Effects of Aluminum (Al) from Water Treatment Residual Applications to Pastures on Mineral Status of Grazing Cattle and Mineral Concentrations of Forages

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Al-Water Treatment Residuals applications to pastures in low to moderately high levels, help alleviate environmental phosphorus contamination.

Summary
Amorphous aluminum (Al) hydroxides applied to land in the form of water treatment residuals (Al-WTR) can reduce soluble soil phosphorus (P) concentrations in soils and thus can reduce P contamination of the environment. Two experiments of 145 or 148 d each using 36 grazing Holstein steers were conducted to determine the effects of Al-WTR pasture applications on mineral status of cattle and mineral concentrations of bahiagrass (Paspalum notatum). Treatments were replicated 3 times each and were as follows: 1) control- no Al-WTR application with steers receiving free-choice mineral supplementation without P, 2) control with free-choice mineral supplement plus P, 3) treatment 1 with Al-WTR, and 4) treatment 2 with Al-WTR. Total application of Al-WTR over two yr was 169.5 tons dry weight/ac on the pastures. In general, there were few treatment effects on weight gains and mineral concentrations in plasma, liver, bone and forage mineral concentrations. Most forage samples were deficient in sodium, copper, selenium and cobalt and at various collection dates deficient in calcium, phosphorus, iron and zinc. The use of Al-WTR applications is an effective method of reducing P contamination that does not adversely affect forage or cattle mineral concentrations.

Introduction
There is an increasing public demand to reduce the amount of phosphorus (P) transported to water bodies due to the risk of eutrophication, mainly from agricultural P-inputs, including the land application of animal manure. Extensive efforts have been focused on finding ways to reduce soluble P in manure-impacted soils. Aluminum (Al) binds to P and application of Al could be one potential solution to the problem. However, application of Al to the land can also result in ingestion by livestock and potential harm to animals.

Aluminum water treatment residuals (Al-WTR) are the by-products of water purification procedures. They may be one solution to the P problem, in that the Al in the product will bind with P, thus preventing leaching into groundwater. Prior research from Florida has shown that amending soils with Al-WTR increases soil retention and reduces leaching of

P (O'Connor et al., 2002).

Two experiments were conducted to determine the effects of pasture application of Al-WTR on mineral status (primarily P) and performance of grazing cattle. A second objective was to evaluate the effects of the applied Al-WTR on forage mineral concentrations.

Procedure

Two experiments were carried out in consecutive yr, 2005 and 2006 using 36 grazing Holstein steers for 145 or 148 d respectively. Aluminum – water treatment residuals (Al-WTR) pasture applications were applied over two yr totaling 169.5 tons dry weight/ac.

Steers were allotted (three/pasture) to one of twelve 2.0 ac bahiagrass (*Paspalum notatum*) pastures on d 0 and provided *ad libitum* water and grazing access. Soil series that exist at this location are Millhopper sand, Bonneau fine sand, and Gainesville sand. Experimental pastures were randomly allotted to one of four treatments with three replications per treatment. The Al-WTR product contained 0.30% iron (Fe), 7.8% Al, 0.11% calcium (Ca), 0.024% magnesium (Mg), 0.30% P, 0.004% manganese (Mn), 0.73% sulfur (S), 0.006% copper (Cu), 0.002% zinc (Zn), and approximately 70% solids. The treatments were 1) control-no Al-WTR application with steers receiving commercial free-choice mineral supplement but no P, 2) control with free-choice mineral supplement plus P, 3) treatment 1 with Al-WTR and 4) treatment 2 with Al-WTR.

Weights, blood and liver biopsies were taken at d 0, 84 and 148 and bone biopsies were obtained on d 148. Forage samples were taken on d 0 and approximately every 28 d thereafter for five mo. Forage samples were analyzed for Al, Ca, Cu, Fe, potassium (K), Mg, Mn, sodium (Na), P, Zn, cobalt (Co) molybdenum (Mo) and selenium (Se).

Data were analyzed for treatment effects using Proc Mixed in SAS (SAS for Windows v9; SAS Inst., Inc. Cary, NC) for a completely randomized design with a 2x2 arrangement of treatments. Contrasts (control vs. Al-WTR, no P vs. P, and the interaction) were used for mean separation. Significance was declared at $P < 0.05$.

