REMEDIATION OF UPLAND ACTIVE ACID SULFATE SOILS WITH LIME-STABILIZED BIOSOLIDS, LIME AND YARDWASTE COMPOST[1]

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Abstract: Excavation of sulfidic materials during construction has resulted in acid rock drainage (ARD) problems on disturbed lands throughout much of Virginia. In particular, exposure of sulfide-bearing Tertiary marine sediments in the Coastal Plain has become increasingly prevalent. Once exposed, these sediments rapidly produce acid sulfate soils which do not readily support vegetation. To date, the most extensive case of acid sulfate weathering problems in the Coastal Plain occurs at Stafford Regional Airport (SRAP) in Stafford, Virginia. Field plots were established at SRAP in 2002 to evaluate a variety of amendments for remediation and revegetation of acid sulfate soils. The plots were constructed in a completely randomized design with 5 treatments and 4 replications per treatment. Prior to treatment, surface (0–15cm) soil samples were collected from all plots to determine pH and peroxide potential acidity (PPA). Treatments included two rates of lime-stabilized biosolids (184 and 92 Mg ha^{-1}) with small amounts of additional lime to achieve calcium carbonate equivalences (CCE) of 53 and 27 Mg ha^{-1}, two rates of lime (47 and 23 Mg ha^{-1} CCE) with N, P, and K fertilizers, yardwaste compost (101 Mg ha^{-1}) with lime (24 Mg ha^{-1} CCE) and P and K fertilizers, and a control. The plots were seeded with a mix of acid- and salt-tolerant grasses. Soil and vegetation samples were collected in duplicate from each plot after 1 and 2 years. No significant differences were observed among the amended treatments for surface soil pH, surface soil EC, or vegetation production for either of the sampling dates, indicating that all of the tested amendment combinations were effective in stabilizing these materials.

Additional Key Words: acid sulfate soils, lime-stabilized biosolids, peroxide potential acidity, pyrite, yardwaste compost.

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Introduction

Acid producing *sulfidic materials* (as defined by *Soil Taxonomy*, Soil Survey Staff, 2006) are found in various geologic and geomorphic settings across the state of Virginia (Orndorff and Daniels, 2004). In many of these settings, construction for highways as well as commercial and residential sites has resulted in localized acid rock drainage (ARD) that threatens water quality, fill stability, integrity of building materials, and vegetation management. In particular, several problem sites have resulted from exposure of sulfidic Tertiary marine sediments in the Upper Coastal Plain (Fig. 1).

Unoxidized Tertiary marine sediments in the Virginia Coastal Plain occur in drab shades of green, blue, and gray, and consist of fine- to coarse-grained, quartzose sand, silt, and clay that is variably shelly, diatomaceous, and glauconitic (Rader and Evans, 1993). Unoxidized samples typically have pH values between 5.5 to 8.0, total-S values between 1.0 to 2.5%, and peroxide potential acidity (PPA; described below; Barnhisel and Harrison, 1976; Orndorff et al., 2008) values between 30 to 50 Mg $CaCO_3$/1000 Mg material. Upon exposure to oxidizing conditions and weathering, field pH rapidly drops to values between 2.5 to 3.5, total-S drops to <1.0%, and PPA values drop to < 20 Mg $CaCO_3$ per 1000 Mg material (Orndorff and Daniels, 2004).

The most extensive (> 150 ha) documented uncontrolled disturbance of Tertiary marine sediments at a single location is Stafford County Regional Airport (SRAP) in Stafford, Virginia (Figs. 1 and 2). Construction of SRAP began in 1998, and after the failure of multiple revegetation efforts via conventional hydro-mulching with lime, the authors were contacted for assistance in the late fall of 2001. The authors first visited the SRAP site in November 2001 at which time acid-sulfate weathering problems were readily apparent. Over 150 ha of cut and fill slopes were barren of vegetation, acid drainage was prominent, concrete lined drainage ditches and culverts were coated with iron (hydr)oxide precipitates, and significant etching and degradation of the cement components were noted. Where *sulfidic materials* were exposed by construction, a *sulfuric horizon* (as defined by *Soil Taxonomy*, Soil Survey Staff, 2006) had developed at the soil surface to a depth of approximately 0.3 m with prominent coatings of white salt-efflorescence and pH values ranging from 1.8 – 3.5. The *sulfuric horizon* was directly underlain by *sulfidic materials.* These soils would be classified as Typic Sulfudepts (Soil Survey Staff, 2006). A detailed discussion of the active acid sulfate soils at SRAP can be found in Fanning et al. (2004).

