	0.31	112.3	27.78	293
3 cm sludge	90-105	3.15	262	161	<0.08	<0.80	391	3.34	4.58	2.07	0.22	3.15	0.62	128.0	27.66	244
5 cm sludge	0-15	18.87	291	760	<0.08	<0.80	680	9.57	3.16	1.50	0.38	2.65	0.27	85.9	12.76	277
5 cm sludge	15-30	6.23	273	436	<0.08	<0.80	499	5.37	3.17	1.38	0.28	2.82	0.26	94.2	10.39	273
5 cm sludge	30-45	3.73	285	254	<0.08	<0.80	420	3.56	3.54	1.71	0.22	2.66	0.30	116.7	11.77	247
5 cm sludge	45-60	2.56	280	179	0.09	<0.80	420	2.65	3.56	1.74	0.17	2.31	0.26	128.0	11.47	170
5 cm sludge	60-75	2.78	270	181	<0.08	<0.80	428	2.55	3.84	1.80	0.19	2.80	0.27	130.7	24.59	171
5 cm sludge	75-90	2.58	274	209	0.12	<0.80	385	2.97	4.61	1.80	0.16	2.81	0.25	146.9	39.64	161
5 cm sludge	90-105	3.26	237	178	0.09	<0.80	375	2.52	4.54	1.77	0.18	2.82	0.29	126.9	53.49	179
5 cm sludge&ash	0-15	41.16	368	557	<0.08	<0.80	657	7.29	3.69	1.22	0.29	2.38	0.77	253.0	17.07	206
5 cm sludge&ash	15-30	10.68	268	605	<0.08	<0.80	536	7.15	2.83	1.29	0.32	2.99	0.36	117.4	12.30	271
5 cm sludge&ash	30-45	4.83	279	217	<0.08	<0.80	406	5.25	3.57	1.78	0.28	3.06	0.29	115.7	13.50	314
5 cm sludge&ash	45-60	3.52	272	167	<0.08	<0.80	377	4.71	4.16	2.27	0.28	3.38	0.34	114.7	21.55	340
5 cm sludge&ash	60-75	3.56	279	167	<0.08	<0.80	395	5.17	4.38	2.38	0.28	3.73	0.45	116.8	64.42	321
5 cm sludge&ash	75-90	3.67	290	198	0.09	<0.80	418	6.39	4.75	2.33	0.30	4.11	0.64	118.7	100.78	297
5 cm sludge&ash	90-105	4.07	288	201	0.11	<0.80	345	5.22	5.06	2.50	0.24	4.10	0.62	129.1	139.47	298
5 cm sludge/yr	0-15	31.01	291	1157	<0.08	<0.80	674	8.86	3.27	1.45	0.37	2.67	0.24	154.6	14.64	224
5 cm sludge/yr	15-30	15.70	272	679	<0.08	<0.80	509	7.41	3.88	1.70	0.32	3.29	0.27	139.8	18.63	269
5 cm sludge/yr	30-45	4.79	278	288	<0.08	<0.80	429	4.40	4.07	1.74	0.26	3.54	0.31	123.9	26.98	250
5 cm sludge/yr	45-60	3.98	266	215	<0.08	<0.80	399	4.09	4.48	1.90	0.23	3.91	0.37	111.8	55.71	253
5 cm sludge/yr	60-75	2.89	284	201	0.10	<0.80	362	2.89	5.09	2.03	0.19	3.96	0.38	131.5	57.60	213
5 cm sludge/yr	75-90	4.32	252	251	0.10	<0.80	376	5.14	4.97	2.20	0.24	4.32	0.50	120.5	139.14	236
5 cm sludge/yr	90-105	3.74	270	299	0.11	<0.80	342	5.26	5.21	2.17	0.23	3.94	0.53	136.2	90.22	262

Table 8. Selected mean DTPA-NH₄CO₃ extractable element data for the zone of sludge incorporation on three sampling dates.

Treatment	Phosphorus µg/g			Potassium µg/g			Sodium µg/g		
	Baseline	June 92	August 93	Baseline	June 92	August 93	Baseline	June 92	August 93
Control	9.2	13.2	5.8	103	102	91	315	252	252
1 cm sludge	7.0	18.1	7.0	92	129	108	215	505	251
3 cm sludge	6.2	22.9	10.7	87	199	85	204	940	494
5 cm sludge	7.3	24.3	18.9	93	196	86	228	1126	760
5 cm sludge and ash	8.5	42.5	41.2	91	427	253	235	1003	557
5 cm sludge/yr.	6.4	29.4	31.0	96	227	155	303	1334	1157

Table 9. Mean Elemental Analysis of Sludge and Ash Amended Soils in 1993.

Treatment	Depth (cm)	Zr	Sr	Ba	P	Mg	V	Na	Mo	Al	Ca	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	K	Mn	Fe	Cr	
		ug/g																						
control	0-15	94.5	169.5	562	867	4177	67.9	7306	<17.0	36408	17415	87.6	24.1	9.9	25.3	2170	0.72	21.3	27.5	10099	431	19683	54.1	
control	15-30	94.3	182.0	535	807	3989	65.1	7776	<17.0	34429	17047	84.6	23.6	9.5	23.1	2065	0.54	22.3	26.0	9626	456	19266	53.3	
control	30-45	100.2	93.8	400	662	2860	77.9	8290	<17.0	26076	10797	73.3	22.1	11.1	24.2	2434	0.28	<17.0	26.8	9512	483	19839	52.3	
control	45-60	100.2	114.0	486	609	3689	80.0	8159	<17.0	32629	9654	68.1	19.8	10.9	25.5	2487	0.25	<17.0	27.6	11008	511	20706	52.8	
control	60-75	101.0	92.5	405	591	2819	78.2	7923	<17.0	27037	9884	68.0	19.4	11.1	24.2	2431	0.46	<17.0	27.4	9308	606	20202	48.7	
control	75-90	102.3	112.1	470	737	3601	83.1	8055	<17.0	32100	10047	71.2	20.9	11.3	25.8	2537	0.67	<17.0	27.6	10795	521	24352	52.7	
control	90-105	103.1	132.4	533	693	4590	79.8	8491	<17.0	36584	12369	75.6	22.4	10.5	25.3	2482	0.48	<17.0	27.7	11427	437	22985	54.9	
30	1 cm sludge	0-15	97.4	189.0	637	773	5010	75.4	8071	<17.0	43829	15169	80.8	22.4	9.1	26.9	2389	0.81	21.2	28.3	11270	522	21743	61.6
	1 cm sludge	15-30	91.6	143.8	543	688	3908	72.0	7850	<17.0	36076	14653	76.8	22.0	9.6	26.4	2308	0.64	21.9	28.9	9976	438	20680	57.8
	1 cm sludge	30-45	103.2	118.0	447	699	3973	92.0	8050	<17.0	33782	13832	77.3	24.6	11.5	29.1	2737	0.35	24.9	29.6	9752	460	22634	60.1
	1 cm sludge	45-60	103.3	151.4	534	679	4556	82.2	8011	<17.0	40041	13422	74.2	21.4	11.1	27.8	2540	0.30	22.2	27.5	10617	488	22460	61.7
	1 cm sludge	60-75	106.4	178.6	642	760	5448	91.3	8537	<17.0	46784	15835	81.3	25.4	11.4	32.2	2679	0.46	24.5	32.8	11755	509	24898	66.7
	1 cm sludge	75-90	106.6	132.5	511	649	4276	85.0	7973	<17.0	38087	12972	110.8	84.4	11.6	28.4	2550	0.47	25.7	29.8	10631	466	21376	61.3
	1 cm sludge	90-105	123.2	115.1	485	605	4020	89.4	8477	<17.0	36186	10819	73.4	24.2	10.9	27.9	2828	0.34	23.9	31.2	10940	443	22144	62.4
30	3 cm sludge	0-15	100.6	150.1	573	849	4036	63.9	7457	<17.0	32901	17007	77.9	22.0	9.2	22.5	2068	0.49	25.1	25.3	9250	411	18701	49.1
	3 cm sludge	15-30	103.6	158.7	596	747	4350	64.0	7665	<17.0	35167	16974	74.9	21.5	10.7	22.1	2055	0.40	23.8	25.9	9572	442	18746	51.2
	3 cm sludge	30-45	109.1	130.1	563	637	4463	70.6	7589	<17.0	37348	12620	68.8	20.2	13.7	23.0	2251	0.39	24.5	26.8	10586	444	20404	54.2
	3 cm sludge	45-60	114.5	123.6	553	595	4464	81.9	7789	<17.0	39113	11452	72.4	21.4	11.7	26.8	2473	0.32	28.8	29.9	10861	483	22368	60.2
	3 cm sludge	60-75	106.8	103.6	443	616	3548	83.5	8320	<17.0	32961	10770	74.8	21.2	11.9	26.1	2540	0.60	<17.0	28.2	10095	484	21860	54.9
	3 cm sludge	75-90	97.6	116.3	480	649	3618	71.8	8075	<17.0	33771	11370	68.3	19.8	12.2	23.3	2262	0.34	<17.0	26.2	10154	501	20866	52.4
	3 cm sludge	90-105	106.4	113.9	510	632	3923	79.8	7863	<17.0	34971	11873	70.9	22.5	12.1	25.6	2466	0.27	<17.0	26.6	10587	401	20677	54.4

continued...

Table 9. (Concluded) Mean Elemental Analysis of Sludge and Ash Amended Soils in 1993.

Treatment	Depth (cm)	Zr	Sr	Ba	P	Mg	V	Na	Mo	Al	Ca	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	K	Mn	Fe	Cr	
		ug/g																						
5 cm sludge	0-15	95.7	172.2	615	1056	4545	67.3	8294	<17.0	37466	18715	81.1	22.4	9.9	20.5	2160	0.56	19.8	25.3	10036	448	19395	54.6	
5 cm sludge	15-30	102.6	139.4	571	729	4293	77.7	9029	<17.0	37301	13753	75.1	21.0	10.8	22.9	2466	0.38	20.2	23.3	11081	442	21491	57.7	
5 cm sludge	30-45	108.8	122.3	511	704	4116	82.7	8979	<17.0	36299	12582	74.4	22.5	11.4	24.7	2582	0.31	23.3	25.3	11133	448	22341	60.7	
5 cm sludge	45-60	123.1	133.6	587	639	5213	80.1	8321	<17.0	41259	12500	71.5	20.0	11.4	23.1	2462	0.32	26.3	25.0	12106	464	22413	58.4	
5 cm sludge	60-75	116.5	112.2	504	666	4467	76.8	9210	<17.0	34633	12313	73.8	21.3	11.8	20.6	2412	0.28	25.6	21.3	11262	445	21138	55.2	
5 cm sludge	75-90	129.7	96.0	456	688	4137	86.5	8449	<17.0	30946	12381	83.1	23.8	11.9	21.3	2573	0.28	25.7	25.7	10681	443	22082	58.6	
5 cm sludge	90-105	119.2	107.9	512	672	4517	80.4	8355	<17.0	34752	11893	77.9	22.4	15.5	20.9	2493	0.53	23.5	24.5	11434	424	21082	55.5	
151	5 cm sludge&ash	0-15	93.7	207.3	687	1342	4766	62.7	8140	<17.0	36468	26132	87.3	23.0	9.9	20.5	2045	0.60	19.0	26.3	10660	423	18618	51.2
	5 cm sludge&ash	15-30	94.9	157.9	596	864	4297	69.7	8728	<17.0	37469	15789	84.9	23.0	10.4	22.6	2247	0.40	22.2	25.8	10746	489	20251	55.2
	5 cm sludge&ash	30-45	96.1	120.8	510	708	3720	77.5	8945	<17.0	32851	11711	82.9	22.6	10.5	24.1	2415	0.31	21.6	27.3	10537	542	21972	56.8
	5 cm sludge&ash	45-60	93.6	127.6	511	648	4103	73.8	8298	<17.0	35923	11540	76.8	21.2	10.8	23.6	2327	0.32	20.0	24.9	10738	460	20648	57.4
	5 cm sludge&ash	60-75	96.3	137.9	513	678	4097	73.6	8316	<17.0	34949	12769	84.2	22.2	11.4	25.1	2349	0.21	20.8	25.4	10604	502	21397	54.6
	5 cm sludge&ash	75-90	96.1	173.5	574	752	4664	74.3	7805	<17.0	36695	15027	85.4	22.8	11.6	24.3	2340	0.21	20.5	28.0	10618	611	21280	58.7
	5 cm sludge&ash	90-105	99.6	145.3	554	717	4802	78.3	8537	<17.0	39833	13042	83.1	23.3	12.9	25.0	2434	0.53	22.4	25.5	11014	459	21992	58.8
	5 cm sludge/yr	0-15	97.5	155.4	553	1176	4153	69.2	8789	<17.0	35752	16173	83.3	23.7	9.1	25.3	2211	0.39	22.9	27.4	10449	465	19947	56.1
	5 cm sludge/yr	15-30	98.1	147.4	536	889	4053	72.3	8353	<17.0	36261	14245	79.7	21.8	10.9	25.2	2303	0.34	22.2	27.3	10651	447	20789	54.6
	5 cm sludge/yr	30-45	101.8	118.8	452	706	3449	81.1	8341	<17.0	33874	11087	74.8	23.1	11.2	27.5	2491	0.31	25.0	29.5	10438	524	21563	59.5
	5 cm sludge/yr	45-60	99.6	136.4	506	665	3852	75.1	8081	<17.0	35826	11484	70.7	20.5	12.0	25.7	2380	0.32	22.3	26.7	10724	521	21200	56.7
	5 cm sludge/yr	60-75	103.7	132.2	490	688	4188	83.8	8578	<17.0	38135	11330	91.6	42.1	11.8	28.1	2556	0.34	23.3	30.3	11125	545	22816	59.8
	5 cm sludge/yr	75-90	105.1	161.4	573	655	4633	74.7	7764	<17.0	41058	12641	75.9	21.1	10.5	26.3	2374	0.47	21.9	27.9	11181	539	21939	57.8
	5 cm sludge/yr	90-105	105.0	138.1	507	697	4313	85.9	7687	<17.0	37830	12157	84.1	24.9	12.4	28.7	2599	0.32	19.8	30.9	10961	463	22595	59.1

these values over time is shown in Table 10. As noted previously (Thacker and Macyk 1993), most elements are present in lower concentrations in the ash and sludge than in the soils. The exceptions to this are phosphorus (five to ten times higher concentration) and sodium (three times higher concentration). There are also slightly higher concentrations of Mg, Ca, Zn, Cu, K, and Mn, but the differences were too small to have a detectable effect on the treated soils. After the soils were amended in 1992 there were slight increases in total phosphorus with the 5 cm sludge and sludge/ash treatments only, and possibly very slightly increased total sodium with those same treatments.

Table 10 Selected mean total elemental data for the zone of sludge incorporation on three sampling dates.

Treatment	Phosphorus µg/g			Sodium µg/g		
	Baseline	June 92	August 93	Baseline	June 92	August 93
Control	818	968	867	5463	5407	7306
1 cm sludge	724	905	773	6322	5784	8071
3 cm sludge	794	935	849	5628	5602	7457
5 cm sludge	764	1018	1056	5758	5746	8294
5 cm sludge and ash	645	1272	1342	5169	6215	8140
5 cm sludge/yr.	807	1041	1176	5604	6304	8789

At the end of the 1993 growing season the 5 cm sludge and sludge/ash treatments still have slightly higher levels of phosphorus. There are no remaining differences in total sodium that can be detected.

Measured total calcium is two to three times higher than the 5000 to 7000 µg/g detected in 1992. The 1992 values were considered to be low and this was attributed to difficulties in achieving complete dissolution of complexed calcium (Thacker and Macyk 1993). The 1993 values appear to be more consistent with what should be expected for these soils. The data shows a 50% increase in total calcium with the sludge/ash treatment, which was not apparent in the data from the previous year. This is likely a real effect.

Compared to average values for soils (Table 11) the elemental concentrations in the soils are within the normal range, generally very close to the average value for soils (Lindsay 1979). The

Table 11 Elemental Constituents of Soils

Element	Mean	Maximum	Minimum	Element	Mean	Maximum	Minimum
C (%)	2.00			Li ($\mu\text{g/g}$)	20.00	200.0	5.000
Ca (mg/g)	13.70	500.0	7.000	Cr ($\mu\text{g/g}$)	100.00	1000.0	1.000
Mg (mg/g)	5.00	6.0	0.600	Cu ($\mu\text{g/g}$)	30.00	100.0	2.000
Ti (mg/g)	4.00	10.0	1.000	Hg ($\mu\text{g/g}$)	0.03	0.3	0.010
Na (mg/g)	6.30	7.5	0.750	Ni ($\mu\text{g/g}$)	40.00	500.0	5.000
S (mg/g)	0.70	10.0	0.030	Pb ($\mu\text{g/g}$)	10.00	200.0	2.000
P (mg/g)	0.60	5.0	0.200	Co ($\mu\text{g/g}$)	8.00	40.0	1.000
Sr (mg/g)	0.20	1.0	0.050	Mo ($\mu\text{g/g}$)	2.00	5.0	0.200
Al (mg/g)	71.00	300.0	10.000	Cd ($\mu\text{g/g}$)	0.06	0.7	0.010
Si (mg/g)	320.00	350.0	230.000	Se ($\mu\text{g/g}$)	0.30	2.0	0.100
B (mg/g)	0.01	0.1	0.002	Ag ($\mu\text{g/g}$)	0.05	5.0	0.010
Ba (mg/g)	0.43	3.0	0.100	Zn ($\mu\text{g/g}$)	50.00	300.0	10.000
Fe (mg/g)	38.00	550.0	7.000	V ($\mu\text{g/g}$)	100.0	500.0	20.000
K (mg/g)	8.30	30.0	0.400	As ($\mu\text{g/g}$)	5.00	50.0	1.000
Mn (mg/g)	0.60	3.0	0.020	Zr ($\mu\text{g/g}$)	300.0	2000.0	60.0

From Lindsay (1979).

slight change in phosphorus concentration that is related to sludge application is insignificant when compared to the normal range for phosphorus in soils.

PLANT TISSUE COMPOSITION

Table 12 provides data for the elemental composition of dried plant tissue from each plot. In 1992 it was noted that tissue sodium increased several fold with the higher rates of amendment. Other changes were minor, amounting to less than a 50% change from control plot values, and included decreases in tissue calcium and magnesium (ash treatment only) and increases in tissue chloride, sulfur, and phosphorus.

In 1993 there still appears to be a significant increase in tissue sodium as the rate of sludge increases. There is quite a bit of variability between plots within each treatment, but the average concentration of tissue sodium increases several fold from the control to the 3 cm and 5 cm sludge treatments. The actual levels of tissue sodium appear to be several times lower than was observed in 1992.

Tissue phosphorus increases from approximately 2000 µg/g in the control plots to almost 4000 µg/g in the plots receiving 5 cm of sludge. The 1 cm and 3 cm rates produce intermediate results. The pattern for sulfur is similar, with mean concentrations increasing from about 1500 µg/g in the control plots to 2500-3000 µg/g with the 5 cm rate of sludge application. There also appears to be an approximately 50% increase in Sr, Mg, Ca, Zn and Fe with the 5 cm rate of sludge application, and somewhat lesser increases with the 1 cm and 3 cm rates of sludge. The sludge plus ash treatment results in an approximately 50% increase in tissue potassium.

The tissue elemental concentrations can be compared to mean values reported for brome grass by Jones et. al. (1991), for grasses in general reported by Chapman (1966), and for "plants" reported by Page et. al. (1981). Table 13 shows nutrient and some trace element concentrations that are considered low, sufficient, or high for brome grass tissue.

The tissue from the control plots is deficient in phosphorus, the 1 cm and 3 cm sludge plot tissue has sufficient phosphorus, and the 5 cm rate of sludge yields tissue that is considered high in phosphorus. Tissue potassium is increased in the ash plots, but the change is not great, and all treatments yield tissue with sufficient potassium. Tissue calcium is normal with all treatments. Magnesium is low in the control and 1 cm sludge plots and also in the plots that include ash. Magnesium is sufficient with the 3 cm and 5 cm rates of sludge. Tissue sulfur is low in the control plots and normal with all other treatments.

The trace element concentrations at less than several µg/g should be regarded with some caution as these concentrations are near the detection limit of the ICP-AES. For the trace elements listed in Table 13, the tissue from all treatments appears to be slightly deficient in boron, copper, and manganese. Zinc is low in the control plots and iron is low in the control and 1 cm plots. Higher rates of sludge yield tissues with normal concentrations of zinc and iron.

