Effect of Alum Treated Water Treatment Plant Residuals Applied to a Loblolly Pine Plantation in the Lower Coastal Plain of South Carolina

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Abstract

The effect of water treatment plant alum residuals on forest stand health when applied to a loblolly pine plantation is the focus of this paper. Over six years of foliage, soil, and residuals field sampling, visual observations, and vegetation inventories were performed on the 57 acres of sprayed forestlands. Maintaining forest health and vigor to maximize site life is the major objective for Hanahan Commission of Public Works (CPW). There are concerns that eventual Al elevated levels in the foliage and soil and reduced P and Mg levels in the soil and foliage may reduce stand health. Macro-, micronutrient, aluminum levels, and soil and residual pH values were quantified. Trends over time were also discerned. In general, soil concentrations of extractable Al and Mn have increased while loblolly pine foliar Mg levels have decreased. Magnesium was applied in the form of Epsom salts at an equivalent rate of 17 lbs elemental-Mg per acre in July 2001. December 2001 foliar Mg concentration increased to 1996 baseline level and foliar Al:Mg ratio decreased to the 1996 baseline level. Foliar P concentrations in sampled loblolly pine are currently at or just above "sufficiency". A possible near-term recommendation is for the addition of P to maintain N:P and Al:P ratios, stand vigor, and further site life.

Introduction

Hanahan CPW generates 51.5 mgd of potable water for the greater Charleston area. In 1994 Hanahan CPW's directors were faced with choosing a final resting-place for their treatment plant residuals. Several options existed but two major alternatives appeared to be most attractive: land application under a hay cutting field system or in forested system. The adjacent land to the plant was in an unthinned 12-year-old loblolly pine stand with a component of sweetgum and water oak. Advantages to keeping the site in trees were: (1) no conversion costs, (2) reduced erosion rates in trees, (3) close to year around utilization of the nutrients and water from the residuals, and (4) a long time frame before major timber activities were warranted. Advantages to converting the site to a hay cutting (bermuda grass and winter rye) field were (1) increased access, (2) estimated higher nutrient and aluminum uptake rates than for loblolly pine, and (3) annual removal and nutrients and aluminum (Al) from the site. Ironically, the annual removal of nutrients and Al from the site with hay cutting also proved to be a disadvantage as no one was willing to cut and remove the hay under a long-term contract. Keeping the site forested under a land application scheme has turned out to be beneficial also from the standpoint of residuals depth on the site is now from 4 inches to 18 inches. Cutting hay would have been futile with the current residuals depth between tractor maneuverability and stability and growing a clean, quality hay.

Project Background

Once Hanahan CPW decided to land apply their residuals in the adjacent loblolly pine stand, several other factors had to be addressed. These included: (1) irrigation scheme and scheduling, (2) riser type, position above ground, and spray head psi, (3) silvicultural treatments to the pine stand prior to or during the site life, and (4) an estimation of site life. A critical question arose as to the effect of large doses of aluminum applied weekly in the loblolly pine stand on forest health and stand vigor. Aluminum can tie up soil phosphorus (P) and make it non-plant available. Large amounts of soil Al can create a soil cation imbalance, reducing other cation (K^{+}, Mg^{+2}, and Ca^{+2}) uptake by loblolly pine and other plant roots. In this case increases in soil Al may have reduced Mg soil availability as evidenced by decreasing foliar Mg levels during the first 6 years of residuals application (Figure 2).

Project Objectives

The project objectives were to (1) discern soil pH, P, K, Ca, Mg, S, B, Cu, Mn, and Al values/levels over time and to compare soil nutrient ratios and soil Al:nutrient ratios during the irrigation of residuals period. (2) Quantify foliar N, P, K, Ca, Mg, S, B, Cu, Mn, and Al concentrations, nutrient ratios, and Al:nutrient ratios during the irrigation period. These activities were performed to maintain pine plantation health, which in turn should maximize site life.