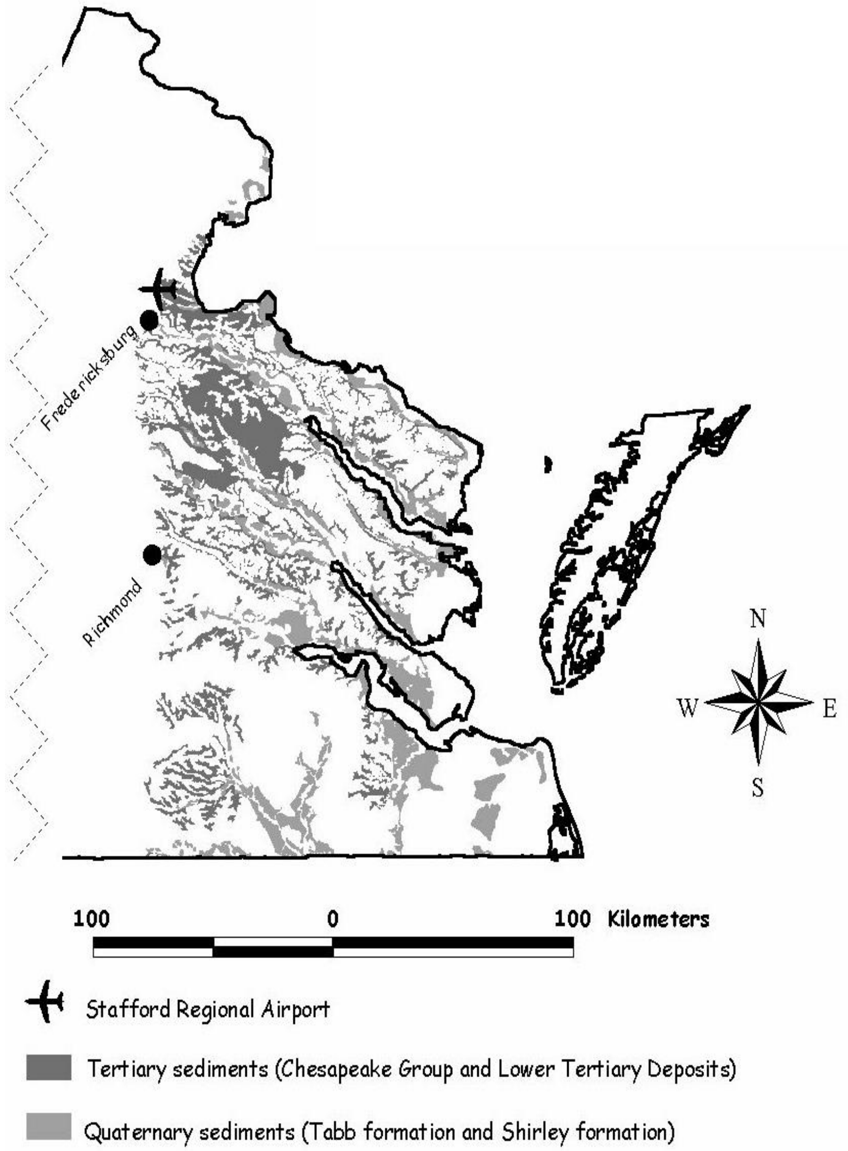

Figure 1. Location of Stafford Airport in eastern Virginia. Also shown are surface outcrops of known Coastal Plain geologic units with significant levels of sulfidic materials. Significant sulfide bearing units also occur in the Piedmont to the west of the airport, but are not shown here.