Results

In general, differences in animal performance among treatments were limited throughout the experiment in both yr. In both experiments, application of Al-WTR to pastures of grazing ruminants to control environmental P was not detrimental to the animal when considering BW alone.

Plasma macrominerals (Ca, Mg and P) concentrations were greater, in general, in experiment 1. Yet, the microminerals (Al, Cu and Zn) concentrations were generally greater in experiment 2. Plasma P concentrations were greater in experiment 1 than experiment 2 (6.02 vs. 5.18 mg/dL).

In both experiments, P plasma levels were normal to low, but never reached a level of deficiency at any collection. Therefore, the Al in the Al-WTR did not complex with P enough to cause a deficiency in the cattle during either experiment. In both experiments, the Al plasma concentrations were very low (0.02 μg/mL, on average), indicating that the Al in Al-WTR may be unavailable to the animal and safe to use on pastures to reduce the P environmental problem. In general, there were few treatment effects on mineral concentrations in liver and bone.

Forage mineral concentrations as affected by Al-WTR are presented in Tables 1 and 2. Throughout the collection periods forage Ca concentration was below or slightly above the critical level of 0.35%. Using 0.18% P as a critical level, both treatment groups produced adequate forage P concentrations until August/September for both experiments. Magnesium, K and Mn forage concentrations were adequate for both treatments during both yr.

All forage Na concentrations were below the critical level of 0.06% during both experiments. All forage Cu concentrations were below the critical level of 10 mg/kg in both experiments and were lower, on average, in experiment 1. Aluminum concentration were similar in experiments 1 and 2 and varied by date ($P<0.05$)

in all but treatment 1 of experiment 2. Zinc concentrations also varied by date in both experiments and were similar between treatments ($P>0.05$). Most Zn concentrations were below the critical level of 30 mg/kg in both experiments.

Only a limited number of samples were analyzed for Co, Mo and Se. Forage Mo concentrations means were not variable between treatments, and generally low throughout all sampling periods. Forage Mo concentrations ranged from 0.09 to 2.45 mg/kg and averaged 0.69 ± 0.60 mg/kg. Over 99% of all Co samples taken were below the critical concentration of 0.1 mg/kg.

Forage Se concentrations in this study were extremely deficient and were all less than the requirement of 0.1 mg/kg. Previous Florida studies have shown the majority of forages to be deficient in Na, P, Ca, Cu, Co, Se and Zn (McDowell and Arthington, 2005).

Literature Cited
McDowell and Arthington. 2005. Minerals for Grazing Ruinants in Tropical Regions, IFAS/Animal Sciences, Gainesville, FL.
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Table 1. Forage minerals (dry basis) as affected by water treatment residuals (Experiment 1) [1-4]