For other trace elements the information is somewhat less reliable because published data are for

Table 12. Analysis of Tissue Samples.

Treatment	Plot No.	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo	Se	Al	Ca	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	B	K	Mn	Fe	Cr	Cl
		ug/g																										
control	6	11.64	2.85	2298	1730	1121	<6.0	622.9	<0.6	21.8	<0.6	<6.0	<6.0	2419	21.18	5.14	<0.6	<6.0	<0.6	0.17	<0.6	<6.0	7.30	27786	32.91	43.58	<0.6	6353
control	7	13.28	3.18	2157	1376	1037	<6.0	718.0	<0.6	<6.0	<0.6	<6.0	<6.0	2734	16.73	3.32	<0.6	<6.0	<0.6	0.11	<0.6	<6.0	8.13	22670	24.30	35.29	<0.6	4276
control	17	12.04	4.30	1828	1188	1002	<6.0	625.7	<0.6	<6.0	0.64	<6.0	<6.0	2759	14.66	3.52	<0.6	<6.0	<0.6	0.17	<0.6	<6.0	4.42	20344	26.10	45.10	<0.6	3714
1 cm sludge	2	13.96	3.57	2846	2038	1279	<6.0	551.3	<0.6	41.8	<0.6	<6.0	<6.0	2765	103.49	4.33	<0.6	<6.0	<0.6	0.17	<0.6	<6.0	8.94	26571	30.08	48.58	<0.6	4375
1 cm sludge	11	13.55	4.43	2616	1897	1341	<6.0	667.5	<0.6	<6.0	<0.6	<6.0	<6.0	3313	22.14	3.77	<0.6	<6.0	<0.6	0.29	<0.6	<6.0	6.34	26309	34.20	48.66	<0.6	3906
1 cm sludge	15	13.69	5.04	2389	1798	1280	<6.0	511.2	<0.6	<6.0	<0.6	<6.0	<6.0	3234	23.10	4.24	<0.6	<6.0	<0.6	0.17	<0.6	<6.0	3.12	26426	32.49	43.12	<0.6	4392
3 cm sludge	4	16.68	5.22	3407	2590	1603	<6.0	498.3	<0.6	122.7	<0.6	<6.0	<6.0	3532	29.79	5.13	<0.6	<6.0	<0.6	0.23	<0.6	<6.0	5.40	26868	28.50	65.07	<0.6	3773
3 cm sludge	9	16.44	5.83	3833	3044	1664	<6.0	518.8	<0.6	137.6	<0.6	<6.0	<6.0	3654	29.55	5.57	<0.6	<6.0	<0.6	0.23	<0.6	<6.0	5.60	26972	28.41	60.77	<0.6	2821
3 cm sludge	18	15.01	5.51	3222	2540	1668	<6.0	537.9	<0.6	21.4	<0.6	<6.0	<6.0	3517	29.45	4.49	<0.6	<6.0	<0.6	0.18	<0.6	<6.0	1.22	23731	28.07	62.01	<0.6	3145
5 cm sludge	3	16.52	5.79	4035	3083	1663	<6.0	558.5	<0.6	132.0	<0.6	<6.0	<6.0	3440	31.68	5.28	<0.6	<6.0	<0.6	0.18	<0.6	<6.0	10.16	30316	28.75	95.88	<0.6	4555
5 cm sludge	12	14.85	5.68	3544	2705	1525	<6.0	419.1	<0.6	84.5	<0.6	<6.0	<6.0	3275	32.67	5.09	<0.6	<6.0	<0.6	0.22	<0.6	<6.0	25.23	24026	26.16	60.71	<0.6	3126
5 cm sludge	14	17.20	6.03	3309	2662	1755	<6.0	510.2	<0.6	98.9	<0.6	<6.0	<6.0	3865	29.86	4.22	<0.6	<6.0	<0.6	0.24	<0.6	<6.0	4.61	23163	21.44	62.01	<0.6	3356
5 cm sludge&ash	1	11.79	3.40	3959	2647	1237	<6.0	619.0	<0.6	110.9	<0.6	<6.0	<6.0	2415	27.44	5.64	<0.6	<6.0	<0.6	0.17	<0.6	<6.0	51.64	35268	30.49	61.20	<0.6	3540
5 cm sludge&ash	10	13.49	4.19	3657	3116	1372	<6.0	551.4	<0.6	38.3	<0.6	<6.0	<6.0	3027	24.57	4.93	<0.6	<6.0	<0.6	0.97	<0.6	<6.0	6.29	33807	23.59	72.60	<0.6	2589
5 cm sludge&ash	13	15.37	4.72	3347	2621	1358	<6.0	565.6	<0.6	48.1	<0.6	<6.0	<6.0	3257	25.32	4.85	<0.6	<6.0	<0.6	0.23	<0.6	<6.0	3.88	29449	17.00	54.99	<0.6	2087

"grasses" or "plants" and there may be significant differences between species. Chapman (1966) reports the normal chloride level for grasses is 7000 µg/g, thus all the treatments have low tissue chloride levels in comparison. In 1992 the grasses had high tissue chloride. Chapman also reports normal tissue sodium levels for grasses are 300 to 1100 µg/g, which makes the tissue from all plots deficient in sodium. Because of the interpretation questions raised above it may be more significant to note that tissue sodium has decreased in all treatments compared to the 1992 data, and still shows a pattern of increasing sodium levels as the rate of sludge increases.

Some other trace elements, which are not affected by the sludge or ash treatments, can be compared to the normal elemental concentrations in plant tissues reported by Page et. al. (1981). Arsenic does not appear to exceed the normal tissue concentration of 0.1 to 5 µg/g, vanadium is at or below the normal range for plants of 0.1 to 10 µg/g, molybdenum is at or below the normal plant range of 1 to 100 µg/g, selenium is well below the toxic level of 50 µg/g, lead is at or below the normal range for plants of 0.1 to 10 µg/g, cadmium does not exceed the normal level of 0.2 to 0.8 µg/g, cobalt does not exceed normal tissue levels of 0.05 to 0.5 µg/g, nickel is at or below the normal plant tissue level of 1 to 10 µg/g, and chromium does not exceed the normal concentration of 0.2 to 1.0 µg/g. These levels are very similar to those observed in 1992.

Table 13 Concentration of selected elements in brome grass tissue.

Element	Low	Sufficient	High
	%		
N	<2.00	2.00 - 3.5	>3.5
P	<0.25	0.25 - 0.35	>0.35
K	<2.00	2.00 - 3.5	>3.5
Ca	<0.25	0.25 - 0.4	>0.4
Mg	<0.14	0.14 - 0.3	>0.3
S	<0.17	0.17 - 0.3	>0.3
	ppm		
B	<10	10 - 20	>20
Cu	<5	5 - 10	>10
Fe	<50	50 - 100	>100
Mn	<40	40 - 80	>80
Zn	<20	20 - 50	>50

From Jones, et. al. (1991).

Where the sludge has had an impact on the chemical composition of the brome grass tissue the impacts appear to be favourable:

1. Tissue sulfur and tissue zinc are low in the control plots only.
2. Tissue iron is below normal in the control and 1 cm sludge treatments only.
3. Tissue sodium is low with all treatments, but higher sodium levels are noted as the rate of sludge increases.
4. Tissue magnesium is normal with the 3 cm and 5 cm rates of sludge, and below normal with all other treatments.
5. Tissue phosphorus is low in the control plots, normal with the 1 cm and 3 cm rates of sludge, but above normal with the 5 cm rates of sludge and sludge/ash.

SUMMARY

GRASS HARVEST

After two full growing seasons the sludge still has a strong fertilizing effect on the brome grass at the 3 cm and 5 cm sludge application rates. June yields were about double those of the controls with these two treatments, and August yields were three times those of the controls with 3 cm sludge, and five times with 5 cm sludge. This indicates that the rate of nutrient release from the sludge occurs over a considerable length of time, which is beneficial both in terms of plant nutrition and in protecting groundwater quality. Yields with 1 cm of sludge have not shown a significant difference from those of the control plots.

The August 1993 harvest was the first time that a statistical difference between the 3 cm and 5 cm sludge treatments was evident. This may be an indication that nutrients are being depleted from the 3 cm sludge treatment; in which case it should become more apparent in 1994.

CHEMICAL AND PHYSICAL PROPERTIES

Soil pH values in the amended plots have declined from those measured immediately following sludge application and only the sludge plus ash treatment has a pH value more than one half unit higher than the control plots (7.0 vs. 7.8) for the zone of incorporation). In 1992 this treatment was 1.2 pH units higher than the control plot values. Below the zone of incorporation there are no differences in pH that can be related to soil treatment.

The calcium carbonate equivalent for the ash treatment is four to five times higher than for the control treatment, although it still is fairly low at about two percent. Other treatments have had no effect on the calcium carbonate equivalent. Carbon and nitrogen should have been increased by the sludge based on the carbon and nitrogen content of the sludge, but no evidence of this can be found in the data. There is no pattern in C/N ratios that can be related to soil treatment.

Using the ASAC (1987) guidelines for pH (using calcium chloride pH values), organic carbon, and calcium carbonate equivalent, the incorporation zone of these soils receives a good rating

for all treatments, except for pH with the sludge plus ash treatment, which is rated fair.

SATURATED PASTE EXTRACTS

The plots receiving 5 cm sludge in 1992 now have EC values in the incorporation zone of about 1.1 dS/m, compared to 2.0 dS/m shortly after incorporation. In the plots receiving annual additions of sludge the EC is about 1.6 dS/m. The 1993 values would all meet the ASAC requirement for a good rating of an EC less than 2.0 dS/m. EC values in the incorporation zone are decreasing as salts are leached downward, but there was no identifiable zone at depth where EC was higher than background levels.

The SAR was identified previously as the main potential chemical limitation to the land application of these sludges. Soil quality ratings (ASAC 1987) based on SAR were poor for all treatments using 5 cm of sludge, and fair for treatments using 1 cm or 3 cm of sludge. Only the control plots received a good rating. At the end of the 1993 growing season these ratings have improved so that the control and 1 cm treatments receive a good rating, and all other treatments are rated as fair except for the treatment using annual additions of sludge, which continues to warrant a poor rating. The reduction in SAR is a very positive trend in the evolution of these sludge amended soils. The effect on SAR continues to be restricted to the incorporation zone; the leaching of sodium has not produced an identifiable increase in SAR at depth.

The soils treated with the 3 cm or 5 cm of sludge or sludge/ash have several times more ammonium-nitrogen and phosphorus in the incorporation zone than the control soils (except for ammonium in the ash treated plots). Potassium in the 5 cm sludge plots has decreased from elevated levels in 1992 to levels comparable to the control plots, but remains higher in the plots receiving ash and the plots given additional sludge in 1993. There is also a substantial increase in nitrite and nitrate in the plots receiving 3 cm or 5 cm of sludge that shows up in the 1993 data but not the 1992 data. The source of this nitrate is decomposition of the sludge material. This increase in nitrate levels is limited to the upper 45 cm of the soil profile so does not appear to pose a threat of contamination to groundwater. These increased nutrient levels in the sludge treated soils should be beneficial to plant nutrition.

The slight increase of many trace elements in the incorporation zone immediately after sludge addition is no longer apparent except for zinc and copper in the plots receiving fresh sludge in 1993.

DTPA EXTRACTABLE ELEMENTS

DTPA available phosphorus is approximately three times higher in the plots treated with 5 cm of sludge than in the control plots, approximately five times higher in the plots given annual applications of sludge, and seven times higher in the plots receiving ash. The 1 cm and 3 cm treatments have intermediate levels, depending on the application rate. DTPA extractable potassium is two to three times higher in the ash treated plots than in the controls and approximately fifty percent higher in the plots receiving annual additions of sludge. Other treatments do not differ from the controls. In absolute terms the level of DTPA extractable

potassium has declined in all plots because fertilizer was not applied in 1993. Phosphorus and potassium are important plant nutrients so these elevated levels in the sludge treated plots should benefit plant nutrition.

DTPA extractable sodium is four to five times higher with the annual sludge application treatment than in the control treatment, two to three times higher in the 3 cm and 5 cm sludge and sludge/ash treatments, and no different with the 1 cm sludge rate. The sodium levels in the control plots and the plots receiving annual applications of sludge have not changed from the previous year, but plant available sodium has decreased with all other treatments. This reflects the reduction in SAR noted above.

TOTAL ELEMENTAL ANALYSIS

At the end of the 1993 growing season the soils receiving the 5 cm sludge and sludge/ash treatments have slightly higher total phosphorus than soils from the other treatments as was also observed in 1992. The ash treated soils have approximately 50% more calcium than the other treatments.

Compared to average values for soils the elemental concentrations in the soils from all treatments are within the normal range and are generally very close to the average values for soils. The slight trends in phosphorus and calcium that are related to sludge treatment are insignificant when compared to the normal range for these elements in soils.

PLANT TISSUE COMPOSITION

The plant tissue from the various treatments had normal or below normal elemental concentrations when compared to published values for brome grass, grass, or plants in general. The sludge had no impact on the tissue concentration of most elements, but where it does have an impact it is generally favourable in raising below normal values to those considered more normal.

POSITIVE AND NEGATIVE IMPACTS

Positive impacts

The major positive impact of the amendments continues to be a marked increase in grass yield as the rate of sludge increases. Yields with the 1 cm rate are not significantly different from the control treatment, but the 3 cm and 5 cm rates of sludge increased the dry matter yields by a factor of two for the June harvest and a factor of three to five for the August harvests.

Other impacts that can be considered positive are a general improvement in plant tissue elemental concentrations and an increase in extractable nutrients in the soil, most notably the major plant nutrients nitrogen, phosphorus and potassium (K in ash treated soils only). The increased availability of nitrogen and phosphorus is likely the main cause of the increased yields in the sludge treated soils.

A positive effect that is difficult to quantify is that the measurable impact of the sludge remains restricted to the incorporation zone after two growing seasons. The only exception to this is the nitrates and nitrites in saturation extracts, but these drop to background levels below 45 cm depth.

Overall, the positive impacts identified in 1992 continue to be very evident in 1993.

Negative impacts

The most potentially serious negative impact of the sludge and ash amendments noted in 1992 was the observed increase in EC and especially SAR. EC no longer is a concern as all soils receive a good rating for EC according to the ASAC guidelines. Leaching has reduced the EC at the highest treatment rates from about 2.0 dS/m in 1992 to about 1.1 dS/m in 1993.

The SAR has also shown a significant improvement. According to the ASAC guidelines, at the end of the 1993 growing season the soils with the 5 cm sludge and sludge/ash treatments were rated as fair, rather than the poor rating they received in 1992. The treatment receiving annual applications of sludge is the only treatment that still is rated as poor.

The increase in pH associated with the sludge and ash was also identified as a negative impact in 1992. However, the pH values have decreased from those measured after incorporation and it is now only the treatment that includes ash that differs by more than one half a pH unit (0.8) from the control soils. In more acidic soils this increase in pH could be beneficial.

In 1992 the amendments resulted in high chloride and sulfur concentrations in the plant tissue. This is not an issue in 1993, as tissue chloride in 1993 is considered low and appears unrelated to the sludge treatment, and tissue sulfur is low in the control plots but normal with all other treatments. The sludge also tended to improve tissue concentrations of magnesium, zinc, and iron. Phosphorus was normal with the 1 cm and 3 cm rates of sludge only, the control plots had low tissue phosphorus and the 5 cm rate resulted in above normal phosphorus levels.

The negative impacts identified in 1992 have generally become much less pronounced in 1993.

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APPENDIX 1

Appendix 1 . Chemical and Physical Properties of Sludge and Ash Amended Soils in 1993 .

Treatment	Plot No.	Depth (cm)	pH H ₂ O	pH CaCl ₂	Total N (%)	Total C (%)	Organic C (%)	C/N Ratio	CaCO ₃ Eq. (%)	Extractable Cations				CEC
										Na	K	Ca	Mg	
													cmol(+) /Kg	
control	6	0-15	7.4	7.0	0.45	7.23	7.18	15.9	0.4	1.43	0.30	51.5	8.94	63.9
control	6	15-30	7.4	7.1	0.43	7.76	7.73	18.1	0.2	1.92	0.33	52.8	9.06	64.3
control	6	30-45	7.5	7.2	0.26	3.98	3.87	15.0	1.0	1.44	0.43	35.4	6.76	39.0
control	6	45-60	7.6	7.3	0.12	1.61	1.43	12.3	1.5	1.04	0.40	33.8	4.90	22.9
control	6	60-75	7.9	7.5	0.08	1.43	1.21	16.2	1.8	0.84	0.39	24.9	4.64	18.7
control	6	75-90	7.8	7.4	0.10	1.74	1.59	15.7	1.3	1.07	0.37	23.0	4.18	20.8
control	6	90-105	8.1	7.7	0.06	1.13	0.88	14.2	2.1	1.57	0.45	24.1	5.03	17.8
control	7	0-15	7.4	7.0	0.56	7.20	7.15	12.7	0.4	1.16	0.33	65.7	10.79	81.8
control	7	15-30	7.4	7.0	0.55	8.99	8.94	16.2	0.4	1.32	0.39	70.2	11.60	87.7
control	7	30-45	7.6	7.4	0.22	3.60	3.52	15.8	0.7	0.71	0.37	37.0	6.97	39.8
control	7	45-60	7.6	7.3	0.17	2.65	2.58	15.7	0.6	0.66	0.37	30.0	6.18	33.5
control	7	60-75	7.4	7.2	0.20	2.66	2.62	13.4	0.3	0.85	0.37	31.8	6.51	37.3
control	7	75-90	7.6	7.3	0.21	3.74	3.65	17.7	0.7	1.07	0.44	35.4	6.96	40.1
control	7	90-105	7.5	7.2	0.21	3.48	3.31	15.5	1.4	1.09	0.41	36.6	6.58	39.1
control	17	0-15	7.4	7.0	0.56	7.21	7.17	12.8	0.3	0.85	0.40	65.8	10.43	81.0
control	17	15-30	7.4	6.9	0.48	5.81	5.78	12.0	0.3	0.91	0.32	57.5	9.49	71.6
control	17	30-45	7.4	7.0	0.24	2.63	2.59	11.0	0.3	0.49	0.33	31.6	6.16	36.5
control	17	45-60	7.5	7.1	0.18	2.81	2.75	15.4	0.5	0.35	0.32	27.1	5.49	30.8
control	17	60-75	7.5	7.1	0.23	3.42	3.39	14.7	0.3	0.42	0.32	31.8	5.87	36.1
control	17	75-90	7.6	7.2	0.21	4.10	4.03	18.9	0.6	0.49	0.34	33.4	6.01	35.8
control	17	90-105	7.2	6.8	0.35	4.90	4.85	13.9	0.4	0.99	0.33	47.2	7.49	57.0
1 cm sludge	2	0-15	7.5	7.2	0.47	6.83	6.79	14.3	0.4	1.28	0.39	52.7	8.88	63.5
1 cm sludge	2	15-30	7.7	7.2	0.35	5.55	5.52	15.6	0.2	1.44	0.35	54.1	8.57	53.0
1 cm sludge	2	30-45	7.8	7.5	0.19	3.35	3.12	16.5	1.9	1.42	0.54	44.8	8.54	40.4
1 cm sludge	2	45-60	7.7	7.3	0.29	4.13	4.06	13.9	0.6	0.81	0.42	46.0	8.35	51.0
1 cm sludge	2	60-75	7.6	7.3	0.24	3.59	3.48	14.8	0.9	0.84	0.55	38.9	8.26	45.5
1 cm sludge	2	75-90	7.4	7.1	0.25	2.89	2.82	11.2	0.6	0.77	0.41	38.7	7.58	45.4
1 cm sludge	2	90-105	7.9	7.5	0.14	2.18	2.02	14.5	1.4	0.63	0.37	28.4	5.37	26.3
1 cm sludge	11	0-15	7.5	7.1	0.38	5.34	5.28	13.8	0.5	0.99	0.29	47.6	7.73	57.1
1 cm sludge	11	15-30	7.4	7.1	0.37	5.12	5.07	13.7	0.4	1.28	0.24	51.7	8.30	60.6
1 cm sludge	11	30-45	7.6	7.3	0.35	5.36	5.27	15.3	0.8	1.01	0.31	51.7	8.58	56.3
1 cm sludge	11	45-60	7.8	7.4	0.20	2.59	2.44	12.5	1.3	0.66	0.33	37.9	6.86	37.3
1 cm sludge	11	60-75	7.7	7.3	0.27	2.70	2.64	9.6	0.5	0.89	0.32	49.5	9.39	57.6
1 cm sludge	11	75-90	7.5	7.1	0.42	1.75	1.70	4.0	0.4	1.17	0.31	56.0	9.94	72.2
1 cm sludge	11	90-105	7.7	7.2	0.29	1.99	1.91	6.5	0.6	1.12	0.37	46.6	7.83	53.3
1 cm sludge	15	0-15	7.5	7.1	0.35	4.83	4.77	13.8	0.5	1.07	0.31	42.4	7.04	49.6
1 cm sludge	15	15-30	7.4	7.1	0.27	4.00	3.96	14.5	0.4	0.92	0.27	35.1	6.14	41.4
1 cm sludge	15	30-45	7.5	7.1	0.28	5.63	5.60	19.8	0.3	0.79	0.31	40.9	7.41	47.0
1 cm sludge	15	45-60	7.5	7.1	0.28	5.22	5.17	18.5	0.4	0.65	0.32	38.5	7.00	43.3
1 cm sludge	15	60-75	7.4	7.0	0.37	6.53	6.47	17.3	0.5	0.70	0.31	48.6	8.18	58.0
1 cm sludge	15	75-90	7.6	7.2	0.17	1.34	1.31	7.7	0.3	0.41	0.26	27.6	5.09	31.8
1 cm sludge	15	90-105	7.9	7.5	0.05	0.59	0.54	11.7	0.4	0.25	0.26	13.2	3.97	14.9

continued...