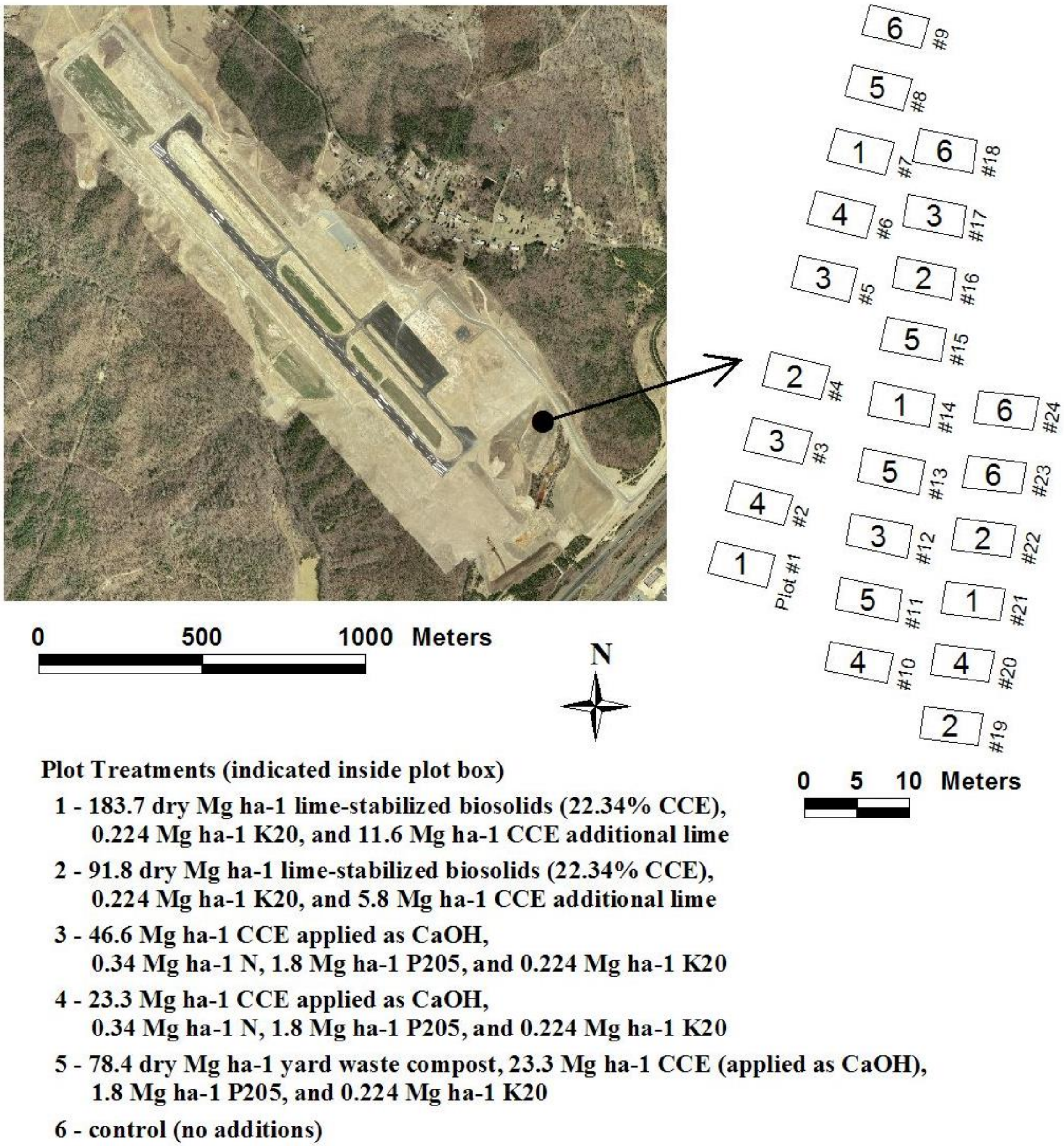

Figure 2. An overview of Stafford Regional Airport (2002 – prior to completed reclamation) indicating location of the field plots is shown to the left. The layout and treatments used for the field plots are shown to the right.

After consideration of possible remediation strategies the airport authority opted to use lime-stabilized biosolids as a cost-effective treatment. Municipal wastewater treatment biosolids are commonly applied to surface mined lands to enhance organic matter, nutrient pools, water holding capacity and overall long-term productivity (Haering et al., 2000). Reclamation efforts were conducted in the spring and fall of 2002, and soil and water quality were monitored from 2002 to 2006. Orndorff et al. (2008) provide a detailed study of the revegetation and water quality studies at SRAP.