Project Methodology

The original spray site is 26 acres and the expansion area spray site is 29 acres for a total of 55 sprayed acres. The original spray site had most of the understory and midstory hardwoods removed. The expansion area had many of the hardwoods and some suppressed pines removed. These silvicultural activities were performed to increase wind speed and site drying in the 0-30 feet zone. Soil series were verified over the spray sites. The soils that dominate the original spray area are Bonneau and Blanton. The soil that dominates the expansion area is Bonneau with a small area in Ocilla and Craven. Permanent sampling plots (1/4 acre in size) were located proportionally on the soil series that dominated the spray sites. These plots were installed to collect foliage, soil (0-6, and 6-12 inch depths) and from 1999 on the surface residuals. There are currently 6 sampling points on the Bonneau soil and 3 sampling points on the Blanton soil on the original spray site. In the expansion area there are 4 sampling points on the Bonneau soil, and 1 each on the Ocilla and Craven soils. Each winter soil (10 sample points/plot), foliage (3 trees/plot), and residuals are collected from each sample point. These samples are bagged or boxed, labeled, and analyzed at the Clemson University Agricultural Service Lab for pH (soil and residuals only), N (foliage only), P, K, Ca, Mg, S, B, Cu, Mn, and Al. Soil, foliage, and residuals values are then graphed by year, spray site, and soils to discern trends over time. The Al concentration in the residuals is over 50 times greater than the P applied and at least 12 times greater than the Mg applied (Table 1). Average dry weight of residuals applied ranged from 6000 pounds/day in November 1999 to approximately 21000 pounds/day in May 1998 (Figure 1).

Table 1. Hanahan CPW residuals characteristics in January 2001.

Parameter	mg/kg (dry wt basis)	Parameter	unit
Aluminum	2800	pH	5.7
Ammonia-N	<250	solids	2 percent
Nitrate-N	<100		
TKN	420		
Calcium	<240		
Iron	320		
Magnesium	<240		
Phosphorus	55		
Potassium	<1.2		
Sodium	<240		