	Trt[5]	May	Jul	Aug	Sept	Oct	Nov	Dec	Means[6]	SD[7]
Ca, %	1	0.38[a]	0.30[bc]	0.27[c]	0.27[c]	0.28[bc]	0.32[b]	0.31[bc]	0.30	0.04
	2	0.33[bc]	0.27[bcd]	0.31[bcd]	0.27[bcd]	0.26[d]	0.42[a]	0.35[b]	0.32	0.06
	SD	0.04	0.20	0.03	0.00	0.10	0.07	0.03	0.01	
K, %	1	1.38[a]	1.43[b]	1.33[bc]	0.82[cd]	1.09[bc]	2.14[a]	0.43[d]	1.23	0.50
	2	1.51[b]	1.36[bc]	1.18[bc]	1.02[c]	1.09[bc]	2.09[a]	0.44[d]	1.24	0.47
	SD	0.09	0.05	0.11	0.14	0.00	0.04	0.01	0.01	
Mg, %	1	0.18[ab]	0.19[a]	0.16[b]	0.16[b]	0.18[ab]	0.16[b]	0.13[c]	0.17	0.02
	2	0.17[bc]	0.20[a]	0.19[ab]	0.15[c]	0.17[bc]	0.19[ab]	0.15[c]	0.17	0.02
	SD	0.01	0.10	0.02	0.01	0.01	0.02	0.01	0.00	
Na, %	1	0.02[abc]	0.02[abc]	0.02[abc]	0.02[abc]	0.03[a]	0.03[a]	0.01[c]	0.02	0.01
	2	0.02[b]	0.02[b]	0.02[b]	0.01[b]	0.02[b]	0.04[a]	0.01[b]	0.02	0.01
	SD	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	
P, %	1	0.23[a]	0.23[a]	0.15[b]	0.14[b]	0.14[b]	0.14[b]	0.06[c]	0.16	0.05
	2	0.22[a]	0.21[a]	0.17[ab]	0.12[b]	0.14[b]	0.15[b]	0.06[c]	0.15	0.05
	SD	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	
Al, mg/kg	1	35.0[b]	65.3[a]	17.3[c]	36.1[b]	18.7[c]	26.2[bc]	17.7[c]	30.9	15.8
	2	25.1[bcd]	31.9[ab]	15.8[e]	28.9[bc]	39.2[a]	37.4[a]	20.1[cde]	28.3	8.00
	SD	7.0	23.6	1.06	5.09	14.5	7.92	1.70	1.84	
Cu, mg/kg	1	9.69[a]	8.17[bc]	8.75[ab]	5.76[d]	6.18[d]	6.87[cd]	7.95[bc]	7.66	1.31
	2	8.41[a]	8.23[a]	7.52[a]	5.32[b]	5.55[b]	8.48[a]	8.29[a]	7.39	1.27
	SD	0.91	0.04	0.87	0.31	0.45	1.14	0.24	0.19	
Fe, mg/kg	1	66.3[a]	59.1[a]	33.3[b]	34.3[b]	35.4[b]	54.9[a]	42.1[b]	44.5	12.48
	2	43.9[c]	43.1[bc]	33.7[c]	36.7[c]	36.4[c]	66.6[a]	52.4[bc]	44.7	10.66
	SD	15.8	11.3	0.28	1.70	0.71	8.27	7.28	0.14	
Mn, mg/kg	1	78.3[b]	83.8[ab]	60.5[c]	56.5[c]	90.7[ab]	96.1[a]	95.1[a]	80.1	14.89
	2	48.9[c]	49.7[c]	48.6[c]	48.3[c]	63.2[b]	70.0[ab]	79.6[a]	58.3	11.78
	SD	20.8	24.1	8.41	5.80	19.4	18.5	11.0	15.4	
Zn, mg/kg	1	34.4[a]	28.8[b]	28.7[b]	25.9[bc]	23.3[cd]	23.0[cd]	18.6[d]	26.1	4.73
	2	43.9[bc]	43.1[bc]	33.7[c]	36.7[c]	36.4[c]	66.6[a]	52.4[b]	44.7	10.66
	SD	6.72	10.1	3.54	7.64	9.26	30.8	23.9	13.2	

[a-e]Means with same letters within rows are not different ($P<0.05$).

[1]Water treatment residual contained 0.30% Fe, 7.8% Al, 0.11% Ca, 0.024% Mg, 0.30% P, 0.004% Mn, 0.73% S, 0.006% Cu and 0.002% Zn.

[2]Critical concentrations are as follows: Ca, 0.35%; P, 0.18%; Mg, 0.10%; K, 0.60%; Na, 0.06%; Cu, 10.0 mg/kg; Fe, 50.0 mg/kg; Mn, 20.0 mg/kg; Zn, 30.0 mg/kg (NRC, 1986; McDowell and Arthington, 2005).

[3]Means represent 12 samples per month per treatment.

[4]In November for forage Ca, treatment with Al-WTR was lower (<0.05) than the control. In July for forage Al, control treatment was lower ($P<0.05$) than treatment with Al-WTR.

[5]Treatments were as follows: 1) Al-WTR; 2) Control- no Al-WTR.