In conjunction with the remediation efforts conducted throughout the site, a field plot study was established in 2002 to compare various amendments used for the reclamation of active acid sulfate soils. The objective of this study was to evaluate the relative effectiveness of two different loading rates of lime-stabilized biosolids versus more conventional revegetation strategies such as heavy liming plus straw mulch and yardwaste compost plus lime. This paper focuses on the results of that field plot study.

Materials and Methods

Field plots were installed on a cut surface at SRAP on September 24th and 25th, 2002. The plots were laid out in a completely randomized design with six treatments and four replications per treatment, for a total of 24 plots (Fig. 2). Each plot was 3.0 x 4.6 m, with a 3.0 x 4.6 m alleyway in between plots. A double alleyway (6.1 x 4.6 m) was installed between plots 4 and 5 to avoid an existing erosion gully. The area slopes gently (< 8%) from west-northwest to east-southeast. The six treatments used in this study included:

1. Bio 2X - 184 dry Mg ha^{-1} lime-stabilized biosolids (22.34% CCE), 0.22 Mg ha^{-1} K_2O, and 11.6 Mg ha^{-1} CCE additional lime (applied as $Ca(OH)_2$). Total applied CCE = 52.6 Mg ha^{-1}.

2. Bio 1X - 92 dry Mg ha^{-1} lime-stabilized biosolids (22.34% CCE), 0.22 Mg ha^{-1} K_2O, and 5.8 Mg ha^{-1} CCE additional lime (applied as $Ca(OH)_2$). Total applied CCE = 26.3 Mg ha^{-1}.

3. Lime 2X - 47 Mg ha^{-1} CCE applied as $Ca(OH)_2$, 0.34 Mg ha^{-1} N, 1.8 Mg ha^{-1} P_2O_5, and 0.22 Mg ha^{-1} K_2O.

4. Lime 1X - 23 Mg ha^{-1} CCE applied as $Ca(OH)_2$, 0.34 Mg ha^{-1} N, 1.8 Mg ha^{-1} P_2O_5, and 0.22 Mg ha^{-1} K_2O.

5. Compost & Lime - 101 dry Mg ha^{-1} yard waste compost, 23 Mg ha^{-1} CCE (applied as $Ca(OH)_2$), 1.8 Mg ha^{-1} P_2O_5, and 0.22 Mg ha^{-1} K_2O.

6. Control - no lime, fertilizer or organic amendments.

Alleyways and buffer zones received 23 Mg ha^{-1} CCE (applied as $Ca(OH)_2$), 0.34 Mg ha^{-1} N, 1.8 Mg ha^{-1} P_2O_5, and 0.224 Mg ha^{-1} K_2O. Chemical properties of the lime-stabilized biosolids and yard waste compost are provided in Table 1.

Table 1. Chemical properties of Blue Plains lime-stabilized biosolids and yard waste applied to field plots at Stafford County Regional Airport. (bd = below detection, na = not analyzed).

	Blue Plains Biosolids	**Yard Waste Compost**
Solids (%)	25.81	61.00
Total N (%)	4.12	0.65
Ammonium-N (%)	0.14	0.01
Nitrate-N (mg/kg)	25	bd
Organic N (%)	3.98	0.64
Total Organic C (%)	34.68	34.95
C:N Ratio	8.4	53.8
P (%)	1.38	0.07
K (%)	0.17	0.29
S (%)	0.86	0.08
Ca (%)	12.80	1.29
Mg (%)	0.23	0.17
Na (%)	0.02	bd
Fe (%)	3.56	0.73
Al (%)	0.43	0.77
Mn (mg/kg)	315	515
Cu (mg/kg)	213	24
Zn (mg/kg)	390	71
Soluble Salts (mg/kg)	82240	7680
CCE (%)	22.34	na

Composite surface (0–15 cm) soil samples were collected from each plot prior to the application of amendments. After soil sampling was completed, the control plots along with a 0.6 m buffer zone around each plot were covered with plastic tarps. A tractor mounted spinner spreader was used to spread 0-0-60 potash over the plots, alleys and buffer zone.