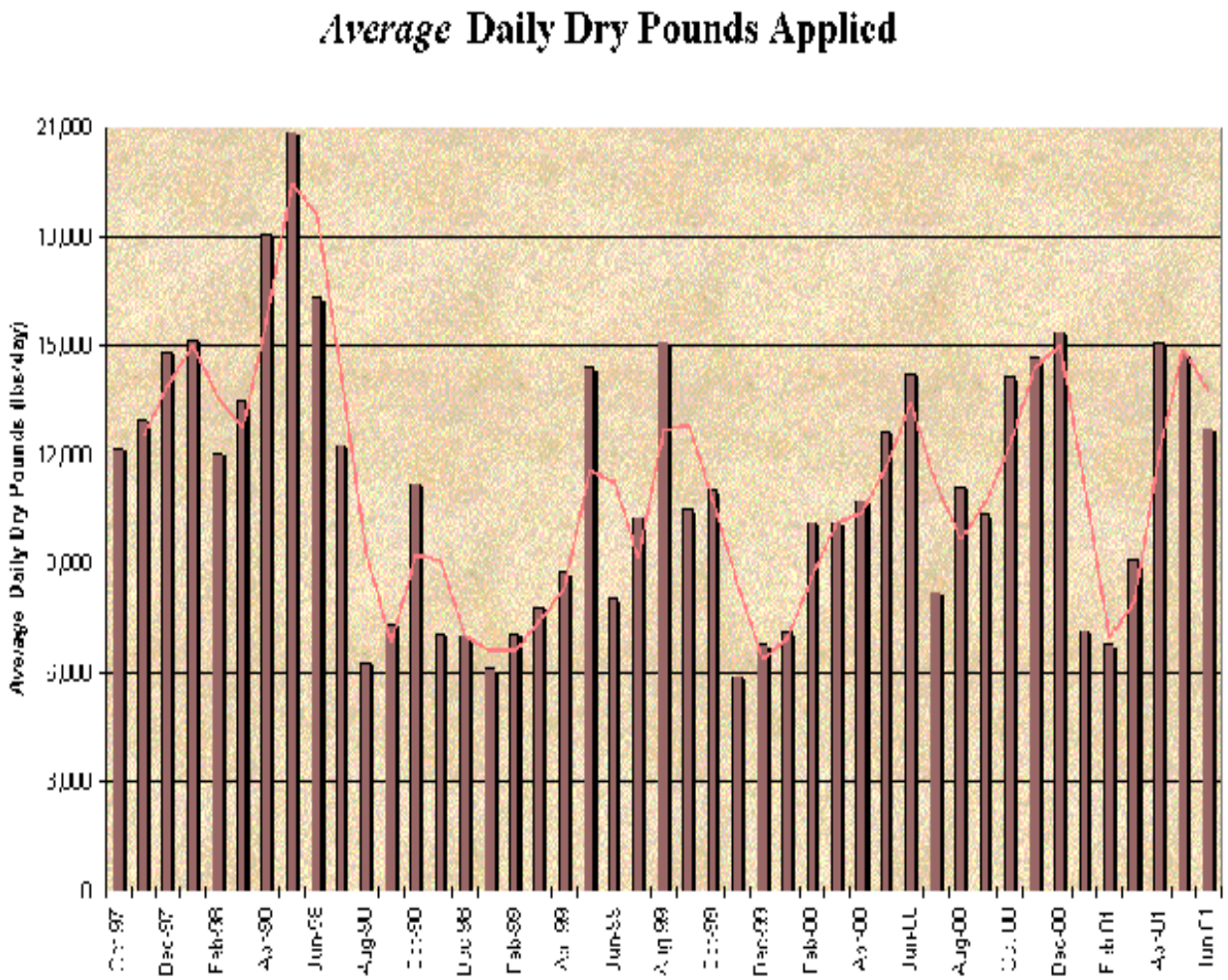

Figure 1. Average daily dry pounds of residuals applied to the spray sites between October 1997 and June 2001 at Hanahan CPW.

Results

The largest near-term impact of the application of Alum water treatment plant residuals at Hanahan CPW on loblolly pine vigor appears to be the decrease in foliar magnesium (Mg) and a change in foliar Al:Mg ratios between 1996 and 2001 (Figure 2). The major functions of Mg in plants are as an activator of numerous enzymes, particularly ATP: phosphotransferases and as a component of chlorophyll. In July 2001 Epsom salts were applied to both spray sites. Late winter 2001/2002 foliar samples in the original spray site (Figure 2) indicate that foliar Mg levels returned to approximately their original levels and well as the Al:Mg ratio.

Foliar P levels for loblolly pine are considered to be "sufficient" when between 0.10 to 0.12 percent. Loblolly pine foliar concentrations less than 0.10 percent indicate a need For P fertilization. In general loblolly pine foliar sample concentrations on the original