Appendix 1. Chemical and Physical Properties of Sludge and Ash Amended Soils in 1993.

Treatment	Plot No.	Depth (cm)	pH H ₂ O	pH CaCl ₂	Total N (%)	Total C (%)	Organic C (%)	C/N Ratio	CaCO ₃ Eq. (%)	Extractable Cations				CEC
										Na	K	Ca	Mg	
													cmol(+) / Kg	
3 cm sludge	4	0-15	7.6	7.2	0.59	7.51	7.47	12.6	0.3	2.74	0.26	63.5	10.47	79.6
3 cm sludge	4	15-30	7.5	7.1	0.52	6.55	6.46	12.4	0.7	2.06	0.29	63.1	10.30	79.8
3 cm sludge	4	30-45	7.8	7.4	0.12	1.91	1.87	15.6	0.3	0.75	0.38	28.3	5.44	26.4
3 cm sludge	4	45-60	7.8	7.3	0.10	1.26	1.10	11.5	1.3	0.75	0.53	26.8	6.64	29.7
3 cm sludge	4	60-75	7.7	7.3	0.10	1.28	1.20	11.6	0.6	0.72	0.57	28.1	7.27	31.1
3 cm sludge	4	75-90	7.5	7.1	0.16	3.20	3.12	19.2	0.6	0.56	0.33	28.1	4.94	29.3
3 cm sludge	4	90-105	7.8	7.3	0.11	1.61	1.47	13.1	1.1	0.53	0.37	27.5	5.19	24.4
3 cm sludge	9	0-15	7.6	7.2	0.69	11.84	11.81	17.1	0.2	2.66	0.28	71.3	11.43	88.0
3 cm sludge	9	15-30	7.4	7.1	0.54	8.90	8.86	16.5	0.3	2.01	0.25	60.2	10.01	74.3
3 cm sludge	9	30-45	7.2	7.0	0.28	3.82	3.79	13.5	0.2	0.83	0.26	36.2	6.47	43.1
3 cm sludge	9	45-60	7.4	7.1	0.29	4.85	4.80	16.3	0.4	0.99	0.34	43.3	7.83	48.9
3 cm sludge	9	60-75	7.5	7.2	0.30	4.41	4.35	14.7	0.5	0.93	0.37	42.9	7.79	48.3
3 cm sludge	9	75-90	7.6	7.3	0.22	4.10	4.03	18.2	0.6	0.95	0.33	37.3	6.58	40.4
3 cm sludge	9	90-105	7.7	7.5	0.15	1.92	1.55	10.5	3.1	0.74	0.36	35.5	5.67	28.5
3 cm sludge	18	0-15	7.3	6.9	0.47	8.20	8.18	17.5	0.2	1.37	0.35	55.9	8.99	67.7
3 cm sludge	18	15-30	7.2	6.9	0.50	8.49	8.47	17.0	0.2	1.75	0.26	59.6	9.62	73.9
3 cm sludge	18	30-45	7.1	6.7	0.46	7.90	7.88	17.1	0.2	0.86	0.36	53.4	9.14	67.6
3 cm sludge	18	45-60	7.4	7.0	0.26	3.29	3.26	12.6	0.2	0.41	0.32	32.3	6.00	37.4
3 cm sludge	18	60-75	7.4	7.0	0.23	4.09	4.06	17.5	0.3	0.42	0.32	32.0	5.67	36.1
3 cm sludge	18	75-90	7.2	6.9	0.32	4.38	4.33	13.8	0.4	0.62	0.33	42.9	6.83	49.2
3 cm sludge	18	90-105	7.1	6.7	0.38	6.36	6.34	16.8	0.2	0.85	0.37	48.6	7.79	60.3
5 cm sludge	3	0-15	7.7	7.3	0.70	9.07	9.01	12.8	0.5	3.79	0.31	64.5	10.52	79.3
5 cm sludge	3	15-30	7.8	7.3	0.29	2.77	2.67	9.3	0.9	1.69	0.32	40.5	7.27	43.9
5 cm sludge	3	30-45	7.8	7.4	0.15	2.37	2.22	14.8	1.2	0.99	0.38	31.0	6.24	30.3
5 cm sludge	3	45-60	7.8	7.5	0.09	1.53	1.36	14.4	1.5	0.58	0.40	26.7	5.53	21.6
5 cm sludge	3	60-75	7.8	7.5	0.10	2.04	1.84	17.8	1.7	0.48	0.38	30.2	5.21	22.5
5 cm sludge	3	75-90	7.9	7.5	0.08	1.29	1.08	13.6	1.8	0.38	0.35	24.4	4.82	18.6
5 cm sludge	3	90-105	7.9	7.4	0.10	1.34	1.19	12.3	1.2	0.36	0.32	25.8	4.37	19.6
5 cm sludge	12	0-15	7.6	7.2	0.68	12.41	12.36	18.1	0.4	3.75	0.26	67.7	10.66	84.8
5 cm sludge	12	15-30	7.5	7.2	0.48	5.91	5.87	12.1	0.4	2.77	0.27	58.2	9.30	70.5
5 cm sludge	12	30-45	7.5	7.2	0.27	3.46	3.40	12.5	0.5	1.46	0.29	36.1	6.33	41.0
5 cm sludge	12	45-60	7.6	7.3	0.14	1.59	1.48	10.8	1.0	0.86	0.33	27.4	5.33	24.8
5 cm sludge	12	60-75	7.6	7.4	0.14	2.20	1.99	14.1	1.7	0.85	0.38	31.5	5.58	28.3
5 cm sludge	12	75-90	7.7	7.4	0.12	1.90	1.70	14.7	1.6	0.68	0.36	31.2	5.07	25.2
5 cm sludge	12	90-105	7.9	7.4	0.12	1.47	1.27	11.0	1.7	0.67	0.36	31.2	5.29	24.5
5 cm sludge	14	0-15	7.7	7.2	0.62	8.57	8.53	13.8	0.3	3.84	0.26	61.9	9.48	77.2
5 cm sludge	14	15-30	7.7	7.2	0.30	4.63	4.61	15.6	0.2	1.84	0.24	38.5	6.64	45.0
5 cm sludge	14	30-45	7.4	7.0	0.27	3.99	3.95	14.7	0.4	0.79	0.34	37.5	7.20	44.2
5 cm sludge	14	45-60	7.5	7.0	0.23	2.99	2.91	12.9	0.7	0.75	0.31	33.9	6.47	39.9
5 cm sludge	14	60-75	7.5	7.0	0.21	3.12	3.05	14.7	0.6	0.95	0.30	32.5	6.23	38.2
5 cm sludge	14	75-90	7.7	7.2	0.27	2.06	1.89	6.9	1.4	1.72	0.57	37.7	7.75	42.3
5 cm sludge	14	90-105	7.7	7.0	0.21	2.28	2.15	10.1	1.1	1.23	0.36	33.8	5.74	38.4

continued...

Appendix 1. (Concluded) Chemical and Physical Properties of Sludge and Ash Amended Soils in 1993 .

Treatment	Plot No.	Depth (cm)	pH	pH	Total N (%)	Total C (%)	Organic C (%)	C/N Ratio	CaCO ₃ Eq. (%)	Extractable Cations				CEC
			H ₂ O	CaCl ₂						Na	K	Ca	Mg	
			cmol(+) / Kg											
5 cm sludge&ash	1	0-15	8.1	7.8	0.62	7.84	7.58	12.3	2.1	2.42	1.03	83.2	12.92	64.1
5 cm sludge&ash	1	15-30	7.8	7.3	0.36	5.57	5.50	15.4	0.6	1.85	0.38	46.9	7.78	51.0
5 cm sludge&ash	1	30-45	7.6	7.3	0.20	3.18	3.10	15.4	0.6	0.77	0.38	31.3	6.22	33.0
5 cm sludge&ash	1	45-60	7.7	7.3	0.23	4.44	4.35	19.0	0.7	0.70	0.39	38.3	7.08	39.6
5 cm sludge&ash	1	60-75	7.6	7.1	0.36	5.55	5.46	15.4	0.8	0.70	0.41	49.3	8.65	55.6
5 cm sludge&ash	1	75-90	7.4	7.0	0.41	7.11	6.99	16.9	1.0	0.83	0.40	57.4	9.52	65.6
5 cm sludge&ash	1	90-105	7.7	7.3	0.14	1.26	1.15	8.0	0.9	0.57	0.42	29.1	6.45	31.4
5 cm sludge&ash	10	0-15	8.2	7.8	0.59	9.13	8.95	15.2	1.5	2.63	0.71	80.7	10.75	58.8
5 cm sludge&ash	10	15-30	7.7	7.3	0.44	7.41	7.37	16.7	0.4	2.63	0.34	55.6	8.84	61.3
5 cm sludge&ash	10	30-45	7.6	7.3	0.34	5.69	5.64	16.8	0.4	1.31	0.31	42.7	7.22	46.8
5 cm sludge&ash	10	45-60	7.6	7.2	0.26	4.31	4.26	16.4	0.4	0.76	0.30	36.0	6.62	38.6
5 cm sludge&ash	10	60-75	7.5	7.1	0.26	5.18	5.13	19.4	0.4	0.72	0.28	39.2	6.82	44.1
5 cm sludge&ash	10	75-90	7.7	7.4	0.20	2.98	2.93	14.9	0.4	0.60	0.31	33.5	6.26	33.9
5 cm sludge&ash	10	90-105	7.6	7.2	0.42	5.45	5.37	12.7	0.7	1.05	0.34	58.5	8.95	64.4
5 cm sludge&ash	13	0-15	8.2	7.7	0.47	5.12	4.87	10.4	2.1	2.82	0.72	67.4	10.04	51.8
5 cm sludge&ash	13	15-30	8	7.6	0.51	8.31	8.21	16.0	0.8	4.40	0.42	66.5	9.61	64.1
5 cm sludge&ash	13	30-45	7.5	7.1	0.26	4.67	4.60	17.9	0.6	0.72	0.32	36.2	6.60	41.8
5 cm sludge&ash	13	45-60	7.4	7.0	0.27	4.96	4.90	18.1	0.5	0.69	0.32	37.0	6.76	44.1
5 cm sludge&ash	13	60-75	7.5	7.1	0.24	2.71	2.63	11.0	0.7	0.73	0.34	36.1	6.74	40.3
5 cm sludge&ash	13	75-90	7.5	7.0	0.38	4.28	4.21	11.2	0.6	1.20	0.35	46.6	8.50	57.6
5 cm sludge&ash	13	90-105	7.5	7.0	0.27	4.18	4.10	15.3	0.7	1.05	0.37	37.9	7.03	43.8
5 cm sludge/yr	5	-15, Ju	7.8	7.5	0.78	13.32	13.23	16.9	0.8	9.54	1.01	66.1	10.61	77.7
5 cm sludge/yr	8	-15, Ju	7.8	7.5	0.85	12.22	12.15	14.4	0.6	8.94	0.98	68.2	10.90	83.1
5 cm sludge/yr	16	-15, Ju	7.8	7.4	0.61	10.68	10.65	17.4	0.3	6.83	0.75	54.7	8.91	66.2
5 cm sludge/yr	5	0-15	7.7	7.3	0.65	8.05	7.97	12.3	0.7	4.10	0.58	55.8	9.27	64.9
5 cm sludge/yr	5	15-30	7.8	7.5	0.49	5.74	5.67	11.7	0.6	3.82	0.62	49.2	8.36	52.3
5 cm sludge/yr	5	30-45	7.7	7.3	0.20	3.51	3.42	17.0	0.7	1.10	0.41	32.1	6.28	33.4
5 cm sludge/yr	5	45-60	7.8	7.4	0.17	2.64	2.52	15.0	1.0	0.78	0.36	32.1	6.22	33.4
5 cm sludge/yr	5	60-75	7.5	7.1	0.15	2.66	2.53	16.6	1.1	0.65	0.40	30.6	5.69	28.6
5 cm sludge/yr	5	75-90	7.6	7.2	0.08	1.44	1.25	15.0	1.6	0.47	0.37	24.0	4.36	19.2
5 cm sludge/yr	5	90-105	7.7	7.3	0.07	1.21	1.06	15.0	1.2	0.47	0.36	26.0	4.73	18.8
5 cm sludge/yr	8	0-15	7.7	7.4	0.65	8.50	8.42	12.9	0.6	5.28	0.49	61.2	10.12	74.8
5 cm sludge/yr	8	15-30	7.7	7.3	0.46	7.00	6.93	15.2	0.6	2.85	0.40	56.1	9.29	64.7
5 cm sludge/yr	8	30-45	7.8	7.5	0.23	4.51	4.40	18.9	0.9	0.95	0.42	40.5	7.12	41.0
5 cm sludge/yr	8	45-60	7.7	7.4	0.21	3.70	3.62	17.3	0.6	0.73	0.37	37.6	7.06	39.1
5 cm sludge/yr	8	60-75	7.8	7.5	0.18	2.41	2.33	13.2	0.7	0.64	0.34	31.2	6.67	34.3
5 cm sludge/yr	8	75-90	7.6	7.2	0.41	6.42	6.29	15.2	1.1	1.55	0.38	54.9	9.00	64.6
5 cm sludge/yr	8	90-105	7.6	7.3	0.32	4.52	4.34	13.4	1.5	2.23	0.55	46.7	8.98	56.9
5 cm sludge/yr	16	0-15	7.8	7.4	0.66	9.67	9.64	14.7	0.3	6.25	0.39	55.5	9.02	68.3
5 cm sludge/yr	16	15-30	7.5	7.1	0.36	5.55	5.54	15.6	0.1	2.38	0.35	42.3	7.29	50.5
5 cm sludge/yr	16	30-45	7.4	7.0	0.34	5.05	5.03	14.9	0.1	1.52	0.32	39.2	6.96	46.7
5 cm sludge/yr	16	45-60	7.5	7.0	0.37	6.96	6.94	18.8	0.2	1.26	0.33	45.6	7.69	55.1
5 cm sludge/yr	16	60-75	7.7	7.3	0.23	2.91	2.76	12.4	1.2	1.22	0.45	36.8	7.45	41.4
5 cm sludge/yr	16	75-90	7.5	7.1	0.29	5.10	5.03	17.4	0.6	1.09	0.36	39.8	6.90	45.9
5 cm sludge/yr	16	90-105	7.3	6.9	0.33	6.31	6.25	19.3	0.5	0.92	0.33	41.8	7.04	49.3

A P P E N D I X 2

Appendix 2. Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	pH	E.C. (dS/m)	%SAT	SAR	HCO ₃	CO ₃	Cl	NO ₂ -N	NO ₃ -N & NO ₂ -N	NH ₄ -N	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo	(mg/L)											
control	6	0-15	7.0	0.67	72.4	3.7	269	0.23	16.8	<0.1	<0.1	1.85	0.39	0.16	0.83	46.6	14.92	<0.15	4.34	<0.01	135.7	<0.03												
control	6	15-30	6.8	0.95	75.2	4.9	277	0.16	15.0	<0.1	<0.1	0.60	0.50	0.17	0.87	105.8	19.60	<0.15	4.08	<0.01	199.8	<0.03												
control	6	30-45	7.3	1.40	60.0	4.6	195	0.37	13.7	0.45	0.76	<0.3	0.91	0.22	0.26	248.1	33.77	<0.15	2.81	<0.01	243.4	<0.03												
control	6	45-60	7.5	1.08	48.0	4.9	140	0.42	10.8	0.23	0.49	<0.3	0.60	0.09	<0.20	175.8	18.23	<0.15	2.56	<0.01	197.2	<0.03												
control	6	60-75	7.7	0.70	43.6	4.8	178	0.84	11.5	0.15	0.41	<0.3	0.32	0.12	<0.20	79.8	9.16	<0.15	2.62	<0.01	142.0	<0.03												
control	6	75-90	7.6	0.59	43.5	6.0	228	0.85	13.7	<0.1	0.41	<0.3	0.23	0.10	0.33	40.4	5.97	<0.15	2.85	<0.01	146.3	<0.03												
control	6	90-105	7.8	0.81	43.2	9.5	235	1.39	12.5	0.13	0.60	<0.3	0.24	0.06	<0.20	84.4	5.29	<0.15	2.48	<0.01	207.6	0.03												
48	control	7	0-15	6.5	0.52	91.0	2.5	193	0.06	17.1	<0.1	<0.1	<0.3	0.39	0.18	1.03	27.2	13.76	<0.15	4.47	<0.01	89.9	<0.03											
	control	7	15-30	6.6	0.72	96.0	2.6	208	0.08	13.7	<0.1	<0.1	0.44	0.57	0.16	0.71	74.2	21.31	<0.15	4.78	<0.01	112.5	<0.03											
	control	7	30-45	7.3	0.61	58.4	2.6	189	0.35	8.9	<0.1	<0.1	0.43	0.58	0.11	0.38	68.5	16.31	<0.15	2.57	<0.01	97.2	<0.03											
	control	7	45-60	7.2	0.63	55.0	2.6	162	0.24	10.8	<0.1	<0.1	<0.3	0.63	0.13	0.32	80.3	17.02	<0.15	2.70	<0.01	99.0	<0.03											
	control	7	60-75	7.2	0.66	54.5	3.0	168	0.25	12.0	<0.1	0.32	<0.3	0.68	0.16	0.43	90.9	17.86	<0.15	3.11	<0.01	117.0	<0.03											
	control	7	75-90	7.4	0.67	59.0	3.9	220	0.52	12.6	0.52	1.04	<0.3	0.62	0.21	0.48	67.9	14.46	<0.15	2.89	<0.01	136.8	<0.03											
	control	7	90-105	7.5	0.40	52.4	4.2	260	0.69	12.8	<0.1	0.24	0.76	0.47	0.23	0.50	40.8	11.66	<0.15	3.26	<0.01	136.1	<0.03											
control	17	0-15	6.9	0.53	86.5	1.5	205	0.15	20.2	<0.1	<0.1	0.69	0.44	0.20	0.48	31.6	17.97	<0.15	4.53	<0.01	59.4	<0.03												
control	17	15-30	6.6	0.55	87.6	1.7	165	0.06	14.1	<0.1	<0.1	<0.3	0.42	0.17	0.59	47.8	18.18	<0.15	4.96	<0.01	66.1	<0.03												
control	17	30-45	7.0	0.58	54.8	1.5	182	0.17	10.7	<0.1	<0.1	<0.3	0.41	0.17	0.29	57.3	20.19	<0.15	3.85	<0.01	59.1	<0.03												
control	17	45-60	7.2	0.44	47.2	1.3	165	0.25	9.7	1.71	2.05	<0.3	0.29	0.14	0.34	28.8	14.33	<0.15	3.54	<0.01	44.9	<0.03												
control	17	60-75	7.1	0.45	56.0	1.3	178	0.21	9.3	1.24	2.38	<0.3	0.33	0.13	0.33	27.0	14.88	<0.15	3.46	<0.01	46.5	<0.03												
control	17	75-90	7.2	0.52	57.6	1.5	185	0.28	10.9	1.93	2.61	<0.3	0.40	0.18	0.31	38.4	16.05	<0.15	2.88	<0.01	56.3	<0.03												
control	17	90-105	7.1	0.58	66.8	2.4	252	0.30	15.7	0.93	1.07	1.38	0.41	0.22	0.54	24.3	15.69	<0.15	4.28	<0.01	86.6	<0.03												

continued...