Lime, at rates indicated above, was spread by hand on the plots, alleyways and buffer zones. The areas were raked after spreading to even the application rate. The biosolids plots (plus two buffer zones) were covered with plastic tarps and 0-46-0 triple superphosphate was spread over the area with a tractor mounted spinner spreader. The yard waste plots (plus buffer zones) were then covered, and 34-0-0 ammonium nitrate was spread over the area with the tractor mounted spinner spreader.

The biosolids plots were uncovered, and all fertilizer that had collected on the plastic was retained for off-plot disposal. Biosolids were applied to the plots with a tractor mounted 0.5 m loader bucket on the tractor. The yard waste plots were uncovered, again retaining material collected on the plastic for off plot disposal, and yard waste compost was spread using the tractor mounted loader bucket. Rakes and shovels were used to spread both the biosolids and the yard waste evenly across the plots and plot buffer zones. The check plots were uncovered, retaining all material collected on the plastic for off-plot disposal, and the entire area (plots, alleys, and buffer zones) were disked thoroughly with a tractor mounted disk to a depth of 15 to 30 cm then rototilled. The area was seeded on September 25, 2002 with the following seed mix:

Tall fescue: 11 kg - *Festuca arundinaceae* - 85% germ
Annual Ryegrass: 4 kg - *Lolium multiflorum* - 96%
Korean Lespedeza: 4 kg - *Lespedeza stipulacea* - 76.5%
Yellow Sweetclover: 2 kg - *Melilotus officinalis* - 76%
Birdsfoot Trefoil : 2 kg - *Lotus corniculatus*, Norcen - 63%
Hard Fescue: 7 kg - *Festuca ovina* var duriuscula - 89%

Each batch of seed was inoculated with *Rhizobia* specific for trefoil, clover, and lespedeza. Two thirds of the seed was weighed and added to the tank of a 6000 L (1600 gal) hydraulic seeder and sprayed out with wood fiber mulch at a rate of 4480 Mg ha^{-1}. Straw was blown on and tacked with the final third of the seed mix.

Soil and vegetation samples were collected after one year (September, 2003) and two years (October, 2004). For each plot, two 0.25 m^2 quadrats were randomly placed and vegetation within the quadrat was collected by snipping all vegetation at its base and snipping all vegetation along the inside edge of the quadrat. Vegetation was trimmed as close to, but not including, the rooty mass at the soil surface, and dead grassy vegetation that did not appear to be rooted in the plot was avoided. All loose vegetation within the quadrat was collected and placed in a paper bag. After removing the vegetation, the topsoil (0 – 15 cm) and a composite subsoil (15 – 30cm) sample within each quadrat were collected and stored in plastic bags.

All soil samples were dried, ground and analyzed for saturated paste pH and EC. In addition, surface soils from 2002 were analyzed for total C and N, and acid producing potential was determined by potential peroxide acidity (PPA). The PPA method is a modified H_2O_2 method based on Barnhisel and Harrison (1976) and O'Shay et al. (1990). By this method, a 1 g finely ground sample is oxidized with 120 ml H_2O2_2 and the resulting solution is titrated with NaOH to determine the amount of acidity produced. A detailed discussion of this method is provided in Orndorff et al. (2008). Surface soils from 2004 were analyzed for total C and N, and for dilute acid (Mehlich I) extractable nutrient and metal levels. Vegetation samples were desiccated in drying racks for 24 hours, then the dry weight was recorded to determine dry biomass. For each plot, average values from the two random samples were used to represent the plot. A conventional ANOVA and mean separation approach was used to analyze for treatment effects on soil properties and plant yields along with several non-parametric approaches (Kruskal-Wallis and Wilcoxon rank sums). As discussed later, the data set in this study frustrated statistical analyses.

Results and Discussion

Characterization of initial active acid sulfate soil material

A summary of results from all soil sampling events is shown in Table 2. Prior to reclamation (2002), the surface soil (0 – 15 cm) had pH values for all plots ranged from 2.2 to 2.9, except for plot #9 (control) which had a pH of 4.2. Similarly, while surface soil PPA values ranged from 4.3 to 18.5 Mg $CaCO_3$/1000 Mg material, plot #9 had a PPA value of only 0.2 Mg $CaCO_3$/1000 Mg material. The surface soil in plot #9 was not as severely affected by acid sulfate weathering as were the other plots, and therefore the control had initial average values that were slightly higher in pH and lower in PPA than the other five treatments. Plot #9 had a total C concentration of 0.62% and N concentration of 0.07%; for the remaining 23 plots, C concentrations ranged from 0.2 – 0.5% and N concentrations ranged from 0.03 – 0.04%.