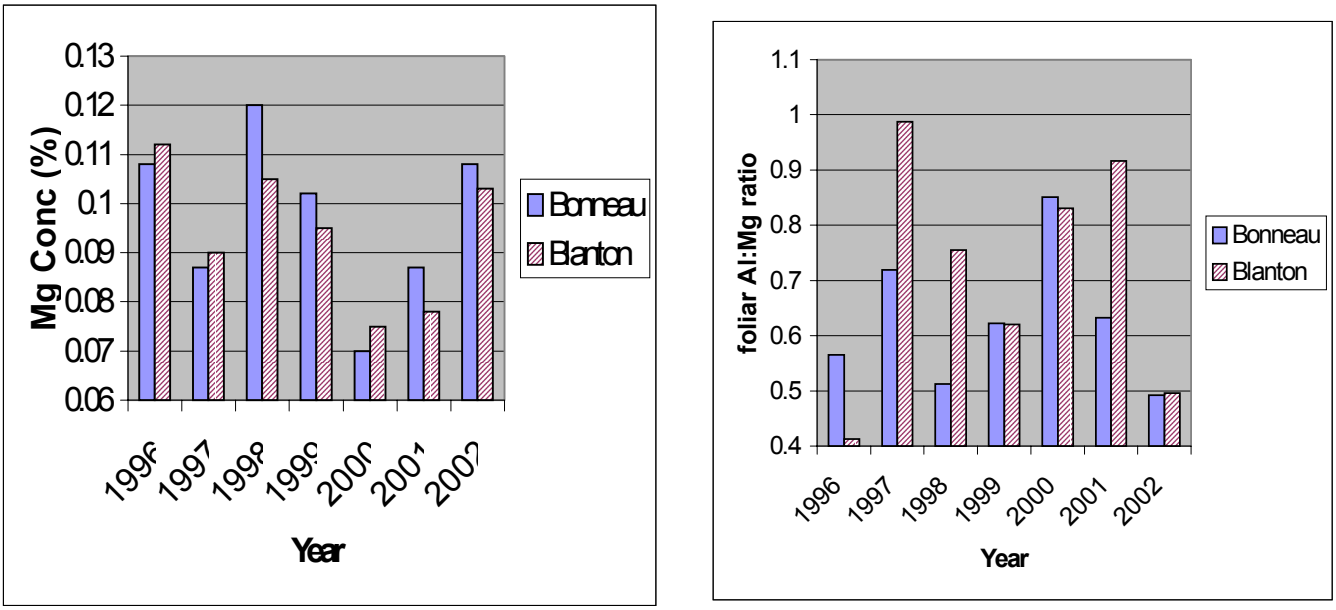

Figure 2. Foliar Mg concentrations and foliar Al:Mg ratios between 1996 (baseline) and 2002 in the original spray site on the Bonneau and Blanton soils. Epsom salts were applied in July 2001.

spray site were at or above 0.10 percent between 1996 and the present except the Blanton soil in 1997 (Table 2). Foliar N:P ratios should be in the 10:1 to 12:1 range and are generally as such through the study period (Table 2). Foliar Al:P ratios have not changed dramatically between 1996 and the present (Table 2) except between 1996 (pre-application value) and 1997 on the deeper sand Blanton soil. Surface (0-6 inches) soil extractable-Al has been increasing between 1996 and 2001 on the Bonneau and Blanton soils but dramatically decreased between 2001 and 2002 (Table 2) on the original spray site. Surface soil P followed no real trend between 1996 and the last sampling period ranging from 15 to 66 lbs/acre on the Bonneau soil and from 7 to36 lbs/acre (Table 2) on the Blanton soil (< 8 to 12 lbs/acre is critical for loblolly pine).

Table 2. Mean loblolly pine N, P, and Al foliage concentrations, N:P and Al:P foliage ratios and soil P and Al from the original spray site on Hanahan CPW

		foliage					soil	
Soil	Year	N	P	Al	N:P	P:Al	P	Al
		percent			ratio		lb/ac	
Bonneau	1996	1.49	.122	.061	12.2	.50	21	825
	1997	1.21	.111	.063	10.9	.56	30	764
	1998	1.31	.123	.062	10.7	.50	66	1127
	1999	1.32	.112	.064	11.8	.57	15	1673
	2000	1.43	.125	.060	11.4	.48	35	1966
	2001	1.54	.122	.055	12.6	.45	36	2740
	2002	1.46	.127	.053	11.5	.42	51	1662
Blanton	1996	1.36	.117	.046	11.6	.39	14	316
	1997	1.13	.097	.089	11.6	.92	45	1010
	1998	1.31	.115	.079	11.4	.69	7	1195
	1999	1.33	.112	.059	11.6	.57	15	1408
	2000	1.32	.125	.062	11.5	.54	23	1538
	2001	1.54	.108	.072	12.4	.66	36	2220
	2002	1.46	.117	.051	11.9	.44	16	903

Summary and Conclusions

The alum treated residuals applied to a young loblolly pine plantation have not adversely effected stand health from a visual standpoint other than five flushes of growth and some top dieback occurring in 2000. These minor visual observations may have been an indication of the need for a plant nutrient to be added to the site. Foliage sampling and analysis indicated a need to add Mg to the site in the winter of 2000/2001 (Figure 2). Magnesium was added to the site in July 2001 in the form of Epsom salts. December 2001 foliage samples indicate that foliar Mg concentrations have returned to approximately pre-alum residuals application levels. Since the Epsom salts application flush numbers are now more typical of loblolly pine (3 to 4 flushes) and there is no more evidence of top dieback.

Triple super phosphate (0-46-0) was added in August 2002 to sampling points in the Bonneau and Blanton soils in the original spray site. This application was performed to quantify a foliage P response this or next winter. If the N:P ratio is reduced to approximately 10:1 we will most likely add P in the next year or two to the spray sites to maintain stand vigor.

Although Al is the third most common element in our soils, most of the soil Al is not plant available when soil pH is greater than 5.5. Too much Al, when in the plant available form can be toxic to plants. Therefore careful monitoring of the dominant tree species, in this case loblolly pine, is recommended when high levels of Al are applied annually to a water treatment plant residuals application site to maximize site life.