[6]Means of seven months of sampling

[7]SD = standard deviation

Table 2. Forage minerals (dry basis) as affected by water treatment residuals (Experiment 2) [1-4]

	Trt[5]	May	Jun	Jul	Aug	Sep	Oct	Means[6]	SD[7]
Ca, %	1	0.42[a]	0.32[c]	0.38[ab]	0.38[ab]	0.33[c]	0.37[bc]	0.37	0.04
	2	0.37[a]	0.29[c]	0.31[bc]	0.36[ab]	0.39[a]	0.35[ab]	0.33	0.05
	SD	0.04	0.20	0.05	0.01	0.04	0.01	0.03	
K, %	1	1.49[a]	1.39[ab]	1.33[b]	0.31[bc]	1.23[bc]	1.21[c]	1.33	0.10
	2	1.42[a]	1.96[b]	1.14[b]	1.40[a]	1.58[a]	1.45[a]	1.33	0.23
	SD	0.05	0.30	0.13	0.06	0.25	0.17	0.00	
Mg, %	1	0.18[cd]	0.20[ab]	0.19[bc]	0.21[a]	0.17[d]	0.19[bc]	0.19	0.01
	2	0.18[b]	0.20[a]	0.18[b]	0.19[ab]	0.19[ab]	0.18[b]	0.19	0.01
	SD	0.00	0.00	0.01	0.01	0.01	0.01	0.00	
Na, %	1	0.02 [a]	0.01[b]	0.02 [a]	0.02 [a]	0.02 [a]	0.02 [a]	0.02	0.00
	2	0.02 [b]	0.02 [b]	0.01 [a]	0.02 [b]	0.02 [b]	0.02 [b]	0.02	0.00
	SD	0.00	0.01	0.01	0.00	0.00	0.00	0.00	
P, %	1	0.02	0.19	0.19	0.19	0.15	0.17	0.18	0.19
	2	0.21[a]	0.21[a]	0.19[ab]	0.19[ab]	0.18[ab]	0.17[b]	0.19	0.02
	SD	0.01	0.01	0.00	0.00	0.02	0.00	0.01	
Al, mg/kg	1	23.4[cd]	24.7[cd]	26.3[bc]	21.3[d]	33.7[a]	30.3[ab]	26.6	4.61
	2	26.2[cd]	30.8[bc]	23.2[d]	27.5[cd]	40.5[a]	37.7[ab]	31.0	6.80
	SD	1.98	4.31	2.19	4.38	4.81	5.23	3.11	
Cu, mg/kg	1	9.54 [a]	8.33[b]	8.67[b]	8.41[b]	8.78[b]	7.63[c]	8.54	0.62
	2	9.16[a]	9.27[a]	8.13[bc]	7.47[c]	8.39[b]	7.88[c]	8.35	0.71
	SD	0.27	0.66	0.38	0.66	0.28	0.18	0.13	
Fe, mg/kg	1	50.8[ab]	47.2[b]	54.5[a]	55.2[a]	48.4[b]	39.5[c]	49.3	5.75
	2	58.5[a]	53.8[a]	44.8[b]	42.2[b]	43.8[b]	41.0[b]	47.4	7.10
	SD	5.44	4.67	6.86	9.19	3.25	1.06	1.34	
Mn, mg/kg	1	92.0[a]	69.1[a]	84.7[a]	64.8[a]	88.2[a]	142.4	90.2	27.76
	2	55.7[bc]	58.9[bc]	40.6[c]	74.1[b]	90.1[ab]	93.3[a]	68.7	20.77
	SD	25.7	7.21	31.2	6.58	1.34	34.7	15.2	
Zn, mg/kg	1	37.4[ab]	26.3[cd]	31.5[bc]	19.8[d]	20.5[cd]	44.4[a]	30.0	9.72
	2	25.5[b]	24.9[b]	21.0[bc]	29.1[ab]	15.7[c]	32.4[a]	24.8	5.90
	SD	8.41	1.00	7.42	6.58	3.39	8.49	3.68	

[a-d]Means with same letter within rows are not different (P<0.05).
[1]Water treatment residual contained 0.30% Fe, 7.8% Al, 0.11% Ca, 0.024% Mg, 0.30% P, 0.004% Mn, 0.73% S, 0.006% Cu and 0.002% Zn.
[2]Critical concentrations are as follows: Ca, 0.35%; P, 0.18%; Mg, 0.10%; K, 0.60%; Na, 0.06%; Cu, 10.0 mg/kg; Fe, 50.0 mg/kg; Mn, 20.0 mg/kg; Zn, 30.0 mg/kg (NRC, 1986; McDowell and Arthington, 2005).
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[5]Treatments were as follows: 1) Al-WTR; 2) Control- no Al-WTR.
[6]Means of seven months of sampling
[7]SD = standard deviation