Soil pH and EC after reclamation

In 2003, pH for the plots that received amendments increased noticeably with only one exception (Table 2). Plot #19 (treatment 2) yielded pH values of 3.7 and 4.3. Based on visual inspection we believe this plot was affected by erosion along the edge of the research area, and the surface soil samples did not accurately represent the reclaimed material. Therefore, plot #19 was removed from the following statistical analyses of pH and EC and from the data presented in Table 2 for yrs 2003 and 2004. For the remaining plots which received amendments, pH values ranged from 6.6 to 7.9, with a median value of 7.6. In 2004, the pH values were similar ranging from 6.2 to 8.1, with a median value of 7.9. As indicated in Table 2, the highest average pH values were observed for treatments 3 and 4 (the two treatments which received lime only) and the lowest value was observed for treatment 2 (the lower rate of biosolids); however, there were no statistically significant differences ($\alpha = 0.05$) in pH values among the 5 amended treatments for either year.

Analysis of pH values over time for the control plots was problematic. As discussed above, the surface soil in control plot #9 initially had a relatively high pH value (4.2) which did not accurately represent the severely acidified soil material present in all other plots. It is worth noting that the surface soil pH for this plot showed little change in years 2003 and 2004 (pH = 4.1 for both years) as would be expected given that the plot did not receive any amendments. Control plots #23 and #24 had very low initial pH values (2.4 and 2.5, respectively), but showed unexpected increases to pH values of 7.7 and 7.4 for year 2003. These values decreased to 7.0 and 5.8 for year 2004. One hypothesis for the higher than expected pH in the control plots in 2003 and 2004 was the possibility that the relatively soluble $Ca(OH)_2$ had migrated with surface runoff from uphill limed plots. The pH increase also could be explained by movement of amendment material from adjacent plots into these control plots, however the amended surface was straw mulched immediately after treatment and vegetation rapidly germinated on all plots except the checks. The overall plot area slopes slightly downward from west to east with plots #23 and #24 at the base, but no obvious surface movement of materials was noted in the field. Furthermore, the surface soil was sampled from 0 – 15 cm; movement of enough material to replace or alter the characteristics of such a large volume of material seems unlikely. Further consideration regarding movement of materials is discussed (below) relative to Ca and P levels. Of the four control plots, only one (#18) started with a low pH value (2.4) and, as expected, yielded low pH values for year 2003 (pH = 3.2) and year 2004 (pH = 2.9).

Table 2. Average soil chemical properties before and after reclamation.

	treatment					
	1 Biosolids 2X	**2 Biosolids 1X**	**3 Lime 2X**	**4 Lime 1X**	**5 Compost & Lime**	**6 Control**
n = 4; for treatment 2, yrs 2003 and 2004 surface soil, n = 3						
2002 surface soil (0 – 15 cm) prior to reclamation						
pH	2.45	2.37	2.33	2.36	2.46	2.87
PPA (Mg $CaCO_3$/1000 Mg)	10.6	9.8	9.6	9.9	8.3	6.90
C (%)	0.37	0.31	0.31	0.40	0.42	0.41
N (%)	0.03	0.03	0.03	0.04	0.03	0.04
2003 surface soil (0 – 15 cm)						
pH	7.45	7.29	7.71	7.54	7.42	5.61
EC (dS m^{-1})	1.58	1.85	1.52	1.55	1.72	2.56
2003 subsoil (15 – 30 cm)						
pH	2.54	2.60	2.49	2.90	2.34	3.17
EC (dS m^{-1})	8.78	7.25	11.31	6.28	10.62	4.99
2004 surface soil (0 – 15 cm)						
pH	7.35	7.63	7.88	8.00	7.34	4.96
EC (dS m^{-1})	2.39	2.54	1.97	2.56	2.51	2.78
Ca (ug/ml)	3173	3947	4566	4470	3560	1351
P (ug/ml)	35	20	6	6	16	25
K (ug/ml)	51	48	46	37	46	43
C (%)	1.17	0.91	0.82	0.78	1.29	0.79
N (%)	0.10	0.07	0.04	0.04	0.06	0.07
2004 subsoil (15 – 30 cm)						
pH	2.64	2.33	2.27	2.29	2.59	2.45
EC (dS m^{-1})	9.66	9.60	12.43	6.68	11.07	6.81