Appendix 2 . (Continued) Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	pH	E.C. (dS/m)	%SAT	SAR	HCO ₃	CO ₃	Cl	NO ₂ -N	NO ₃ -N & NO ₂ -N	NH ₄ -N	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo	(mg/L)											
1 cm sludge	2	0-15	6.5	0.62	81.2	3.4	253	0.08	21.0	<0.1	<0.1	<0.3	0.43	0.19	1.17	32.4	15.10	<0.15	4.98	<0.01	122.7	<0.03												
1 cm sludge	2	15-30	7.1	1.10	68.8	3.9	219	0.23	8.9	<0.1	0.11	<0.3	0.72	0.13	0.32	168.9	27.21	<0.15	3.05	<0.01	184.7	<0.03												
1 cm sludge	2	30-45	7.3	1.39	64.4	4.3	157	0.29	6.4	0.49	0.76	<0.3	1.26	0.10	<0.20	250.1	34.23	<0.15	1.65	<0.01	219.6	<0.03												
1 cm sludge	2	45-60	7.4	0.69	61.6	2.5	208	0.49	8.8	1.01	1.76	<0.3	0.63	0.13	0.31	73.3	18.67	<0.15	2.52	<0.01	98.2	<0.03												
1 cm sludge	2	60-75	7.2	0.77	67.6	2.6	164	0.24	10.6	0.29	0.71	<0.3	0.69	0.16	0.21	99.9	20.29	<0.15	2.76	<0.01	103.6	<0.03												
1 cm sludge	2	75-90	7.3	0.66	61.9	2.7	196	0.37	14.0	0.54	1.22	<0.3	0.45	0.15	0.31	61.2	16.39	<0.15	3.72	<0.01	95.9	<0.03												
1 cm sludge	2	90-105	7.6	0.47	45.6	3.3	199	0.75	10.1	<0.1	<0.1	<0.3	0.25	0.10	0.26	27.0	8.48	<0.15	3.16	<0.01	88.2	<0.03												
49																																		
1 cm sludge	11	0-15	6.6	0.50	66.4	2.5	198	0.07	18.8	<0.1	<0.1	<0.3	0.39	0.21	0.98	26.2	15.25	<0.15	4.10	<0.01	90.1	<0.03												
1 cm sludge	11	15-30	6.8	0.76	68.0	2.8	196	0.10	10.6	<0.1	<0.1	<0.3	0.45	0.16	0.57	81.8	19.76	<0.15	3.82	<0.01	116.2	<0.03												
1 cm sludge	11	30-45	7.1	0.57	67.6	2.3	206	0.24	9.3	<0.1	<0.1	<0.3	0.39	0.14	0.38	45.9	15.98	<0.15	2.79	<0.01	85.1	<0.03												
1 cm sludge	11	45-60	7.5	0.51	54.4	2.1	176	0.52	9.6	<0.1	0.18	<0.3	0.36	0.12	0.29	41.8	13.91	<0.15	2.65	<0.01	69.4	<0.03												
1 cm sludge	11	60-75	7.4	0.46	60.4	2.2	196	0.46	11.8	1.46	2.19	<0.3	0.30	0.13	0.32	24.0	13.45	<0.15	3.04	<0.01	70.6	<0.03												
1 cm sludge	11	75-90	7.3	0.47	74.0	2.5	239	0.45	15.5	<0.1	0.16	0.85	0.33	0.17	0.44	16.3	14.26	<0.15	4.67	<0.01	83.8	<0.03												
1 cm sludge	11	90-105	7.4	0.50	61.6	2.9	222	0.52	16.4	<0.1	0.16	<0.3	0.34	0.13	0.39	20.3	11.30	<0.15	3.92	<0.01	90.2	<0.03												
1 cm sludge	15	0-15	6.8	0.56	68.4	2.8	225	0.13	16.6	<0.1	<0.1	<0.3	0.38	0.21	0.85	26.6	14.79	<0.15	3.77	<0.01	100.3	<0.03												
1 cm sludge	15	15-30	6.9	0.53	59.6	2.6	186	0.14	10.7	<0.1	<0.1	<0.3	0.33	0.16	0.65	40.9	14.18	<0.15	3.65	<0.01	89.6	<0.03												
1 cm sludge	15	30-45	7.1	0.64	66.4	2.4	183	0.22	9.3	<0.1	0.16	<0.3	0.48	0.09	0.45	71.6	19.93	<0.15	2.87	<0.01	93.8	<0.03												
1 cm sludge	15	45-60	7.3	0.53	64.4	1.9	184	0.34	11.0	0.55	0.85	<0.3	0.43	0.13	0.36	45.7	16.84	<0.15	2.80	<0.01	68.6	<0.03												
1 cm sludge	15	60-75	7.3	0.51	69.2	1.8	224	0.42	13.1	0.37	0.55	1.38	0.45	0.20	0.47	24.6	16.34	<0.15	3.37	<0.01	64.3	<0.03												
1 cm sludge	15	75-90	7.5	0.41	46.0	1.7	202	0.60	12.6	<0.1	0.18	0.92	0.31	0.15	0.27	11.3	11.77	<0.15	4.43	<0.01	52.6	<0.03												
1 cm sludge	15	90-105	7.7	0.30	38.8	1.6	146	0.69	12.7	0.67	1.16	<0.3	0.20	0.12	<0.20	6.4	7.55	<0.15	4.02	<0.01	39.9	<0.03												

continued...

Appendix 2. (Continued) Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	pH	E.C. (dS/m)	%SAT	SAR	HCO ₃	CO ₃	Cl	NO ₂ -N	NO ₃ -N & NO ₂ -N	NH ₄ -N	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo
							(mg/L)															
3 cm sludge	4	0-15	7.0	0.78	81.6	5.5	441	0.41	15.6	<0.1	<0.1	2.61	0.39	0.21	2.31	46.1	13.90	<0.15	4.73	<0.01	198.9	<0.03
3 cm sludge	4	15-30	6.9	0.83	78.4	4.5	249	0.19	9.4	4.68	5.82	0.67	0.44	0.12	0.55	97.5	16.88	<0.15	4.13	<0.01	175.8	<0.03
3 cm sludge	4	30-45	7.4	0.72	47.2	3.6	159	0.38	5.8	0.28	0.62	<0.3	0.43	0.10	<0.20	105.7	14.76	<0.15	3.35	<0.01	129.5	<0.03
3 cm sludge	4	45-60	7.2	0.59	57.2	3.0	133	0.20	10.9	0.19	0.69	<0.3	0.29	0.10	<0.20	76.5	12.20	<0.15	3.91	<0.01	97.9	<0.03
3 cm sludge	4	60-75	7.5	0.49	55.0	2.8	138	0.41	10.3	0.25	0.96	<0.3	0.25	0.08	<0.20	52.1	10.54	<0.15	3.90	<0.01	83.4	<0.03
3 cm sludge	4	75-90	7.4	0.52	49.2	2.7	199	0.47	14.3	0.43	1.39	<0.3	0.34	0.16	0.36	39.5	11.90	<0.15	3.67	<0.01	89.7	<0.03
3 cm sludge	4	90-105	7.4	0.38	46.4	2.9	177	0.42	12.8	<0.1	0.22	<0.3	0.21	0.10	<0.20	19.1	7.43	<0.15	3.43	<0.01	73.5	<0.03
3 cm sludge	9	0-15	6.9	0.79	110.0	5.2	480	0.36	15.0	9.38	15.50	6.03	0.49	0.15	2.11	50.4	17.69	<0.15	4.97	<0.01	206.4	<0.03
3 cm sludge	9	15-30	6.8	0.95	90.0	4.3	260	0.15	10.2	<0.1	<0.1	1.17	0.71	0.21	1.03	162.9	28.23	<0.15	3.85	<0.01	210.2	<0.03
3 cm sludge	9	30-45	7.1	0.79	56.8	2.8	130	0.15	6.7	1.73	2.23	<0.3	0.56	0.14	0.36	164.4	27.25	<0.15	3.41	<0.01	134.9	<0.03
3 cm sludge	9	45-60	7.2	0.82	62.4	3.0	160	0.24	8.0	1.07	1.54	<0.3	0.66	0.12	0.34	153.2	26.88	<0.15	2.73	<0.01	140.9	<0.03
3 cm sludge	9	60-75	7.3	0.53	61.6	3.0	174	0.33	10.2	1.05	1.30	<0.3	0.55	0.16	0.41	96.5	18.63	<0.15	2.46	<0.01	118.4	<0.03
3 cm sludge	9	75-90	7.3	0.64	56.4	2.8	175	0.33	12.3	1.47	2.08	<0.3	0.60	0.14	0.34	81.7	17.94	<0.15	2.35	<0.01	106.4	<0.03
3 cm sludge	9	90-105	7.3	0.55	52.4	2.7	160	0.30	10.4	0.38	0.55	<0.3	0.44	0.11	0.26	65.8	13.30	<0.15	2.75	<0.01	91.7	<0.03
3 cm sludge	18	0-15	6.9	0.54	90.0	2.8	234	0.17	15.2	<0.1	0.11	0.72	0.36	0.20	1.42	24.5	13.85	<0.15	4.43	<0.01	99.7	<0.03
3 cm sludge	18	15-30	6.8	0.61	92.0	3.1	218	0.13	9.8	<0.1	<0.1	<0.3	0.37	0.20	0.98	49.8	14.79	<0.15	3.71	<0.01	112.6	<0.03
3 cm sludge	18	30-45	6.7	0.49	85.0	1.7	155	0.07	9.1	<0.1	0.17	<0.3	0.38	0.20	0.62	40.9	16.32	<0.15	4.76	<0.01	60.9	<0.03
3 cm sludge	18	45-60	7.0	0.44	55.6	1.3	189	0.18	12.2	<0.1	0.19	<0.3	0.32	0.18	0.42	20.6	15.14	<0.15	3.61	<0.01	44.9	<0.03
3 cm sludge	18	60-75	7.1	0.47	56.0	1.4	193	0.23	11.9	0.63	0.90	<0.3	0.34	0.18	0.36	23.8	15.13	<0.15	3.30	<0.01	48.1	<0.03
3 cm sludge	18	75-90	7.2	0.54	62.4	1.7	226	0.34	13.2	2.86	3.13	0.77	0.40	0.23	0.38	26.9	16.50	<0.15	3.81	<0.01	62.2	<0.03
3 cm sludge	18	90-105	7.0	0.49	72.8	1.9	201	0.19	17.2	0.28	0.39	1.64	0.34	0.22	0.55	22.7	13.49	<0.15	4.36	<0.01	66.1	<0.03

Appendix 2 . (Continued) Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	pH	E.C. (dS/m)	%SAT	SAR	HCO ₃	CO ₃	Cl	NO ₂ -N	NO ₃ -N & NO ₂ -N	NH ₄ -N	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo	(mg/L)											
5 cm sludge	3	0-15	7.0	1.48	43.2	7.8	551	0.52	18.7	70.60	94.90	8.04	0.53	0.17	3.13	46.1	18.78	<0.15	6.57	<0.01	319.5	<0.03												
5 cm sludge	3	15-30	7.2	1.04	58.8	5.6	221	0.33	8.2	10.72	22.86	<0.3	0.45	0.11	0.38	113.3	16.53	<0.15	3.37	<0.01	211.2	<0.03												
5 cm sludge	3	30-45	7.4	0.83	54.0	4.2	169	0.40	7.9	2.66	3.72	<0.3	0.41	0.05	0.25	111.1	15.64	<0.15	2.96	<0.01	150.9	<0.03												
5 cm sludge	3	45-60	7.4	0.63	48.4	3.1	134	0.28	8.5	0.43	1.53	<0.3	0.36	0.09	<0.20	77.6	12.18	<0.15	3.15	<0.01	99.2	<0.03												
5 cm sludge	3	60-75	7.5	0.53	46.4	2.6	171	0.51	11.1	0.24	0.50	<0.3	0.36	0.07	0.24	45.9	11.13	<0.15	3.04	<0.01	81.2	<0.03												
5 cm sludge	3	75-90	7.5	0.35	42.5	2.4	154	0.46	11.1	0.39	1.00	<0.3	0.22	0.07	<0.20	21.6	7.61	<0.15	3.23	<0.01	63.2	<0.03												
5 cm sludge	3	90-105	7.5	0.35	43.6	2.2	172	0.51	11.7	0.29	0.66	<0.3	0.22	0.12	0.20	14.0	7.64	<0.15	3.11	<0.01	59.9	<0.03												
51																																		
5 cm sludge	12	0-15	6.9	1.00	108.5	5.8	514	0.38	14.3	1.65	32.50	6.97	0.46	0.19	2.94	38.5	17.62	<0.15	6.36	<0.01	232.4	<0.03												
5 cm sludge	12	15-30	7.2	0.88	74.4	4.7	277	0.41	11.2	<0.1	<0.1	0.63	0.46	0.17	0.86	96.4	18.94	<0.15	3.67	<0.01	189.0	<0.03												
5 cm sludge	12	30-45	7.2	1.05	59.6	3.9	216	0.32	7.7	3.07	3.75	<0.3	0.55	0.14	0.44	158.3	27.23	<0.15	3.66	<0.01	184.0	<0.03												
5 cm sludge	12	45-60	7.5	1.10	50.0	2.9	140	0.41	8.2	1.78	2.15	<0.3	0.79	0.12	<0.20	194.8	30.49	<0.15	2.51	<0.01	147.4	<0.03												
5 cm sludge	12	60-75	7.5	0.83	51.5	2.9	150	0.45	10.0	1.25	1.91	<0.3	0.61	0.13	0.22	122.6	19.31	<0.15	2.63	<0.01	122.3	<0.03												
5 cm sludge	12	75-90	7.6	0.53	48.0	2.7	169	0.63	9.8	0.89	0.71	<0.3	0.34	0.13	0.27	47.9	10.50	<0.15	3.05	<0.01	84.6	<0.03												
5 cm sludge	12	90-105	7.6	0.45	46.4	2.8	163	0.61	11.1	0.92	1.50	<0.3	0.29	0.07	0.30	35.3	9.18	<0.15	2.88	<0.01	80.2	<0.03												
5 cm sludge	14	0-15	7.0	0.96	100.0	6.3	496	0.47	15.1	0.51	41.80	5.97	0.45	0.25	3.75	36.4	16.08	<0.15	5.36	<0.01	244.2	<0.03												
5 cm sludge	14	15-30	7.1	0.64	60.0	4.6	259	0.31	10.1	<0.1	0.20	<0.3	0.32	0.18	0.89	46.2	12.29	<0.15	3.46	<0.01	154.4	<0.03												
5 cm sludge	14	30-45	7.1	0.53	65.0	2.3	205	0.24	7.3	1.10	1.49	<0.3	0.44	0.14	0.33	50.9	16.22	<0.15	2.96	<0.01	80.8	<0.03												
5 cm sludge	14	45-60	7.2	0.55	62.8	2.3	203	0.30	10.2	0.46	1.11	<0.3	0.43	0.14	0.29	46.9	16.41	<0.15	3.19	<0.01	83.1	<0.03												
5 cm sludge	14	60-75	7.2	0.52	56.4	3.0	180	0.27	12.4	0.93	2.30	<0.3	0.35	0.15	0.40	41.3	12.64	<0.15	3.04	<0.01	95.4	<0.03												
5 cm sludge	14	75-90	7.4	0.89	69.0	4.4	216	0.45	15.2	1.43	2.12	1.74	0.64	0.20	<0.20	112.7	17.57	<0.15	3.00	<0.01	164.5	<0.03												
5 cm sludge	14	90-105	7.3	0.65	55.2	4.0	267	0.50	15.2	<0.1	<0.1	1.14	0.39	0.21	0.40	38.7	12.13	<0.15	4.10	<0.01	131.9	<0.03												

continued...

Appendix 2. (Continued) Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	pH	E.C. (dS/m)	%SAT	SAR	HCO ₃	CO ₃	Cl	NO ₂ -N	NO ₃ -N & NO ₂ -N	NH ₄ -N	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo	
							(mg/L)																
5 cm sludge&ash	1	0-15	7.4	1.22	86.4	5.2	630	1.49	14.4	48.5	48.7	6.1	0.65	0.18	3.16	34.8	28.09	<0.15	15.69	<0.01	233.9	0.03	
5 cm sludge&ash	1	15-30	7.2	1.09	63.2	5.5	253	0.38	9.0	9.9	13.4	<0.3	0.51	0.12	0.70	132.1	19.37	<0.15	3.51	<0.01	223.9	0.01	
5 cm sludge&ash	1	30-45	7.3	0.80	56.0	3.1	169	0.32	7.3	<0.1	<0.1	<0.3	0.57	0.09	0.29	110.2	18.81	<0.15	2.49	<0.01	122.8	0.00	
5 cm sludge&ash	1	45-60	7.3	0.71	61.5	2.7	191	0.36	9.5	0.4	0.8	<0.3	0.58	0.15	0.30	82.6	18.43	<0.15	2.43	<0.01	102.9	0.01	
5 cm sludge&ash	1	60-75	7.3	0.59	67.0	2.2	236	0.44	12.2	0.4	1.0	<0.3	0.60	0.19	0.48	38.4	18.01	<0.15	3.43	<0.01	83.7	0.01	
5 cm sludge&ash	1	75-90	7.3	0.63	75.5	2.3	279	0.47	14.9	0.2	0.6	0.8	0.73	0.23	0.59	26.7	19.09	<0.15	4.18	<0.01	90.9	0.02	
5 cm sludge&ash	1	90-105	7.6	0.43	50.5	2.7	204	0.76	11.7	0.4	0.8	<0.3	0.34	0.11	0.25	13.9	9.69	<0.15	3.75	<0.01	73.5	0.01	
52	5 cm sludge&ash	10	0-15	7.4	1.09	88.3	5.2	617	1.46	14.2	29.50	27.95	4.46	0.65	0.22	2.78	41.5	27.05	<0.15	13.48	<0.01	237.9	0.04
	5 cm sludge&ash	10	15-30	7.0	1.03	82.0	5.1	296	0.28	11.1	7.52	9.40	0.37	0.54	0.17	1.68	117.2	22.54	<0.15	4.18	<0.01	223.6	<0.03
	5 cm sludge&ash	10	30-45	7.1	0.82	67.2	3.1	202	0.21	7.6	3.56	4.45	<0.3	0.55	0.16	0.58	115.0	24.18	<0.15	3.16	<0.01	135.8	<0.03
	5 cm sludge&ash	10	45-60	7.2	0.73	59.0	2.3	189	0.28	9.5	3.97	4.66	0.34	0.53	0.15	0.39	96.2	24.67	<0.15	2.86	<0.01	99.9	<0.03
	5 cm sludge&ash	10	60-75	7.2	0.59	63.2	2.1	194	0.29	10.5	1.20	1.81	<0.3	0.46	0.14	0.38	61.5	18.57	<0.15	2.97	<0.01	83.1	<0.03
	5 cm sludge&ash	10	75-90	7.4	0.48	55.6	2.0	193	0.46	11.8	0.51	0.70	<0.3	0.46	0.18	0.35	33.7	14.80	<0.15	2.67	<0.01	70.4	<0.03
	5 cm sludge&ash	10	90-105	7.3	0.55	68.8	2.3	265	0.50	13.7	<0.1	0.18	0.88	0.68	0.23	0.64	19.8	18.19	<0.15	3.51	<0.01	87.9	<0.03
5 cm sludge&ash	13	0-15	7.5	1.01	75.3	5.7	641	1.90	15.1	0.10	<0.1	6.76	0.54	0.24	2.27	29.5	22.68	<0.15	11.11	<0.01	239.0	0.04	
5 cm sludge&ash	13	15-30	7.4	1.12	86.0	7.8	620	1.46	18.0	0.13	0.12	1.19	0.51	0.38	3.29	81.3	19.52	<0.15	6.11	<0.01	330.5	0.07	
5 cm sludge&ash	13	30-45	7.1	0.57	62.0	2.2	194	0.23	7.1	0.23	0.73	<0.3	0.41	0.13	0.38	57.8	18.08	<0.15	3.03	<0.01	82.9	<0.03	
5 cm sludge&ash	13	45-60	7.1	0.84	60.8	2.0	187	0.22	9.7	0.73	1.09	<0.3	0.49	0.15	0.31	74.6	21.59	<0.15	3.09	<0.01	80.8	<0.03	
5 cm sludge&ash	13	60-75	7.3	0.61	62.5	2.3	212	0.40	12.6	0.82	1.20	<0.3	0.45	0.18	0.30	54.1	18.13	<0.15	3.02	<0.01	85.4	<0.03	
5 cm sludge&ash	13	75-90	7.2	0.59	68.0	2.9	207	0.31	14.2	0.70	1.05	<0.3	0.47	0.18	0.42	52.2	15.59	<0.15	3.12	<0.01	102.8	<0.03	
5 cm sludge&ash	13	90-105	7.3	0.68	62.8	3.0	228	0.38	14.2	0.16	0.33	0.91	0.56	0.21	0.42	66.1	18.29	<0.15	3.23	<0.01	113.5	<0.03	

continued...