On average, EC values for surface soils (0 – 15 cm) were similar among the amended plots for year 2003 with treatment averages ranging from 1.52 to 1.85 dS m^{-1}. The EC values for control plots #23 and #24, which appear to have been affected by unexplained inputs (as indicated by pH values), had average EC values in this range. In comparison, control plots #9 and #18 had higher values of 4.10 and 2.86, respectively. In year 2004, the EC values appeared to increase. Amended treatment averages ranged from 1.97 to 2.56 dS m^{-1}; treatments 4 and 5 showed the greatest increase while treatment 3 changed the least. Control plots #23 and #24 again were similar to the amended plots with EC values of 2.18 and 2.08 dS m^{-1}, respectively, while control plots #9 and #18 had higher averages (2.67 and 4.19 dS m^{-1}, respectively).

Throughout the study period, pH values for subsoil materials (15 – 30 cm) remained very low; values ranged from 2.0 to 3.7 for year 2003, and from 1.8 to 3.4 for year 2004. Where these pH's were 3.5 or less, this zone of the soils presumably qualifies to be recognized as a *sulfuric horizon* as defined by *Soil Taxonomy* (Soil Survey Staff, 2006) and the soils remain classified as Typic Sulfudepts as they were before the remediation measures were applied. The subsoil EC values were higher and more variable than the surface soils. Treatment averages ranged from 4.3 to 11.3 dS m^{-1} in 2003, and from 6.7 to 12.4 dS m^{-1} in 2004. For both years, the highest values occurred in subsoils beneath treatments 3 and 5, while the lowest values were observed for the control plots.

Ca and P concentrations

The application of lime and biosolids resulted in heavy loadings of Ca and P to all biosolids plots, and Ca to lime treated plots. Although Ca and P data were not available for years 2002 and 2003, relative concentrations of extractable Ca and P among the treatments were evaluated for year 2004 to establish if nutrient levels could provide evidence of surface inputs to plots #23 and #24. For the amended plots, average Ca concentrations were highest for treatments 3 and 4 (4566 and 4470 mg kg^{-1}, respectively), and lowest for treatment 1 (3172). Overall, there were no statistically significant differences ($\alpha = 0.05$) in Ca concentrations among these 5 treatments. In comparison, the average Ca concentration for the control plots was significantly lower with individual values ranging from 1145 to 1487 mg kg^{-1}. Furthermore, plots #23 and #24 which appeared most affected (higher than expected pH) had the lowest Ca concentrations. These relatively low Ca concentrations do not support lime being added to the control plots either through inadvertent application during construction of the plots, or by subsequent movement of materials.

Average P concentrations for the amended plots were, as expected, highest for treatments 1 and 2 (35 and 20 mg kg^{-1}, respectively) and lowest for treatments 3 and 4 (6 mg kg^{-1}). The control plots also had a high average P concentration of 25 mg kg^{-1}, with individual values ranging from 6 to 36 mg kg^{-1}. Regardless, movement of material from the biosolids plots remains questionable for two reasons. First, one of the control plots (#24) which appeared most affected by possible movement of material had a very low P concentration (6 mg kg^{-1}). Second, control plots #9 and #18, which did not appear noticeably affected by inputs, had relatively high P concentrations (33 and 24 mg kg^{-1}, respectively). Thus, we don't see convincing evidence here for surface movement of the biosolids which were very high in P.