Appendix 2. (Continued) Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	pH	E.C. (dS/m)	%SAT	SAR	HCO ₃	CO ₃	Cl	NO ₂ -N	NO ₃ -N & NO ₂ -N	NH ₄ -N	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo	(mg/L)									
5 cm sludge/yr	5	0-15, June	7.2	1.83	122.0	11.9	943	0.90	53.5	nd*	0.24	12.12	0.62	0.65	9.96	98.1	22.23	<0.15	11.52	0.02	547.9	0.06										
5 cm sludge/yr	8	0-15, June	7.2	1.80	124.0	11.5	925	1.38	54.9	nd*	0.27	14.93	0.63	0.67	7.09	70.5	21.01	<0.15	9.72	0.01	519.7	0.04										
5 cm sludge/yr	16	0-15, June	7.2	1.53	95.0	10.3	863	1.29	51.4	nd*	0.24	10.16	0.54	0.65	6.66	57.9	19.68	<0.15	9.27	0.01	455.3	0.04										
5 cm sludge/yr	5	0-15	7.1	1.69	81.5	9.5	626	0.74	18.0	75.80	123.90	3.41	0.60	0.21	3.66	64.0	23.85	<0.15	10.35	<0.01	431.4	0.03										
5 cm sludge/yr	5	15-30	7.4	1.57	68.8	10.1	595	1.40	19.0	56.60	69.30	1.56	0.51	0.15	1.46	101.6	19.32	<0.15	5.86	<0.01	410.8	0.05										
5 cm sludge/yr	5	30-45	7.5	0.82	53.2	4.4	203	0.60	14.5	2.81	2.97	<0.3	0.46	0.13	0.37	103.0	16.36	<0.15	2.71	<0.01	161.7	<0.03										
5 cm sludge/yr	5	45-60	7.5	0.76	50.8	3.2	162	0.48	11.6	0.93	1.56	<0.3	0.54	0.13	0.24	101.3	18.01	<0.15	2.54	<0.01	122.9	<0.03										
5 cm sludge/yr	5	60-75	7.7	0.50	51.2	3.0	191	0.90	9.7	<0.1	<0.1	<0.3	0.33	0.09	0.26	39.9	10.39	<0.15	2.93	<0.01	89.7	<0.03										
5 cm sludge/yr	5	75-90	7.6	0.42	41.6	2.8	174	0.65	9.6	<0.1	0.24	<0.3	0.24	0.10	<0.20	26.1	7.69	<0.15	3.13	<0.01	74.2	<0.03										
5 cm sludge/yr	5	90-105	7.6	0.43	40.4	2.8	161	0.60	12.6	0.51	0.93	<0.3	0.23	0.09	<0.20	29.1	8.60	<0.15	3.26	<0.01	75.8	<0.03										
5 cm sludge/yr	8	0-15	7.1	1.39	88.8	10.8	647	0.77	19.1	68.30	135.00	5.68	0.59	0.32	5.02	64.9	20.95	<0.15	8.56	<0.01	476.2	<0.03										
5 cm sludge/yr	8	15-30	7.2	0.96	68.4	6.5	299	0.45	18.0	25.70	51.10	0.51	0.49	0.19	0.87	76.4	18.38	<0.15	3.91	<0.01	259.2	<0.03										
5 cm sludge/yr	8	30-45	7.3	0.61	57.6	3.2	212	0.40	16.6	6.46	13.20	<0.3	0.55	0.13	0.42	55.7	14.98	<0.15	2.42	<0.01	115.5	<0.03										
5 cm sludge/yr	8	45-60	7.4	0.54	54.4	2.7	194	0.46	14.7	1.93	3.06	<0.3	0.56	0.15	0.44	49.8	14.85	<0.15	2.53	<0.01	93.4	<0.03										
5 cm sludge/yr	8	60-75	7.5	0.40	48.4	2.7	178	0.53	13.0	2.39	4.12	<0.3	0.41	0.15	0.47	31.5	11.19	<0.15	2.56	<0.01	82.4	<0.03										
5 cm sludge/yr	8	75-90	7.4	0.51	66.0	4.2	366	0.86	17.5	<0.1	<0.1	1.62	0.63	0.26	0.91	28.5	15.12	<0.15	3.03	<0.01	150.4	<0.03										
5 cm sludge/yr	8	90-105	7.5	0.86	66.4	6.3	262	0.69	15.4	0.53	0.72	4.20	1.00	0.28	0.37	155.7	20.04	<0.15	2.47	<0.01	248.8	0.05										
5 cm sludge/yr	16	0-15	7.1	1.73	90.5	10.5	623	0.74	23.6	53.30	107.30	6.53	0.57	0.39	6.29	80.7	21.20	<0.15	7.80	<0.01	474.2	0.03										
5 cm sludge/yr	16	15-30	7.2	0.84	68.4	5.3	361	0.54	19.2	0.42	2.60	0.63	0.36	0.18	1.38	56.2	14.86	<0.15	4.30	<0.01	193.4	<0.03										
5 cm sludge/yr	16	30-45	6.9	0.68	65.2	3.6	227	0.17	15.9	19.00	17.60	<0.3	0.37	0.16	0.81	44.4	15.11	<0.15	4.19	<0.01	130.8	<0.03										
5 cm sludge/yr	16	45-60	7.0	0.64	71.6	3.0	233	0.22	18.5	4.43	4.28	<0.3	0.39	0.17	0.67	40.0	16.64	<0.15	3.77	<0.01	109.8	<0.03										
5 cm sludge/yr	16	60-75	7.2	0.79	63.2	3.3	230	0.34	16.1	1.27	1.32	0.68	0.60	0.17	0.25	80.0	19.26	<0.15	2.76	<0.01	128.9	<0.03										
5 cm sludge/yr	16	75-90	7.2	0.65	64.4	2.9	259	0.39	18.7	0.90	1.10	2.07	0.45	0.22	0.59	35.1	16.45	<0.15	3.52	<0.01	108.6	<0.03										
5 cm sludge/yr	16	90-105	7.2	0.59	68.5	2.4	239	0.36	21.0	0.68	0.90	1.95	0.41	0.24	0.60	29.3	16.16	<0.15	3.81	<0.01	88.6	<0.03										

*nd - no data

continued...

Appendix 2. (Continued) Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	Se	Al	Ca	Zn	Cu	Pb	Li	Tl	Cd	Co	Ni	B	K	Mn	Fe	Cr	
			(mg/L)																
control	6	0-15	<0.30	0.18	74.7	0.09	0.03	<0.15	0.02	<0.02	<0.02	<0.04	0.17	<0.30	2.55	0.05	1.17	<0.03	
control	6	15-30	<0.30	0.11	95.8	0.07	0.02	<0.15	0.02	<0.02	<0.02	<0.04	0.26	<0.30	3.79	0.05	0.62	<0.03	
control	6	30-45	<0.30	<0.07	155.4	0.05	0.02	<0.15	0.05	<0.02	<0.02	<0.04	0.18	<0.30	10.54	0.08	0.08	<0.03	
control	6	45-60	<0.30	<0.07	92.8	0.03	0.01	<0.15	0.05	<0.02	<0.02	<0.04	<0.05	<0.30	10.01	0.04	0.03	<0.03	
control	6	60-75	<0.30	<0.07	50.0	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	8.07	0.09	<0.03	<0.03	
control	6	75-90	<0.30	0.09	35.1	0.06	0.03	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	0.33	6.04	0.16	0.70	<0.03	
control	6	90-105	<0.30	<0.07	27.8	0.04	0.02	<0.15	0.05	<0.02	<0.02	<0.04	<0.05	0.45	8.66	0.05	0.02	<0.03	
54	control	7	0-15	<0.30	0.33	72.1	0.12	0.02	<0.15	0.01	0.03	<0.02	<0.04	0.05	<0.30	2.64	0.05	1.75	<0.03
	control	7	15-30	<0.30	0.13	103.0	0.14	0.01	<0.15	0.02	<0.02	<0.02	<0.04	0.12	<0.30	4.68	0.04	0.35	<0.03
	control	7	30-45	<0.30	<0.07	77.1	0.07	0.02	<0.15	0.03	<0.02	<0.02	<0.04	0.06	<0.30	5.14	<0.03	0.16	<0.03
	control	7	45-60	<0.30	<0.07	77.8	0.04	0.02	<0.15	0.04	<0.02	<0.02	<0.04	<0.05	<0.30	4.67	<0.03	0.13	<0.03
	control	7	60-75	<0.30	<0.07	82.8	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	3.26	<0.03	0.20	<0.03
	control	7	75-90	<0.30	<0.07	67.1	0.05	0.03	<0.15	0.04	<0.02	<0.02	<0.04	<0.05	0.37	6.54	0.32	0.13	<0.03
	control	7	90-105	<0.30	<0.07	58.4	0.04	0.03	<0.15	0.04	<0.02	<0.02	<0.04	<0.05	0.49	8.07	0.56	0.24	<0.03
54	control	17	0-15	<0.30	0.07	84.9	0.06	0.02	<0.15	0.02	<0.02	<0.02	<0.04	0.05	<0.30	4.76	0.05	0.30	<0.03
	control	17	15-30	<0.30	0.13	84.1	0.08	0.01	<0.15	0.02	<0.02	<0.02	<0.04	0.05	<0.30	3.35	0.05	0.38	<0.03
	control	17	30-45	<0.30	<0.07	90.5	0.03	0.02	<0.15	0.02	<0.02	<0.02	<0.04	0.06	<0.30	5.63	0.04	0.09	<0.03
	control	17	45-60	<0.30	<0.07	64.7	0.03	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	5.88	<0.03	0.16	<0.03
	control	17	60-75	<0.30	<0.07	68.7	0.04	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	5.26	0.04	0.14	<0.03
	control	17	75-90	<0.30	<0.07	76.8	0.02	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	6.38	0.06	0.08	<0.03
	control	17	90-105	<0.30	<0.07	77.0	0.03	0.03	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	0.33	6.94	0.18	0.24	<0.03

continued...

Appendix 2. (Continued) Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	Se	Al	Ca	Zn	Cu	Pb	Li	Tl	Cd	Co	Ni	B	K	Mn	Fe	Cr
			(mg/L)															
1 cm sludge	2	0-15	<0.30	0.33	73.4	0.11	0.02	<0.15	0.02	0.02	<0.02	<0.04	0.08	<0.30	3.83	0.09	1.36	<0.03
1 cm sludge	2	15-30	<0.30	0.08	123.8	0.05	0.03	<0.15	0.03	<0.02	<0.02	<0.04	0.15	<0.30	6.25	0.05	0.22	<0.03
1 cm sludge	2	30-45	<0.30	<0.07	141.8	0.03	0.02	<0.15	0.10	<0.02	<0.02	<0.04	0.06	<0.30	13.79	0.04	0.03	<0.03
1 cm sludge	2	45-60	<0.30	<0.07	82.4	0.03	0.02	<0.15	0.04	<0.02	<0.02	<0.04	<0.05	<0.30	7.59	0.06	0.10	<0.03
1 cm sludge	2	60-75	<0.30	<0.07	87.0	0.03	0.01	<0.15	0.06	<0.02	<0.02	<0.04	<0.05	0.33	10.36	0.12	0.07	<0.03
1 cm sludge	2	75-90	<0.30	<0.07	71.9	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	0.37	7.99	0.12	0.08	<0.03
1 cm sludge	2	90-105	<0.30	0.08	41.5	0.05	0.04	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	7.68	0.15	0.13	<0.03
11	0-15	<0.30	0.16	76.4	0.11	0.02	<0.15	0.02	<0.02	<0.02	<0.04	0.05	<0.30	2.84	0.08	0.85	<0.03	
1 cm sludge	11	15-30	<0.30	0.08	95.1	0.06	0.02	<0.15	0.02	<0.02	<0.02	<0.04	0.07	<0.30	3.16	0.07	0.33	<0.03
1 cm sludge	11	30-45	<0.30	<0.07	73.5	0.05	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	4.42	0.06	0.19	<0.03
1 cm sludge	11	45-60	<0.30	<0.07	63.9	0.02	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	5.65	0.03	0.11	<0.03
1 cm sludge	11	60-75	<0.30	<0.07	55.6	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	4.72	0.05	0.20	<0.03
1 cm sludge	11	75-90	<0.30	<0.07	62.1	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	0.51	4.66	0.19	0.24	<0.03
1 cm sludge	11	90-105	<0.30	<0.07	55.8	0.03	0.03	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	0.41	5.98	0.20	0.20	<0.03
15	0-15	<0.30	0.14	75.5	0.08	0.02	<0.15	0.02	<0.02	<0.02	<0.04	0.07	<0.30	2.79	0.08	0.76	<0.03	
1 cm sludge	15	15-30	<0.30	0.11	70.1	0.05	0.02	<0.15	0.01	<0.02	<0.02	<0.04	0.10	<0.30	2.71	0.03	0.70	<0.03
1 cm sludge	15	30-45	<0.30	<0.07	80.3	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	4.58	0.06	0.18	<0.03
1 cm sludge	15	45-60	<0.30	<0.07	74.2	0.02	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	5.92	0.06	0.12	<0.03
1 cm sludge	15	60-75	<0.30	<0.07	72.5	0.02	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	6.07	0.25	0.15	<0.03
1 cm sludge	15	75-90	<0.30	<0.07	53.2	0.03	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	7.32	0.28	0.08	<0.03
1 cm sludge	15	90-105	<0.30	<0.07	34.9	0.02	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	5.85	0.05	<0.03	<0.03

continued...

Appendix 2. (Continued) Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	Se	Al	Ca	Zn	Cu	Pb	Li	Tl	Cd	Co	Ni	B	K	Mn	Fe	Cr
			(mg/L)															
3 cm sludge	4	0-15	<0.30	0.44	77.6	0.16	0.04	<0.15	0.01	0.11	<0.02	<0.04	0.18	<0.30	1.57	0.07	5.32	<0.03
3 cm sludge	4	15-30	<0.30	0.13	86.2	0.08	0.03	<0.15	0.02	<0.02	<0.02	<0.04	0.25	<0.30	2.39	0.36	0.49	<0.03
3 cm sludge	4	30-45	<0.30	<0.07	75.1	0.02	0.02	<0.15	0.04	<0.02	<0.02	<0.04	0.07	<0.30	9.14	0.07	0.06	<0.03
3 cm sludge	4	45-60	<0.30	<0.07	59.2	0.10	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	7.28	<0.03	0.05	<0.03
3 cm sludge	4	60-75	<0.30	<0.07	48.8	0.03	0.03	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	6.75	<0.03	0.07	<0.03
3 cm sludge	4	75-90	<0.30	<0.07	61.4	0.06	0.03	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	6.85	0.15	0.23	<0.03
3 cm sludge	4	90-105	<0.30	<0.07	37.8	0.04	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	6.07	0.06	0.10	<0.03
3 cm sludge	9	0-15	<0.30	0.21	91.5	0.07	0.04	<0.15	0.02	<0.02	<0.02	<0.04	0.17	<0.30	1.78	<0.03	0.95	<0.03
3 cm sludge	9	15-30	<0.30	0.11	136.2	0.06	0.03	<0.15	0.02	<0.02	<0.02	<0.04	0.28	<0.30	2.46	0.07	0.42	<0.03
3 cm sludge	9	30-45	<0.30	<0.07	128.6	0.03	0.03	<0.15	0.02	<0.02	<0.02	<0.04	0.06	<0.30	4.94	0.07	0.12	<0.03
3 cm sludge	9	45-60	<0.30	<0.07	122.2	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	6.47	0.05	0.08	<0.03
3 cm sludge	9	60-75	<0.30	<0.07	88.0	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	5.54	0.06	0.10	<0.03
3 cm sludge	9	75-90	<0.30	<0.07	83.8	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	4.96	0.04	0.07	<0.03
3 cm sludge	9	90-105	<0.30	<0.07	66.0	0.02	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	6.27	<0.03	0.06	<0.03
3 cm sludge	18	0-15	<0.30	0.20	70.4	0.07	0.02	<0.15	0.01	0.02	<0.02	<0.04	0.06	<0.30	2.37	0.04	1.10	<0.03
3 cm sludge	18	15-30	<0.30	0.15	73.8	0.06	0.02	<0.15	0.01	<0.02	<0.02	<0.04	0.17	<0.30	1.41	0.06	1.18	<0.03
3 cm sludge	18	30-45	<0.30	0.09	74.2	0.05	0.01	<0.15	0.01	<0.02	<0.02	<0.04	0.07	<0.30	3.63	0.04	0.44	<0.03
3 cm sludge	18	45-60	<0.30	<0.07	69.3	0.03	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	4.45	0.05	0.17	<0.03
3 cm sludge	18	60-75	<0.30	<0.07	70.8	0.02	0.01	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	5.87	0.06	0.10	<0.03
3 cm sludge	18	75-90	<0.30	<0.07	79.0	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	7.44	0.13	0.11	<0.03
3 cm sludge	18	90-105	<0.30	0.10	67.8	0.03	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	0.37	6.29	0.14	0.53	<0.03

continued...

Appendix 2. (Continued) Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	Se	Al	Ca	Zn	Cu	Pb	Li	Tl	Cd	Co	Ni	B	K	Mn	Fe	Cr
			(mg/L)															
5 cm sludge	3	0-15	<0.30	0.21	94.7	0.09	0.05	<0.15	0.02	<0.02	<0.02	<0.04	0.21	<0.30	3.38	0.04	0.99	<0.03
5 cm sludge	3	15-30	<0.30	0.08	80.2	0.06	0.05	<0.15	0.02	<0.02	<0.02	<0.04	0.36	<0.30	4.75	<0.03	0.40	<0.03
5 cm sludge	3	30-45	<0.30	<0.07	74.3	0.04	0.03	<0.15	0.03	<0.02	<0.02	<0.04	0.12	<0.30	7.04	0.05	0.13	<0.03
5 cm sludge	3	45-60	<0.30	<0.07	58.6	0.02	0.01	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	8.16	0.06	<0.03	<0.03
5 cm sludge	3	60-75	<0.30	<0.07	57.0	0.02	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	7.87	0.12	0.08	<0.03
5 cm sludge	3	75-90	<0.30	<0.07	40.1	0.03	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	5.95	0.08	0.05	<0.03
5 cm sludge	3	90-105	<0.30	<0.07	41.2	0.03	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	5.99	0.15	0.10	<0.03
57																		
5 cm sludge	12	0-15	<0.30	0.17	91.6	0.06	0.04	<0.15	0.02	<0.02	<0.02	<0.04	0.17	<0.30	1.59	0.05	1.10	<0.03
5 cm sludge	12	15-30	<0.30	0.10	93.0	0.06	0.03	<0.15	0.02	<0.02	<0.02	<0.04	0.25	<0.30	3.75	0.06	0.78	<0.03
5 cm sludge	12	30-45	<0.30	<0.07	125.4	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	0.16	<0.30	5.91	0.06	0.19	<0.03
5 cm sludge	12	45-60	<0.30	<0.07	142.7	0.02	0.01	<0.15	0.06	<0.02	<0.02	<0.04	<0.05	<0.30	11.17	0.05	<0.03	<0.03
5 cm sludge	12	60-75	<0.30	<0.07	99.3	0.02	0.02	<0.15	0.05	<0.02	<0.02	<0.04	<0.05	<0.30	8.50	0.03	<0.03	<0.03
5 cm sludge	12	75-90	<0.30	<0.07	58.0	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	6.21	0.06	0.10	<0.03
5 cm sludge	12	90-105	<0.30	<0.07	47.4	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	5.10	0.04	0.13	<0.03
5 cm sludge	14	0-15	<0.30	0.34	88.6	0.10	0.05	<0.15	0.01	0.05	<0.02	<0.04	0.21	<0.30	0.77	0.07	2.06	<0.03
5 cm sludge	14	15-30	<0.30	0.25	64.8	0.07	0.04	<0.15	0.02	0.04	<0.02	<0.04	0.34	<0.30	2.36	0.04	3.41	<0.03
5 cm sludge	14	30-45	<0.30	<0.07	70.4	0.05	0.02	<0.15	0.03	<0.02	<0.02	<0.04	0.06	<0.30	4.88	<0.03	0.21	<0.03
5 cm sludge	14	45-60	<0.30	<0.07	71.2	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	4.62	<0.03	0.19	<0.03
5 cm sludge	14	60-75	<0.30	0.10	57.1	0.05	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	4.18	0.04	0.79	<0.03
5 cm sludge	14	75-90	<0.30	<0.07	78.5	0.02	0.02	<0.15	0.07	<0.02	<0.02	<0.04	<0.05	0.33	12.39	0.10	<0.03	<0.03
5 cm sludge	14	90-105	<0.30	<0.07	62.1	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	0.48	8.27	0.31	0.26	<0.03

continued...

Appendix 2. (Continued) Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	Se	Al	Ca	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	B	K	Mn	Fe	Cr
			(mg/L)															
5 cm sludge&ash	1	0-15	<0.30	0.11	109.0	0.07	0.05	<0.15	0.02	<0.02	<0.02	<0.04	0.12	0.33	19.53	<0.03	0.36	<0.03
5 cm sludge&ash	1	15-30	<0.30	0.11	94.5	0.07	0.03	<0.15	0.02	<0.02	<0.02	<0.04	0.31	<0.30	5.47	<0.03	0.56	<0.03
5 cm sludge&ash	1	30-45	<0.30	<0.07	86.4	0.05	0.02	<0.15	0.04	<0.02	<0.02	<0.04	<0.05	<0.30	6.88	0.03	0.08	<0.03
5 cm sludge&ash	1	45-60	<0.30	<0.07	82.9	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	6.82	0.04	0.09	<0.03
5 cm sludge&ash	1	60-75	<0.30	0.08	79.4	0.04	0.03	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	0.44	6.61	0.33	0.20	<0.03
5 cm sludge&ash	1	75-90	<0.30	0.08	83.3	0.07	0.03	<0.15	0.04	<0.02	<0.02	<0.04	<0.05	0.73	7.62	0.69	0.23	<0.03
5 cm sludge&ash	1	90-105	<0.30	<0.07	40.5	0.06	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	0.35	6.91	<0.03	0.08	<0.03
5 cm sludge&ash	10	0-15	<0.30	0.10	112.7	0.06	0.05	<0.15	0.02	<0.02	<0.02	<0.04	0.16	0.33	13.43	<0.03	0.46	<0.03
	10	15-30	<0.30	0.10	106.5	0.06	0.03	<0.15	0.02	<0.02	<0.02	<0.04	0.31	<0.30	4.07	0.04	0.49	<0.03
	10	30-45	<0.30	<0.07	109.6	0.06	0.03	<0.15	0.02	<0.02	<0.02	<0.04	0.12	<0.30	4.80	0.05	0.21	<0.03
	10	45-60	<0.30	<0.07	104.5	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	0.08	<0.30	6.35	0.06	0.10	<0.03
	10	60-75	<0.30	<0.07	85.1	0.05	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	6.03	0.05	0.11	<0.03
	10	75-90	<0.30	<0.07	67.0	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	5.91	0.14	0.13	<0.03
	10	90-105	<0.30	<0.07	84.1	0.04	0.03	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	0.43	7.22	0.63	0.26	<0.03
5 cm sludge&ash	13	0-15	<0.30	0.14	93.5	0.06	0.06	<0.15	0.02	<0.02	<0.02	<0.04	0.11	0.33	10.05	0.04	0.96	<0.03
	13	15-30	<0.30	0.44	102.3	0.13	0.07	<0.15	0.02	0.12	<0.02	<0.04	0.72	<0.30	4.41	0.04	5.15	<0.03
	13	30-45	<0.30	<0.07	79.2	0.03	0.03	<0.15	0.02	<0.02	<0.02	<0.04	0.11	<0.30	5.50	<0.03	0.18	<0.03
	13	45-60	<0.30	<0.07	92.5	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	6.02	0.05	0.08	<0.03
	13	60-75	<0.30	<0.07	77.7	0.02	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	6.69	0.06	0.08	<0.03
	13	75-90	<0.30	<0.07	68.1	0.03	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	0.32	5.57	0.09	0.27	<0.03
	13	90-105	<0.30	<0.07	81.5	0.02	0.02	<0.15	0.04	<0.02	<0.02	<0.04	<0.05	0.41	8.09	0.36	0.11	<0.03

continued...

Appendix 2. (Concluded) Saturated Paste Extract Data of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	Se	Al	Ca	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	B	K	Mn	Fe	Cr
			(mg/L)															
5 cm sludge/yr	5	0-15, June	<0.30	1.15	124.1	0.35	0.13	<0.15	0.03	0.23	0.06	0.04	0.85	<0.30	16.15	0.20	8.06	<0.03
5 cm sludge/yr	8	0-15, June	<0.30	0.66	119.9	0.37	0.10	<0.15	0.02	0.17	0.05	<0.04	0.87	<0.30	15.76	0.17	5.90	<0.03
5 cm sludge/yr	16	0-15, June	<0.30	1.18	115.3	0.31	0.11	<0.15	0.02	0.24	0.05	0.04	0.74	<0.30	11.66	0.21	8.53	<0.03
5 cm sludge/yr	5	0-15	<0.30	0.17	116.2	0.19	0.06	<0.15	0.03	<0.02	<0.02	<0.04	0.35	<0.30	8.37	0.07	0.72	<0.03
5 cm sludge/yr	5	15-30	<0.30	0.12	94.3	0.12	0.06	<0.15	0.03	<0.02	<0.02	<0.04	0.48	<0.30	10.61	0.20	0.61	<0.03
5 cm sludge/yr	5	30-45	<0.30	<0.07	76.1	0.05	0.02	<0.15	0.04	<0.02	<0.02	<0.04	0.06	<0.30	7.82	0.09	0.19	<0.03
5 cm sludge/yr	5	45-60	<0.30	<0.07	81.4	0.04	0.02	<0.15	0.04	<0.02	<0.02	<0.04	<0.05	<0.30	7.80	0.07	0.06	<0.03
5 cm sludge/yr	5	60-75	<0.30	<0.07	51.9	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	6.75	0.05	0.10	<0.03
5 cm sludge/yr	5	75-90	<0.30	<0.07	40.1	0.03	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	<0.30	6.47	0.09	0.04	<0.03
5 cm sludge/yr	5	90-105	<0.30	<0.07	41.2	0.04	0.02	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	6.11	0.06	0.06	<0.03
5 cm sludge/yr	8	0-15	<0.30	0.27	113.7	0.23	0.06	<0.15	0.02	0.03	<0.02	<0.04	0.61	<0.30	5.85	0.12	1.88	<0.03
5 cm sludge/yr	8	15-30	<0.30	0.11	90.3	0.12	0.04	<0.15	0.02	<0.02	<0.02	<0.04	0.40	<0.30	5.47	0.05	0.59	<0.03
5 cm sludge/yr	8	30-45	<0.30	<0.07	72.4	0.05	0.03	<0.15	0.03	<0.02	<0.02	<0.04	0.07	<0.30	5.14	0.06	0.14	<0.03
5 cm sludge/yr	8	45-60	<0.30	<0.07	69.5	0.05	0.03	<0.15	0.04	<0.02	<0.02	<0.04	0.06	<0.30	4.89	0.15	0.16	<0.03
5 cm sludge/yr	8	60-75	<0.30	<0.07	52.6	0.05	0.03	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	<0.30	3.80	0.09	0.23	<0.03
5 cm sludge/yr	8	75-90	<0.30	0.09	72.2	0.09	0.07	<0.15	0.03	<0.02	<0.02	<0.04	<0.05	0.49	6.42	0.80	0.56	<0.03
5 cm sludge/yr	8	90-105	<0.30	<0.07	86.6	0.03	0.02	<0.15	0.07	<0.02	<0.02	<0.04	<0.05	0.68	12.44	0.59	0.12	<0.03
5 cm sludge/yr	16	0-15	<0.30	0.40	119.0	0.20	0.08	<0.15	0.02	0.08	0.02	<0.04	0.91	<0.30	4.33	0.08	3.44	<0.03
5 cm sludge/yr	16	15-30	<0.30	0.18	75.2	0.07	0.04	<0.15	0.01	0.02	<0.02	<0.04	0.43	<0.30	4.06	0.07	1.73	<0.03
5 cm sludge/yr	16	30-45	<0.30	0.14	73.8	0.06	0.03	<0.15	0.01	<0.02	<0.02	<0.04	0.22	<0.30	3.63	0.06	1.17	<0.03
5 cm sludge/yr	16	45-60	<0.30	<0.07	76.1	0.05	0.02	<0.15	0.02	<0.02	<0.02	<0.04	0.12	<0.30	5.43	0.16	0.39	<0.03
5 cm sludge/yr	16	60-75	<0.30	<0.07	81.6	0.02	0.01	<0.15	0.07	<0.02	<0.02	<0.04	0.06	0.38	11.20	0.23	0.10	<0.03
5 cm sludge/yr	16	75-90	<0.30	<0.07	76.9	0.03	0.03	<0.15	0.03	<0.02	<0.02	<0.04	0.06	0.39	8.24	0.42	0.24	<0.03
5 cm sludge/yr	16	90-105	<0.30	0.08	77.1	0.04	0.02	<0.15	0.02	<0.02	<0.02	<0.04	<0.05	0.39	6.60	0.26	0.38	<0.03

APPENDIX 3

Appendix 3. DTPA-NHCO₃ Extract Data of Sludge and Ash Amended Soils.

Treatment	Plot	Depth (cm)	P	Mg	Na	Mo	Se	Ca	Zn	Cu	Pb	Cd	Ni	B	K	Mn	Fe
			ug/g														
control	6	0-15	6.56	282	352	<0.08	<0.80	590	6.54	3.07	1.46	0.35	2.96	0.25	88.5	10.91	260
control	6	15-30	6.23	276	424	<0.08	<0.80	540	6.23	3.46	1.50	0.31	3.11	0.25	89.0	13.33	313
control	6	30-45	4.08	267	346	<0.08	<0.80	397	3.39	4.34	1.49	0.19	2.97	0.30	126.9	13.75	243
control	6	45-60	1.86	244	276	<0.08	<0.80	395	1.92	4.02	1.48	0.12	2.58	0.27	128.7	13.95	113
control	6	60-75	1.78	219	222	0.10	<0.80	390	1.44	4.46	1.65	0.09	1.93	0.24	129.3	34.50	76
control	6	75-90	2.79	179	274	<0.08	<0.80	324	1.65	4.49	1.82	0.11	2.46	0.31	115.5	72.38	167
control	6	90-105	1.63	217	402	<0.08	<0.80	358	1.52	5.53	1.63	0.08	1.59	0.41	144.4	29.17	66
control	7	0-15	4.98	284	254	<0.08	<0.80	673	10.09	2.53	1.23	0.40	2.97	0.23	78.9	9.92	259
control	7	15-30	5.12	285	274	<0.08	<0.80	709	11.62	2.62	1.33	0.32	3.02	0.24	86.5	16.31	227
control	7	30-45	3.45	296	203	<0.08	<0.80	389	3.67	5.02	2.06	0.27	3.67	0.42	128.9	14.13	306
control	7	45-60	2.70	323	199	<0.08	<0.80	432	2.26	4.22	1.85	0.22	3.26	0.35	132.9	15.09	221
control	7	60-75	2.76	346	248	<0.08	<0.80	475	1.61	4.15	1.73	0.23	3.08	0.32	132.6	14.32	200
control	7	75-90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
control	7	90-105	4.29	259	294	0.10	<0.80	287	5.57	6.41	2.70	0.24	4.22	0.66	140.5	172.18	289
control	17	0-15	5.97	288	151	<0.08	<0.80	570	10.85	3.51	1.63	0.48	3.58	0.29	106.4	9.92	357
control	17	15-30	5.73	291	178	<0.08	<0.80	525	11.52	3.40	1.73	0.43	3.64	0.30	98.2	14.89	362
control	17	30-45	3.63	267	100	<0.08	<0.80	394	4.38	3.15	1.79	0.22	2.79	0.23	113.8	15.44	250
control	17	45-60	3.42	260	74	<0.08	<0.80	399	4.16	2.80	1.76	0.19	2.86	0.19	113.0	16.53	245
control	17	60-75	4.11	247	90	<0.08	<0.80	406	5.83	2.98	1.97	0.23	3.05	0.22	110.0	26.47	265
control	17	75-90	3.39	253	105	<0.08	<0.80	378	3.67	4.44	2.22	0.22	3.63	0.26	121.7	27.74	262
control	17	90-105	5.05	242	198	0.09	<0.80	329	5.34	5.16	2.68	0.26	4.07	0.41	108.2	49.62	422
1 cm sludge	2	0-15	7.44	282	304	<0.08	<0.80	639	6.73	2.70	1.31	0.31	2.54	0.26	102.5	9.81	240
1 cm sludge	2	15-30	4.16	284	350	<0.08	<0.80	532	5.96	3.26	1.41	0.28	3.11	0.35	97.7	10.11	267
1 cm sludge	2	30-45	2.28	345	357	<0.08	<0.80	343	3.50	4.83	1.62	0.18	2.49	0.45	165.0	15.36	242
1 cm sludge	2	45-60	3.15	282	196	<0.08	<0.80	428	5.40	4.33	2.30	0.25	3.50	0.44	116.0	33.08	318
1 cm sludge	2	60-75	2.34	326	205	<0.08	<0.80	355	4.21	5.94	2.41	0.17	3.91	0.42	155.2	42.24	261
1 cm sludge	2	75-90	2.95	271	186	0.08	<0.80	332	4.20	4.73	2.16	0.20	3.83	0.43	115.7	47.91	328
1 cm sludge	2	90-105	2.77	222	166	<0.08	<0.80	344	2.05	4.70	1.74	0.13	2.61	0.29	112.9	57.14	183
1 cm sludge	11	0-15	6.89	294	219	<0.08	<0.80	594	6.21	2.71	1.36	0.33	2.52	0.23	109.4	8.78	259
1 cm sludge	11	15-30	5.68	291	272	<0.08	<0.80	545	7.95	2.77	1.57	0.35	3.02	0.28	88.5	12.92	332
1 cm sludge	11	30-45	4.31	295	217	<0.08	<0.80	434	7.25	4.28	2.30	0.36	3.44	0.45	114.2	24.12	328
1 cm sludge	11	45-60	3.06	310	151	<0.08	<0.80	436	3.69	4.00	2.00	0.25	2.75	0.39	132.4	16.93	209
1 cm sludge	11	60-75	3.51	320	185	<0.08	<0.80	391	5.64	4.49	2.57	0.31	3.03	0.53	116.7	40.37	317
1 cm sludge	11	75-90	4.34	302	252	<0.08	<0.80	393	8.48	5.00	2.87	0.33	3.56	0.76	104.7	108.18	368
1 cm sludge	11	90-105	3.79	281	248	<0.08	<0.80	351	5.26	5.24	2.59	0.27	4.56	0.66	135.3	120.07	286
1 cm sludge	15	0-15	6.59	282	230	<0.08	<0.80	543	5.71	2.88	1.40	0.28	2.51	0.26	112.3	10.66	254
1 cm sludge	15	15-30	4.52	284	203	<0.08	<0.80	501	4.50	2.57	1.37	0.26	2.50	0.25	102.7	9.38	253
1 cm sludge	15	30-45	3.85	292	169	<0.08	<0.80	423	5.24	4.40	2.00	0.29	3.30	0.32	110.4	16.51	306
1 cm sludge	15	45-60	3.46	282	143	<0.08	<0.80	372	5.08	5.39	2.45	0.30	3.86	0.38	117.3	30.15	337
1 cm sludge	15	60-75	4.10	268	146	<0.08	<0.80	379	6.55	6.03	2.97	0.36	4.80	0.45	110.4	101.19	366
1 cm sludge	15	75-90	3.23	245	92	0.10	<0.80	294	3.02	4.50	2.10	0.19	3.18	0.34	100.2	94.10	297
1 cm sludge	15	90-105	0.79	281	62	<0.08	<0.80	434	0.72	2.39	1.19	0.09	1.44	0.11	110.9	34.95	51

continued...

Appendix 3. (Continued) DTPA-NHCO₃ Extract Data of Sludge and Ash Amended Soils.