Vegetation Yields

Average vegetation yields (standing biomass) for years 2003 and 2004 are presented in Table 3. In 2003, for the amended plots, the highest average yield (6.7 Mg ha^{-1}) was observed for treatment 1. Treatments 2 and 3 were similar with slightly lower average yields of 6.2 Mg ha^{-1}. Treatments 4 and 5 had the lowest yields of 5.8 and 5.7 Mg ha^{-1}, respectively. Overall, there were no statistically significant differences (α= 0.05) in vegetation yields among these 5 treatments. In comparison, control plot #18, which best represented an unamended acid sulfate soil, yielded only 1.5 Mg ha^{-1}. Control plot #9, which was not as severely acidified, also had a relatively low yield of 3.7 Mg ha^{-1}. Control plots #23 and #24, which appeared to be affected by movement of material, had yields similar to the amended plots (5.7 and 6.6 Mg ha^{-1}, respectively).

Table 3. Summary of vegetation yield for SRAP field plots.

	treatment					
	Bio 2X	**Bio 1X**	**Lime 2X**	**Lime 1X**	**Compost & Lime**	**Control**
year	---------------------------------- Mg ha^{-1} standing biomass --------------------------------					
2003	6.7	6.2	6.2	5.8	5.7	4.4
2004	7.0	7.2	7.0	7.5	7.8	5.8

Vegetation production for the amended plots was somewhat reversed for year 2004. Treatments 4 and 5 produced the highest average yields (7.5 and 7.8 Mg ha^{-1}, respectively), while treatments 1, 2 and 3 were slightly lower with yields of 7.1, 7.2 and 7.0 Mg ha^{-1}, respectively. Again, no statistically significant differences (α = 0.05) were observed for these 5 treatments. Surprisingly, control plot #18 produced 5.1 Mg ha^{-1} while plot #9 produced 5.7 Mg ha^{-1}. Control plot #24 produced another high yield (8.1 Mg ha^{-1}) while plot #23 declined to only 4.1 Mg ha$^{-1.}$

Discussion

The mix of treatments employed at SRAP were selected to test the two major revegetation alternatives available to airport managers at the time, the use of heavy rates of lime and/or compost versus combined application of lime-stabilized biosolids. The airport opted for the use of biosolids for their reclamation efforts due to the much higher cost of using conventional liming and compost additions. The fact that all of the treatments employed here generated acceptable revegetation is taken as a very positive result and indicates that we may be able to revegetate these problematic acid sulfate materials via use of lime alone with appropriate mulching and acid/salt tolerant vegetation.

The unexpectedly good response of the control plots in this experiment is puzzling. We can only surmise that somehow, lime and/or nutrients must have moved into the plots over time via surface flow, even though no surface evidence was noted of that and the soil chemical data (other than pH) did not support movement of mass lime or biosolids. Surface water flowing over the recently amended plots may have transported hydroxyl ions to the lower plots, essentially liming those plots. However, ion pairing in solution presumably would have moved Ca as well. Similarly, the ability of the vegetation to establish well on three of the four control plots seems to indicate that some sort of remediation of surface soil conditions may have occurred via some unknown mechanism. On the other hand, we have seen this particular seed mix (particularly *Festuca ovina*) establish and persist in soil systems less than pH 4.0 at this site and others. Regardless, there are reasons why we run replicated field experiments such as these and then subject the data to rigorous statistical analyses. From time to time, we have to accept the fact that we cannot explain what we observe. We also need to realize that not being able to determine significant differences among our treatments is not a negative result.

Conclusions

Field plots were established at Stafford County Regional Airport in September 2002 to evaluate the relative effectiveness of different treatments to remediate active acid sulfate soils. The treatments included two rates of lime-stabilized biosolids, two rates of lime (no organic amendment), and yard waste compost with lime. Surface soil was initially highly acidic (pH ~ 2.5) with an average peroxide potential acidity of 9.1 Mg $CaCO_3$/1000 Mg material. Soil samples collected 1 year and 2 years after reclamation indicated significant improvement in pH, with averages for both years of approximately 7.5. For both years, soil and vegetation samples yielded no statistically significant differences with regards to surface soil pH, surface soil EC, or vegetation yields. Of particular interest is the fact that the treatments incorporating only lime and fertilizer appeared to be as effective as those which included organics. Two control plots, which received no amendments at the time of plot construction, showed unexpected increases in surface soil pH (to pH > 7). Analyses of Ca and P concentrations among the plots did not provide strong evidence supporting the movement of lime or biosolids into the control plots. Although we believe the pH increase could be explained only by additions subsequent to plots construction, the exact mechanism of these inputs remains unexplained.

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