Treatment	Plot	Depth (cm)	P	Mg	Na	Mo	Se	Ca	Zn	Cu	Pb	Cd	Ni	B	K	Mn	Fe
			ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
3 cm sludge	4	0-15	10.18	279	569	<0.08	<0.80	638	7.52	2.82	1.37	0.38	2.80	0.24	64.6	10.97	327
3 cm sludge	4	15-30	5.05	287	470	<0.08	<0.80	637	9.74	3.32	1.62	0.37	3.64	0.30	79.4	18.76	317
3 cm sludge	4	30-45	2.15	243	207	<0.08	<0.80	432	1.85	3.20	1.29	0.13	2.01	0.27	122.3	8.95	123
3 cm sludge	4	45-60	1.58	391	202	<0.08	<0.80	404	1.15	2.98	1.17	0.10	1.74	0.15	167.2	5.71	100
3 cm sludge	4	60-75	1.51	397	189	<0.08	<0.80	408	1.09	3.06	1.17	0.09	1.86	0.13	176.5	7.66	91
3 cm sludge	4	75-90	2.38	215	148	<0.08	<0.80	421	2.28	3.22	1.44	0.16	2.83	0.23	99.5	27.73	211
3 cm sludge	4	90-105	1.82	244	145	<0.08	<0.80	389	1.64	3.67	1.56	0.12	2.48	0.23	118.2	31.15	123
3 cm sludge	9	0-15	12.06	300	645	<0.08	<0.80	727	11.14	3.05	1.51	0.43	3.02	0.27	83.3	14.16	263
3 cm sludge	9	15-30	7.34	304	507	<0.08	<0.80	622	9.72	3.00	1.60	0.40	3.39	0.29	78.7	16.21	318
3 cm sludge	9	30-45	4.69	277	229	<0.08	<0.80	433	5.29	3.49	1.86	0.26	2.62	0.23	92.0	13.88	316
3 cm sludge	9	45-60	3.78	279	267	<0.08	<0.80	403	4.79	4.65	2.26	0.31	3.56	0.34	114.4	16.92	338
3 cm sludge	9	60-75	3.44	288	254	<0.08	<0.80	386	4.64	4.86	2.41	0.33	3.50	0.36	124.4	15.32	339
3 cm sludge	9	75-90	3.25	290	218	<0.08	<0.80	395	3.80	5.24	2.41	0.28	3.84	0.37	124.5	20.26	302
3 cm sludge	9	90-105	2.56	286	173	<0.08	<0.80	411	2.36	4.31	1.92	0.19	2.88	1.26	144.3	16.74	180
3 cm sludge	18	0-15	9.75	276	268	<0.08	<0.80	556	7.90	3.40	1.55	0.40	3.06	0.26	108.2	10.55	319
3 cm sludge	18	15-30	6.50	273	335	<0.08	<0.80	503	9.11	3.43	1.74	0.44	3.70	0.30	77.5	14.09	377
3 cm sludge	18	30-45	5.90	289	164	<0.08	<0.80	476	8.61	3.50	1.99	0.42	3.34	0.29	103.4	11.32	391
3 cm sludge	18	45-60	4.61	264	83	<0.08	<0.80	412	4.55	3.23	1.82	0.25	2.95	0.24	108.4	15.06	284
3 cm sludge	18	60-75	3.82	240	84	<0.08	<0.80	374	4.83	3.90	2.31	0.23	3.46	0.27	109.6	25.96	293
3 cm sludge	18	75-90	4.16	240	119	<0.08	<0.80	362	6.09	5.09	2.76	0.27	3.84	0.32	112.9	35.35	366
3 cm sludge	18	90-105	5.08	254	165	<0.08	<0.80	372	6.02	5.77	2.73	0.34	4.08	0.38	121.6	35.09	430
5 cm sludge	3	0-15	20.26	294	812	<0.08	<0.80	730	9.02	2.92	1.39	0.33	2.40	0.24	81.6	13.14	255
5 cm sludge	3	15-30	4.96	273	415	<0.08	<0.80	476	3.78	3.34	1.26	0.23	2.61	0.25	96.7	8.30	245
5 cm sludge	3	30-45	2.51	291	264	<0.08	<0.80	431	2.01	3.41	1.37	0.14	2.33	0.27	120.8	9.37	151
5 cm sludge	3	45-60	1.84	254	157	0.09	<0.80	421	1.46	3.39	1.42	0.12	2.00	0.21	125.7	11.57	83
5 cm sludge	3	60-75	2.83	238	129	<0.08	<0.80	399	1.48	3.60	1.57	0.13	2.40	0.19	121.8	42.50	113
5 cm sludge	3	75-90	2.11	234	103	<0.08	<0.80	391	0.99	2.89	1.31	0.10	1.74	0.11	110.2	50.27	74
5 cm sludge	3	90-105	2.21	204	96	<0.08	<0.80	369	1.31	3.35	1.39	0.11	2.04	0.17	99.0	51.28	112
5 cm sludge	12	0-15	18.45	305	727	<0.08	<0.80	690	10.30	3.37	1.63	0.43	2.75	0.25	90.0	13.39	281
5 cm sludge	12	15-30	8.46	277	511	<0.08	<0.80	511	7.88	3.40	1.66	0.37	3.25	0.25	97.4	14.36	339
5 cm sludge	12	30-45	5.40	271	328	<0.08	<0.80	446	4.20	2.93	1.63	0.24	2.60	0.24	108.7	13.07	252
5 cm sludge	12	45-60	2.55	281	205	<0.08	<0.80	405	2.73	3.55	1.50	0.16	2.36	0.26	138.1	10.88	151
5 cm sludge	12	60-75	2.61	286	204	<0.08	<0.80	444	3.09	4.39	1.65	0.21	3.48	0.28	155.6	14.02	138
5 cm sludge	12	75-90	2.70	261	161	<0.08	<0.80	450	2.74	4.07	1.54	0.20	3.20	0.22	141.0	29.42	116
5 cm sludge	12	90-105	2.89	260	162	<0.08	<0.80	450	2.70	3.83	1.54	0.20	3.09	0.21	141.6	24.27	115
5 cm sludge	14	0-15	17.89	276	742	<0.08	<0.80	620	9.40	3.17	1.47	0.39	2.78	0.31	86.2	11.76	294
5 cm sludge	14	15-30	5.27	269	383	<0.08	<0.80	509	4.46	2.76	1.24	0.24	2.61	0.28	88.6	8.52	236
5 cm sludge	14	30-45	3.26	292	171	<0.08	<0.80	384	4.48	4.27	2.12	0.28	3.04	0.38	120.5	12.87	337
5 cm sludge	14	45-60	3.29	305	175	<0.08	<0.80	433	3.77	3.74	2.30	0.24	2.58	0.31	120.1	11.96	275
5 cm sludge	14	60-75	2.90	286	210	<0.08	<0.80	441	3.08	3.55	2.18	0.23	2.52	0.33	114.7	17.24	264
5 cm sludge	14	75-90	2.92	327	365	0.12	<0.80	315	5.17	6.87	2.55	0.18	3.49	0.42	189.6	39.24	292
5 cm sludge	14	90-105	4.69	247	276	0.09	<0.80	306	3.54	6.45	2.39	0.23	3.34	0.50	140.0	84.91	311

continued...

Appendix 3. (Concluded) DTPA-NHCO₃ Extract Data of Sludge and Ash Amended Soils.

Treatment	Plot	Depth (cm)	P	Mg	Na	Mo	Se	Ca	Zn	Cu	Pb	Cd	Ni	B	K	Mn	Fe
			ug/g														
5 cm sludge&ash	1	0-15	44.85	364	514	<0.08	<0.80	689	7.79	3.60	1.13	0.27	2.29	1.06	272.1	17.42	206
5 cm sludge&ash	1	15-30	5.64	267	448	<0.08	<0.80	539	5.32	2.77	1.29	0.27	2.82	0.31	110.3	9.71	260
5 cm sludge&ash	1	30-45	2.56	274	203	<0.08	<0.80	422	2.96	3.73	1.59	0.18	2.74	0.32	118.1	13.61	223
5 cm sludge&ash	1	45-60	2.80	264	180	<0.08	<0.80	373	3.64	4.06	2.02	0.23	2.95	0.37	112.2	22.92	318
5 cm sludge&ash	1	60-75	3.63	283	165	<0.08	<0.80	402	5.75	4.25	2.28	0.28	4.35	0.67	107.7	145.64	345
5 cm sludge&ash	1	75-90	4.11	281	199	0.09	<0.80	434	7.93	4.14	2.02	0.30	5.26	0.96	108.0	209.49	293
5 cm sludge&ash	1	90-105	2.72	293	159	0.13	<0.80	303	2.25	4.37	2.10	0.15	2.94	0.48	131.1	95.12	253
5 cm sludge&ash	10	0-15	44.01	366	570	<0.08	<0.80	656	7.89	4.18	1.36	0.34	2.75	0.25	257.4	19.97	230
5 cm sludge&ash	10	15-30	10.15	234	464	<0.08	<0.80	461	6.74	2.76	1.13	0.30	2.84	0.24	100.3	14.56	290
5 cm sludge&ash	10	30-45	8.12	289	286	<0.08	<0.80	407	8.42	3.32	1.76	0.38	3.40	0.30	113.2	15.85	385
5 cm sludge&ash	10	45-60	3.91	279	167	<0.08	<0.80	409	5.28	4.30	2.43	0.31	3.56	0.36	114.1	24.50	342
5 cm sludge&ash	10	60-75	3.86	274	167	<0.08	<0.80	397	5.36	4.30	2.45	0.31	3.54	0.36	114.4	24.19	328
5 cm sludge&ash	10	75-90	3.06	299	144	<0.08	<0.80	411	3.45	4.10	2.22	0.21	3.27	0.37	126.2	44.76	228
5 cm sludge&ash	10	90-105	5.75	291	218	<0.08	<0.80	432	8.20	4.95	2.46	0.31	5.19	0.83	121.2	227.83	290
5 cm sludge&ash	13	0-15	34.61	373	587	<0.08	<0.80	625	6.18	3.29	1.18	0.26	2.10	0.99	229.5	13.83	182
5 cm sludge&ash	13	15-30	16.24	301	902	<0.08	<0.80	608	9.39	2.95	1.47	0.39	3.32	0.52	141.4	12.64	265
5 cm sludge&ash	13	30-45	3.82	276	161	<0.08	<0.80	388	4.36	3.67	1.99	0.28	3.06	0.27	115.7	11.03	333
5 cm sludge&ash	13	45-60	3.85	274	154	<0.08	<0.80	350	5.22	4.11	2.35	0.31	3.63	0.28	117.9	17.23	362
5 cm sludge&ash	13	60-75	3.19	280	167	<0.08	<0.80	384	4.39	4.58	2.41	0.26	3.30	0.31	128.3	23.41	288
5 cm sludge&ash	13	75-90	3.83	290	253	0.09	<0.80	408	7.80	6.01	2.75	0.39	3.81	0.58	121.9	48.09	371
5 cm sludge&ash	13	90-105	3.74	279	227	0.10	<0.80	301	5.22	5.88	2.93	0.25	4.19	0.56	135.0	95.45	350
5 cm sludge/yr	5	0-15, June	39.58	272	1447	<0.08	<0.80	565	8.17	3.48	1.34	0.34	2.47	0.26	262.5	17.89	207
5 cm sludge/yr	8	0-15, June	36.35	259	1594	<0.08	<0.80	648	11.24	3.36	1.32	0.38	2.96	0.30	282.1	21.06	189
5 cm sludge/yr	16	0-15, June	6.23	227	190	<0.08	<0.80	387	5.91	4.22	1.97	0.29	3.20	0.27	105.1	24.04	324
5 cm sludge/yr	5	0-15	36.97	290	882	<0.08	<0.80	666	7.20	3.28	1.34	0.30	2.13	0.22	161.4	15.54	223
5 cm sludge/yr	5	15-30	26.57	281	829	<0.08	<0.80	511	5.72	4.16	1.57	0.26	2.93	0.27	175.2	19.11	261
5 cm sludge/yr	5	30-45	3.17	269	284	<0.08	<0.80	429	3.44	3.92	1.47	0.18	3.17	0.32	121.1	21.18	211
5 cm sludge/yr	5	45-60	2.63	251	194	<0.08	<0.80	423	3.22	3.68	1.48	0.16	2.91	0.36	103.8	28.81	176
5 cm sludge/yr	5	60-75	2.45	240	164	<0.08	<0.80	373	2.32	4.39	1.73	0.16	3.05	0.30	116.9	48.00	179
5 cm sludge/yr	5	75-90	1.83	225	122	<0.08	<0.80	402	1.15	3.47	1.36	0.09	2.25	0.18	113.6	35.38	78
5 cm sludge/yr	5	90-105	1.67	238	120	<0.08	<0.80	408	1.08	3.04	1.30	0.09	2.04	0.15	111.4	31.80	72
5 cm sludge/yr	8	0-15	30.26	286	1306	<0.08	<0.80	679	11.05	3.40	1.59	0.40	2.87	0.25	161.5	16.25	215
5 cm sludge/yr	8	15-30	12.28	274	733	<0.08	<0.80	549	10.69	4.37	1.78	0.36	3.57	0.30	129.0	20.42	258
5 cm sludge/yr	8	30-45	4.60	296	268	<0.08	<0.80	387	3.79	5.37	2.25	0.29	4.37	0.37	146.3	44.19	259
5 cm sludge/yr	8	45-60	3.78	300	202	<0.08	<0.80	398	2.86	5.49	2.08	0.24	4.81	0.37	126.8	75.02	219
5 cm sludge/yr	8	60-75	2.71	324	183	<0.08	<0.80	445	1.51	4.47	1.82	0.21	4.28	0.34	120.2	54.31	164
5 cm sludge/yr	8	75-90	5.77	281	402	0.10	<0.80	442	9.49	5.08	2.44	0.37	6.14	0.86	123.8	272.31	261
5 cm sludge/yr	8	90-105	4.38	324	584	0.14	<0.80	293	9.08	6.80	2.67	0.29	5.58	0.97	186.7	173.68	308
5 cm sludge/yr	16	0-15	25.80	298	1284	<0.08	<0.80	677	8.33	3.14	1.41	0.39	3.00	0.26	140.9	12.14	234
5 cm sludge/yr	16	15-30	8.25	262	477	<0.08	<0.80	467	5.81	3.09	1.74	0.33	3.37	0.24	115.2	16.35	287
5 cm sludge/yr	16	30-45	6.60	269	311	<0.08	<0.80	472	5.97	2.92	1.52	0.30	3.09	0.23	104.2	15.58	282
5 cm sludge/yr	16	45-60	5.54	246	248	<0.08	<0.80	377	6.21	4.28	2.14	0.30	4.02	0.39	104.7	63.29	363
5 cm sludge/yr	16	60-75	3.52	289	255	0.10	<0.80	269	4.85	6.41	2.55	0.19	4.53	0.50	157.5	70.50	295
5 cm sludge/yr	16	75-90	5.36	251	229	0.11	<0.80	265	4.78	6.35	2.80	0.25	4.58	0.48	124.2	109.72	369
5 cm sludge/yr	16	90-105	5.16	249	192	0.09	<0.80	324	5.61	5.80	2.55	0.31	4.21	0.46	110.4	65.19	406

APPENDIX 4

Appendix 4. Elemental Analysis of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	ug/g																						
			Zr	Sr	Ba	P	Mg	V	Na	Mo	Al	Ca	Zn	Cu	Pb	Li	Tl	Cd	Co	Ni	K	Mn	Fe	Cr	
control	6	0-15	98.4	144.9	549	865	4002	71.3	7979	<17	35165	14681	88.9	24.0	11.42	25.6	2281	0.54	<17	25.7	10773	481	20537	54.4	
control	6	15-30	101.6	144.6	528	901	3984	70.9	9475	<17	34827	16128	96.0	27.5	9.42	25.5	2241	0.36	<17	24.9	10616	456	20345	53.2	
control	6	30-45	103.1	84.7	333	727	2825	83.6	8708	<17	26356	11096	79.1	24.4	10.20	26.6	2526	0.20	<17	26.2	9834	487	20453	55.3	
control	6	45-60	108.8	106.5	455	640	4113	88.4	8206	<17	35297	11713	74.3	22.9	10.68	28.3	2649	0.20	<17	29.7	11821	441	22095	59.4	
control	6	60-75	101.1	98.0	428	536	4017	74.3	7729	<17	34188	9991	66.7	18.9	10.38	23.6	2270	<0.20	<17	23.9	11002	331	20100	47.9	
control	6	75-90	103.9	109.2	471	791	4160	79.8	8603	<17	35756	9782	70.6	21.3	10.59	25.6	2397	0.86	<17	26.1	11791	450	29540	50.3	
control	6	90-105	109.7	123.3	538	652	5570	86.3	8747	<17	44281	10751	76.2	23.3	9.79	27.3	2580	0.62	<17	27.7	12796	352	25914	57.5	
96	control	7	0-15	88.4	180.2	572	913	4434	61.4	7208	<17	36540	19520	90.2	24.7	9.88	23.1	1975	1.15	<17	25.7	9789	421	18581	46.5
	control	7	15-30	85.2	184.0	537	855	4317	56.0	7405	<17	32823	20639	85.1	22.8	9.32	20.3	1776	0.94	<17	24.4	9127	437	17411	48.1
	control	7	30-45	94.8	124.4	466	679	3655	78.9	8599	<17	33513	10746	72.8	21.9	10.77	25.9	2385	<0.20	<17	28.7	10614	568	20619	53.7
	control	7	45-60	99.9	154.7	590	643	4218	84.0	9139	<17	43150	9554	70.1	20.4	9.99	27.6	2577	<0.20	<17	28.8	12416	651	22130	56.7
	control	7	60-75	110.4	93.5	383	669	1962	96.3	8659	<17	26427	9027	74.0	22.9	11.12	29.3	2837	0.32	<17	34.8	9054	1034	21484	53.6
	control	7	75-90	105.6	146.8	557	759	4262	97.0	8725	<17	40677	10547	82.3	23.7	10.55	30.8	2866	<0.20	<17	34.4	12105	736	24901	61.0
	control	7	90-105	100.2	167.7	614	775	5455	84.0	9510	<17	46433	12836	87.6	24.8	10.28	27.7	2599	<0.20	<17	31.9	12847	581	24564	58.9
control	17	0-15	96.7	183.5	567	823	4096	71.0	6730	<17	37519	18043	83.6	23.7	8.28	27.1	2255	0.47	21.35	31.0	9734	392	19933	61.3	
control	17	15-30	96.2	157.3	539	665	3668	68.4	6449	<17	35636	14374	72.7	20.5	9.80	23.5	2178	0.33	22.33	28.7	9136	474	20041	58.7	
control	17	30-45	102.7	72.4	401	578	2099	71.4	7565	<17	18358	10550	68.0	20.0	12.26	20.1	2392	0.35	<17	25.5	8088	394	18444	47.8	
control	17	45-60	92.0	80.7	412	543	2738	67.7	7133	<17	19441	7697	59.8	16.2	12.12	20.5	2234	0.30	<17	24.2	8786	442	17892	42.3	
control	17	60-75	91.5	86.0	405	568	2478	64.1	7381	<17	20495	10634	63.3	16.5	11.75	19.6	2186	0.60	<17	23.5	7867	454	19021	44.7	
control	17	75-90	97.5	80.2	382	661	2383	72.4	6836	<17	19868	9812	60.6	17.6	12.72	20.9	2348	0.47	<17	22.3	8489	376	18617	46.9	
control	17	90-105	99.3	106.1	447	653	2745	68.9	7216	<17	25038	13520	63.1	19.1	11.51	20.8	2267	0.34	<17	23.3	8638	377	18478	48.4	

continued...

Appendix 4. (Continued) Elemental Analysis of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	Zr	Sr	Ba	P	Mg	V	Na	Mo	Al	Ca	Zn	Cu	Pb	Li	Tl	Cd	Co	Ni	K	Mn	Fe	Cr
			ug/g																					
1 cm sludge	2	0-15	86.2	185.2	631	879	5191	73.0	8148	<17	44183	16478	94.1	24.8	10.21	27.5	2360	0.51	21.16	29.3	11017	429	21494	63.3
1 cm sludge	2	15-30	80.8	171.6	599	755	5086	75.6	7870	<17	42684	18941	93.2	23.5	11.60	27.3	2361	0.46	20.07	33.7	10976	426	21537	57.6
1 cm sludge	2	30-45	96.0	152.6	552	784	5930	116.9	8655	<17	45526	16003	91.0	30.8	15.22	36.4	3305	0.43	23.08	39.2	11982	534	28647	67.9
1 cm sludge	2	45-60	82.5	192.1	619	753	5333	87.1	8916	<17	46968	14453	81.4	23.1	11.37	30.3	2635	0.34	21.50	32.2	11727	640	24395	65.3
1 cm sludge	2	60-75	99.0	157.0	569	761	5789	121.5	9173	<17	52237	12623	89.6	29.1	11.99	39.9	3173	<0.20	23.43	42.4	13165	521	28188	76.1
1 cm sludge	2	75-90	98.2	131.4	502	749	4542	99.3	8253	<17	41080	12756	78.7	24.1	11.72	32.5	2909	0.21	24.28	36.9	11617	502	23989	64.8
1 cm sludge	2	90-105	113.5	126.3	539	655	5058	92.4	8783	<17	41201	12008	75.3	25.8	12.61	29.9	2866	0.20	22.16	32.5	12058	371	23549	65.9
67	11	0-15	97.6	239.3	689	736	5691	73.9	7946	<17	46548	17495	74.3	22.6	8.59	28.4	2269	0.36	<17	29.6	11600	620	21883	57.7
	11	15-30	97.4	138.3	537	703	3474	64.2	7973	<17	30857	14520	68.4	22.2	9.06	23.6	2078	0.37	<17	26.1	9291	462	19185	54.1
	11	30-45	109.1	83.8	364	609	2793	71.4	7273	<17	22582	13264	68.1	17.5	11.94	21.1	2191	0.36	<17	19.8	7969	344	16526	47.0
	11	45-60	120.5	111.8	474	619	4459	79.3	7960	<17	35194	13563	73.5	19.1	12.51	23.2	2450	0.35	<17	20.1	10022	376	19972	57.0
	11	60-75	113.3	185.7	750	744	6076	75.9	8461	<17	47119	18451	81.1	21.8	12.68	26.1	2385	0.50	<17	22.0	11771	421	22581	60.0
	11	75-90	104.2	165.2	632	650	5681	82.6	7502	<17	45042	17181	79.2	20.4	11.45	27.8	2264	0.34	<17	22.9	10976	398	20816	60.9
	11	90-105	131.7	110.5	480	681	4064	97.0	8341	<17	37742	14330	83.3	25.9	14.06	28.5	2906	0.35	<17	29.7	10099	645	22797	61.1
1 cm sludge	15	0-15	108.2	142.5	590	704	4147	79.4	8121	<17	40757	11534	74.1	19.9	10.69	24.8	2537	0.40	<17	25.9	11194	516	21853	63.9
1 cm sludge	15	15-30	96.7	121.6	492	605	3163	76.3	7706	<17	34688	10499	68.9	20.2	10.84	28.4	2485	0.61	23.77	27.0	9660	424	21317	61.6
1 cm sludge	15	30-45	104.4	117.5	426	704	3197	87.5	8223	<17	33237	12230	72.8	25.6	9.75	29.9	2714	0.21	26.72	29.9	9304	500	22730	65.3
1 cm sludge	15	45-60	106.8	150.4	509	664	3877	80.2	7157	<17	37962	12249	67.7	22.0	10.56	29.4	2535	0.32	22.81	30.1	10102	447	23013	62.9
1 cm sludge	15	60-75	106.8	193.1	606	774	4477	76.6	7976	<17	40995	16429	73.1	25.3	10.18	30.7	2478	0.47	25.50	33.9	10330	585	23925	64.0
1 cm sludge	15	75-90	117.4	100.8	400	549	2603	73.3	8165	<17	28139	8979	174.6	208.5	9.18	24.9	2478	0.37	27.10	29.6	9301	497	19323	58.3
1 cm sludge	15	90-105	124.4	108.5	436	480	2937	78.8	8308	<17	29617	6118	61.6	21.0	10.76	25.2	2713	<0.20	25.63	31.3	10664	313	20086	60.1

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Appendix 4. (Continued) Elemental Analysis of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	Zr	Sr	Ba	P	Mg	V	Na	Mo	Al	Ca	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	K	Mn	Fe	Cr	
			ug/g																						
3 cm sludge	4	0-15	116.8	149.4	610	852	4454	61.5	8050	<17	33404	18305	80.9	22.5	9.86	22.3	1976	0.51	25.11	27.7	9640	408	18007	46.4	
3 cm sludge	4	15-30	126.2	156.0	625	742	4940	66.3	8449	<17	36279	18332	80.0	23.4	10.47	23.7	2102	0.50	23.80	27.8	10518	417	19382	53.6	
3 cm sludge	4	30-45	135.9	117.8	585	559	5655	80.3	8500	<17	40859	12120	71.3	21.8	13.49	25.8	2428	<0.20	24.45	29.8	12389	418	22858	56.8	
3 cm sludge	4	45-60	146.8	105.3	541	585	5489	105.3	8467	<17	46043	10932	84.0	25.3	14.21	30.9	2901	<0.20	28.76	36.7	12658	439	26183	68.0	
3 cm sludge	4	60-75	111.5	90.7	399	562	4041	100.4	8117	<17	35845	9542	80.5	23.4	13.02	28.8	2797	<0.20	<17	31.4	10988	433	24037	59.3	
3 cm sludge	4	75-90	88.0	110.4	468	658	3799	85.1	7978	<17	35319	9881	65.6	19.2	11.96	21.6	1982	0.34	<17	26.9	10755	546	22066	49.4	
3 cm sludge	4	90-105	103.8	121.1	610	592	4654	80.7	7931	<17	42121	10464	74.4	23.0	10.96	25.7	2460	<0.20	<17	27.5	12292	418	22678	56.2	
68	3 cm sludge	9	0-15	93.7	171.8	595	894	4409	66.0	7437	<17	36800	17529	82.2	22.6	8.60	24.3	2072	0.59	<17	26.6	9704	438	19726	53.3
	3 cm sludge	9	15-30	93.7	158.9	578	761	3882	65.6	7972	<17	33825	16270	77.4	21.5	8.38	22.9	2019	0.47	<17	27.8	9301	507	18669	53.4
	3 cm sludge	9	30-45	97.9	118.9	517	638	3522	70.8	7684	<17	34730	10959	68.8	19.7	10.00	23.4	2218	<0.20	<17	27.9	10040	529	19980	56.8
	3 cm sludge	9	45-60	100.8	125.0	495	644	3474	72.1	7727	<17	30781	12560	69.6	21.5	12.81	25.4	2238	0.32	<17	24.1	9621	469	19999	55.4
	3 cm sludge	9	60-75	112.7	138.4	546	705	4288	84.8	9060	<17	40117	12635	79.9	23.1	11.18	29.7	2578	0.23	<17	29.9	11113	583	22609	60.7
	3 cm sludge	9	75-90	105.1	110.0	431	662	3069	85.4	8845	<17	29813	11898	78.3	21.7	12.07	27.4	2582	<0.20	<17	29.8	9825	527	20544	58.4
	3 cm sludge	9	90-105	114.6	94.1	389	607	3226	86.0	8361	<17	27700	11535	68.9	22.9	8.19	27.5	2629	0.48	<17	29.2	9792	443	20187	57.3
3 cm sludge	18	0-15	91.4	128.9	516	801	3245	64.2	6885	<17	28498	15188	70.5	21.0	11.03	20.8	2157	0.60	<17	21.5	8407	386	18369	47.7	
3 cm sludge	18	15-30	90.8	161.1	584	739	4229	60.1	6574	<17	35397	16320	67.3	19.5	9.77	19.6	2045	0.71	<17	22.2	8897	402	18186	46.7	
3 cm sludge	18	30-45	93.6	153.8	588	713	4213	60.7	6583	<17	36453	14781	66.3	19.0	11.51	19.7	2107	0.62	<17	22.8	9328	387	18373	48.8	
3 cm sludge	18	45-60	95.8	140.3	622	576	4428	68.2	7173	<17	40516	10864	63.7	17.3	10.79	24.0	2280	0.40	<17	28.8	10302	542	20924	57.3	
3 cm sludge	18	60-75	96.0	81.7	385	580	2314	65.2	7784	<17	22922	10133	63.9	17.3	10.91	19.7	2246	0.33	<17	23.3	8184	435	18933	44.8	
3 cm sludge	18	75-90	99.7	128.6	542	628	3987	64.9	7402	<17	36180	12333	60.9	18.6	10.63	20.8	2221	0.35	<17	21.9	9881	431	19989	49.3	
3 cm sludge	18	90-105	100.8	126.5	530	699	3891	72.7	7298	<17	35094	13620	69.3	21.6	10.67	23.7	2309	0.46	<17	23.2	9677	344	19165	49.9	

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Appendix 4. (Continued) Elemental Analysis of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	Zr	Sr	Ba	P	Mg	V	Na	Mo	Al	Ca	Zn ug/g	Cu	Pb	Li	Ti	Cd	Co	Ni	K	Mn	Fe	Cr	
5 cm sludge	3	0-15	80.0	185.4	612	1043	4792	69.3	8439	<17	40119	18304	80.2	22.6	10.04	24.8	2244	0.47	19.84	32.6	10333	465	20024	56.0	
5 cm sludge	3	15-30	92.6	121.7	483	722	3999	85.7	9446	<17	36533	11831	76.3	23.5	11.49	29.3	2713	0.33	20.18	31.3	10619	361	21871	61.0	
5 cm sludge	3	30-45	104.6	125.3	513	686	4673	96.9	8438	<17	42291	11032	73.0	25.2	13.13	32.6	2885	<0.20	23.25	30.3	11920	375	23925	66.2	
5 cm sludge	3	45-60	133.8	117.2	596	538	5781	76.9	7499	<17	42890	11181	70.1	20.1	12.60	25.0	2346	<0.20	26.33	29.1	12245	383	22178	53.8	
5 cm sludge	3	60-75	129.6	120.8	616	536	5947	76.4	8348	<17	42940	13539	68.3	19.9	12.64	24.7	2321	0.34	25.60	28.8	12351	389	21532	53.5	
5 cm sludge	3	75-90	156.6	89.2	471	572	4515	83.9	8911	<17	33997	12062	76.1	23.6	12.46	25.8	2515	0.34	25.67	31.4	11107	406	20705	56.9	
5 cm sludge	3	90-105	127.7	102.4	544	494	4787	71.1	8035	<17	35901	11399	63.7	20.6	20.78	22.4	2215	<0.20	23.49	25.5	11123	352	19474	50.5	
60	5 cm sludge	12	0-15	104.0	183.2	659	1087	4994	67.5	7992	<17	38833	21368	79.0	21.6	10.06	20.6	2132	0.74	<17	23.0	9710	381	18969	52.3
	5 cm sludge	12	15-30	115.0	183.7	719	781	5558	77.0	8409	<17	46302	17611	76.4	20.2	9.91	22.4	2394	0.48	<17	22.8	11658	487	22643	59.3
	5 cm sludge	12	30-45	117.3	90.8	421	678	2896	76.7	9793	<17	25477	14063	73.5	20.4	10.30	21.5	2457	<0.20	<17	23.6	9537	440	20332	57.1
	5 cm sludge	12	45-60	131.4	112.4	517	620	4735	93.6	8977	<17	36541	12490	71.6	19.5	10.83	26.1	2782	<0.20	<17	26.6	11725	417	22637	65.0
	5 cm sludge	12	60-75	103.4	86.3	389	666	3659	81.2	9067	<17	26953	10952	81.2	24.3	12.43	17.5	2453	0.21	<17	19.3	10232	441	19752	51.4
	5 cm sludge	12	75-90	131.8	84.5	384	668	3570	81.8	8193	<17	26420	11519	85.2	21.2	11.46	17.6	2506	0.21	<17	18.8	10202	407	20585	56.5
	5 cm sludge	12	90-105	111.4	91.8	424	699	4084	82.4	8412	<17	28151	11826	88.2	21.0	14.84	19.1	2550	0.73	<17	23.7	10871	434	20765	56.7
5 cm sludge	14	0-15	103.2	147.8	575	1038	3849	65.0	8449	<17	33445	16474	84.1	23.2	9.69	16.1	2104	0.46	<17	20.3	10064	499	19193	55.5	
5 cm sludge	14	15-30	100.2	112.9	511	683	3321	70.5	9232	<17	29066	11818	72.7	19.4	10.98	17.1	2290	0.32	<17	15.9	10966	478	19959	52.9	
5 cm sludge	14	30-45	104.6	150.6	599	748	4780	74.6	8706	<17	41130	12651	76.8	21.8	10.76	20.1	2404	0.31	<17	22.0	11942	528	22766	58.8	
5 cm sludge	14	45-60	104.0	171.2	647	759	5125	70.0	8488	<17	44346	13831	72.8	20.2	10.70	18.2	2259	0.32	<17	19.2	12349	590	22424	56.3	
5 cm sludge	14	60-75	116.5	129.6	505	796	3796	72.8	10215	<17	34007	12448	72.0	19.6	10.46	19.6	2463	<0.20	<17	15.9	11205	506	22130	60.7	
5 cm sludge	14	75-90	100.8	114.2	513	823	4326	94.1	8242	<17	32422	13562	87.9	26.7	11.81	20.5	2698	<0.20	<17	26.9	10735	515	24955	62.5	
5 cm sludge	14	90-105	118.5	129.5	568	825	4679	87.7	8618	<17	40204	12453	81.9	25.5	11.02	21.2	2714	0.32	<17	24.3	12307	485	23006	59.2	

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Appendix 4. (Continued) Elemental Analysis of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	Zr	Sr	Ba	P	Mg	V	Na	Mo	Al	Ca	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	K	Mn	Fe	Cr
			ug/g																					
5 cm sludge&ash	1	0-15	74.6	214.8	665	1360	4731	60.0	7615	<17	35541	26245	83.4	23.4	8.57	22.2	2005	0.32	19.01	25.5	10104	388	17653	49.4
5 cm sludge&ash	1	15-30	81.3	116.4	468	747	3374	75.6	8398	<17	30699	11882	87.8	21.9	10.86	26.8	2408	0.35	22.23	29.3	9845	474	20629	52.7
5 cm sludge&ash	1	30-45	84.8	142.9	556	649	4749	86.0	9308	<17	43336	10406	82.4	23.1	11.66	29.2	2617	<0.20	21.56	31.7	11443	527	25210	65.8
5 cm sludge&ash	1	45-60	82.0	140.3	526	654	4626	81.4	7945	<17	38527	11691	83.9	20.9	13.22	28.5	2508	0.32	19.99	32.8	10947	461	22086	60.5
5 cm sludge&ash	1	60-75	93.7	185.8	620	759	5263	83.3	8655	<17	43724	14762	105.1	25.3	13.05	32.5	2667	0.34	20.83	35.3	11577	626	25480	60.4
5 cm sludge&ash	1	75-90	81.3	225.4	647	771	5639	76.4	7311	<17	41885	17383	93.9	21.3	9.15	<15.0	2371	0.47	20.47	33.1	10807	716	22583	59.3
5 cm sludge&ash	1	90-105	92.0	147.7	567	659	5449	94.5	8804	<17	47267	10882	92.2	22.8	13.81	31.8	2879	<0.20	22.36	31.1	12624	457	25892	65.2
70	10	0-15	101.3	223.1	736	1451	4757	63.8	7925	<17	36740	29057	84.3	23.2	11.26	23.8	2039	0.20	<17	27.2	10668	438	19048	54.2
	10	15-30	99.7	176.0	669	791	4742	71.3	9175	<17	42538	15616	74.7	23.1	10.17	25.2	2284	0.49	<17	30.6	11347	582	21528	60.8
	10	30-45	106.0	101.5	461	771	2539	77.4	9025	<17	24368	11936	86.0	24.4	10.23	26.4	2409	0.36	<17	29.5	9386	569	19796	56.7
	10	45-60	98.4	111.4	447	633	3407	70.7	8136	<17	31062	11052	85.4	23.1	9.99	25.2	2211	<0.20	<17	24.7	9617	438	19133	55.4
	10	60-75	94.5	99.6	392	621	2725	66.3	7876	<17	24869	11478	82.2	21.4	10.17	25.0	2134	0.20	<17	23.4	8850	411	17786	47.6
	10	75-90	100.3	100.1	396	619	2917	75.3	7394	<17	24999	10990	63.0	20.2	10.20	26.2	2335	0.20	<17	27.4	9192	514	18655	54.6
	10	90-105	93.9	145.1	537	705	3923	62.0	7418	<17	34746	14058	74.9	22.4	11.44	22.9	1980	0.78	<17	23.3	9300	369	18147	52.2
5 cm sludge&ash	13	0-15	105.3	183.9	660	1215	4811	64.3	8880	<17	37125	23094	94.1	22.5	9.75	15.4	2090	0.35	<17	<15.0	11209	442	19153	50.0
5 cm sludge&ash	13	15-30	103.7	181.4	651	1054	4773	62.2	8611	<17	39171	19868	92.4	24.1	10.13	15.7	2049	0.48	<17	17.5	11046	411	18596	52.2
5 cm sludge&ash	13	30-45	97.3	117.9	514	704	3873	69.1	8503	<17	30848	12793	80.2	20.4	11.60	16.8	2219	0.33	<17	20.7	10783	531	20909	47.9
5 cm sludge&ash	13	45-60	100.3	131.0	560	656	4277	69.4	8813	<17	38180	11876	81.1	19.5	12.99	17.0	2261	0.35	<17	17.2	11649	482	20726	56.4
5 cm sludge&ash	13	60-75	100.7	128.1	527	656	4302	71.2	8418	<17	36255	12068	85.4	20.0	13.84	17.8	2246	0.34	<17	17.7	11385	469	20926	55.6
5 cm sludge&ash	13	75-90	106.8	195.1	680	868	5435	71.3	8711	<17	43202	18709	99.2	27.0	12.58	22.4	2313	0.70	<17	23.4	11854	604	22600	62.1
5 cm sludge&ash	13	90-105	112.9	143.0	558	787	5032	78.3	9390	<17	37486	14186	82.2	24.7	11.52	20.3	2443	<0.20	<17	22.1	11117	550	21938	58.8

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Appendix 4. (Concluded) Elemental Analysis of Sludge and Ash Amended Soils in 1993.

Treatment	Plot	Depth (cm)	Zr	Sr	Ba	P	Mg	V	Na	Mo	Al	Ca	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	K	Mn	Fe	Cr
			ug/g																					
5 cm sludge/yr	5	0-15,Jun	82.0	167.1	576	1275	4447	55.9	7964	<17	32960	19387	71.9	20.4	8.88	18.5	1857	0.60	<17	21.2	8836	404	17466	43.0
5 cm sludge/yr	8	0-15,Jun	82.5	175.1	587	1181	4520	57.4	7859	<17	33790	19463	76.8	22.0	9.48	19.4	1907	0.75	<17	23.3	8899	362	17432	44.1
5 cm sludge/yr	16	0-15,Jun	86.0	148.2	569	981	4265	59.7	7871	<17	35248	15244	67.9	20.4	9.57	19.4	1994	0.49	<17	19.1	9193	382	18225	41.6
5 cm sludge/yr	5	0-15	99.4	166.2	588	1381	4803	67.4	9187	<17	39571	17259	91.8	25.5	10.09	25.1	2133	0.33	<17	26.6	11335	506	20425	58.7
5 cm sludge/yr	5	15-30	105.0	138.7	532	996	4435	75.4	8971	<17	37596	13520	85.9	23.3	10.13	25.5	2337	<0.20	<17	27.2	11518	440	21644	56.5
5 cm sludge/yr	5	30-45	97.3	104.9	425	678	3594	74.9	8166	<17	31629	10250	79.3	26.8	11.90	24.7	2299	0.33	<17	25.8	10861	384	20163	55.1
5 cm sludge/yr	5	45-60	105.6	126.4	490	667	4274	78.3	8750	<17	36263	11277	79.4	21.3	10.11	26.2	2405	<0.20	<17	25.9	11675	441	21662	54.0
5 cm sludge/yr	5	60-75	107.1	108.9	452	646	3965	81.9	9019	<17	35507	11043	118.6	80.6	11.64	26.5	2551	<0.20	<17	25.5	11315	462	21620	56.0
5 cm sludge/yr	5	75-90	112.4	113.7	513	618	4549	77.5	8102	<17	39556	10340	76.8	21.5	30.92	24.7	2516	0.35	<17	25.5	12227	409	21818	54.1
5 cm sludge/yr	5	90-105	113.7	101.9	471	639	4115	82.5	7628	<17	34577	10397	78.4	20.1	13.64	25.7	2627	<0.20	<17	25.8	12090	361	22088	54.1
5 cm sludge/yr	8	0-15	94.6	164.5	576	1177	4484	67.2	8774	<17	37003	17196	87.1	23.9	8.26	24.5	2147	0.46	<17	27.7	10748	486	19666	49.4
5 cm sludge/yr	8	15-30	94.7	171.6	580	960	4526	69.0	8373	<17	37647	17381	85.3	23.2	8.56	24.8	2213	0.34	<17	26.4	10945	472	20570	49.2
5 cm sludge/yr	8	30-45	108.3	119.9	447	757	3388	90.2	8858	<17	33181	11956	79.7	23.1	10.37	29.0	2738	<0.20	<17	32.0	10776	768	23611	57.7
5 cm sludge/yr	8	45-60	102.0	124.1	476	706	3208	81.3	8310	<17	30912	10911	68.0	22.3	10.18	26.0	2443	<0.20	<17	27.3	10375	630	21632	55.3
5 cm sludge/yr	8	60-75	111.6	123.1	462	772	3443	83.6	9322	<17	32909	10543	72.8	22.5	10.15	27.9	2532	0.20	<17	34.0	11164	768	22294	57.5
5 cm sludge/yr	8	75-90	101.1	190.9	615	712	4440	74.7	8084	<17	37145	14908	76.5	21.8	11.24	27.2	2274	0.61	<17	30.4	10247	810	22255	56.8
5 cm sludge/yr	8	90-105	101.1	148.1	468	766	4298	101.8	8743	<17	33982	14168	98.8	32.1	11.17	32.7	2800	0.45	<17	39.3	9545	638	24442	61.3
5 cm sludge/yr	16	0-15	98.6	135.5	496	970	3171	73.1	8405	<17	30683	14063	71.0	21.7	9.27	26.2	2354	0.34	22.92	27.9	9265	404	19749	62.3
5 cm sludge/yr	16	15-30	94.7	132.0	496	713	3198	72.4	7713	<17	33540	11833	67.8	18.8	10.33	25.3	2359	0.45	22.18	28.4	9489	430	20151	58.0
5 cm sludge/yr	16	30-45	99.7	131.5	484	684	3366	78.2	8000	<17	36810	11053	65.5	19.3	9.45	28.7	2436	0.22	25.04	30.6	9679	419	20915	65.8
5 cm sludge/yr	16	45-60	91.2	158.8	552	622	4076	65.6	7184	<17	40304	12263	64.8	18.0	8.73	24.8	2291	0.32	22.30	26.7	10123	493	20307	60.9
5 cm sludge/yr	16	60-75	92.3	164.5	555	645	5155	86.0	7394	<17	45988	12405	83.3	23.2	9.47	29.8	2585	<0.20	23.27	31.3	10896	405	24534	65.9
5 cm sludge/yr	16	75-90	101.8	179.6	590	633	4910	72.0	7106	<17	46472	12674	74.4	20.1	8.77	26.8	2332	0.76	21.94	27.9	11070	397	21745	62.5
5 cm sludge/yr	16	90-105	100.2	164.3	583	687	4526	73.5	6690	<17	44932	11906	75.3	22.3	9.94	27.6	2370	<0.20	19.81	27.7	11246	389	21255	61.8

