RE300 Impact on Land Application of Biosolids: Fe and RE fate

Introduction

RE300, a rare earth chloride solution, is being used by several Wisconsin wastewater treatment facilities to remove phosphorus (P) to meet anticipated low P discharge permit limits. During the treatment process, soluble P is transformed into solid rare earth phosphate that ultimately ends up as a component of the facilities' biosolids. In Wisconsin, about 80% of municipal biosolids are land applied. Because RE300 tightly binds phosphorus, a study was conducted to better understand the fertilization properties of rare earth biosolids in land application. In this study, P availability to corn from rare earth biosolids was investigated and compared to P availability from a commercial P fertilizer and ferric biosolids. The distribution of iron and rare earth in the soil, corn plant, and corn kernel was also studied. Corn was chosen for the study as it is the most common crop treated with biosolids and is grown on four million acres in Wisconsin. This study was performed by Richard Wolkowski, Ph.D. (Extension Soil Scientist at University of Wisconsin-Madison) at Alfisol Soil Management, LLC.

Methods

Small plot studies were established at four different locations (TH, TA, B, and C) in south central Wisconsin. The sites selected for the study had not received manure in the past three years and had water extractable P of less than 25 ppm. Treatments at each location included an untreated control, a commercial P fertilizer, ferric biosolids and rare earth biosolids. Each material was hand-applied at rates to supply 100 lb P/acre and 200 lb P/acre. P and solids contents supplied by the treatment facilities prior to application were used to estimate application rates. The actual P loadings were calculated from P measured in biosolids samples collected on the day of application. Routine soil tests P (Bray P1) for individual plots were measured prior to treatment and following harvest, and total dry matter accumulation and P uptake was measured at the corn's physiological maturity. Samples of the soil, corn plant, and corn kernel were also measured for Fe and rare earth content by acid digestion followed by ICP-MS analysis of the solution.

Results

As expected, fertilizer increased soil test P the most (see Table I). Rare earth biosolids addition increased the soil test P more than ferric biosolids addition. This suggests rare earth biosolids have more available P than ferric biosolids.

Table II shows that whole-plant dry matter yield. In general the application of any of the materials positively affected the yield. Otherwise there were no significant effects of material or application rate on the corn whole-plant dry matter production.

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In Table III, P uptake is shown. This measurement is an indication of the biosolids effect on P availability. Added P, either as fertilizer or biosolids, tended to increase plant P uptake at all sites over the control suggesting that adequate P was available from the rare earth biosolids.

Table I. Bray P1 Soil Test Results

Material	P application Rate		Site			
	Proposed	Actual	TH	TA	B	C
	lb P/acre		Bray P1 Soil Test (ppm)			
None	0	0	73	86	22	73
Fertilizer	100	100	102	106	43	93
	200	200	120	157	65	103
Ferric Biosolids	100	63.1	85	96	30	70
	200	126.2	92	94	41	77
Rare Earth Biosolids	100	83.1	95	103	35	82
	200	166.2	94	111	55	99

Table II. Whole-Plant Yield Test Results

Material	P application Rate		Site			
	Proposed	Actual	TH	TA	B	C
	lb P/acre		Whole-plant yield (ton dry mass/acre)			
None	0	0	8.01	3.15	8.17	6.11
Fertilizer	100	100	8.24	3.48	10.07	7.19
	200	200	9.29	3.72	9.03	6.12
Ferric Biosolids	100	63.1	8.36	3.14	10.80	6.67
	200	126.2	10.20	3.11	10.07	8.30
Rare Earth Biosolids	100	83.1	8.52	3.65	8.24	7.10
	200	166.2	9.27	4.23	9.95	8.33

Table III. Whole-Plant P Concentration

Material	P application Rate		Site			
	Proposed	Actual	TH	TA	B	C
	lb P/acre		Plant P Uptake, lb/acre			
None	0	0	39.6	22.1	23.5	22.3
Fertilizer	100	100	44.6	28.7	30.3	26.0
	200	200	50.8	28.2	34.1	25.6
Ferric Biosolids	100	63.1	45.5	20.7	35.0	25.3
	200	126.2	54.6	20.6	29.8	32.7
Rare Earth Biosolids	100	83.1	41.3	24.9	24.0	27.5
	200	166.2	46.2	27.7	30.5	30.9

Table IV shows the Fe content in g/kg in the soil from the 4 sites at the harvesting of the plants. Sites B and C have higher Fe content than sites TH and TA. Within each site the Fe content is comparable to the control sample with a few exceptions. At site TH, the 200 lb Fertilizer and the 200 lb Rare Earth samples appear to have higher Fe content. At site B, the 100 lb Ferric sample appears to have higher Fe content. At site C, both Ferric samples appear to have higher Fe content. Higher Fe content in the soil samples where Ferric is applied is expected. The other higher Fe levels can be attributed to soil variations.

The Fe content in the corn plant is reported in Table V. As expected the Fe content is significantly lower than in the soil samples. For sites TH and TA, most samples were comparable to the control except for site TH 200 lb Ferric and site TA 100 lb Ferric had statistically significant higher Fe content. For sites B and C, the control samples were either higher or comparable to the others.

Table IV. Fe Content in Soil

Material	P application Rate		Site			
	Proposed	Actual	TH	TA	B	C
	lb P/acre		Fe Content (g/kg)			
None	0	0	1.7±0.1	2.8±0.4	14.2±0.2	12.1±0.5
Fertilizer	100	100	1.8±0.2	2.7±0.2	13.3±0.8	11.8±0.5
	200	200	2.7±0.3	3.2±0.5	13.6±1.1	13.1±1.3
Ferric Biosolids	100	63.1	1.87±0.4	2.7±0.2	15.4±0.3	13.8±0.9
	200	126.2	1.9±0.4	3.3±0.9	14.3±0.7	13.2±0.5
Rare Earth Biosolids	100	83.1	1.8±0.08	2.9±0.1	13.9±1.5	12.6±1.8
	200	166.2	2.4±0.2	3.1±0.3	14.0±0.5	12.9±1.2

Table V. Whole-Plant Fe Content

Material	P application Rate		Site			
	Proposed	Actual	TH	TA	B	C
	lb P/acre		Fe Content (ppm)			
None	0	0	45±8	137±13	87±50	74±28
Fertilizer	100	100	31±8	140±7	35±19	22±18
	200	200	50±14	145±45	54±36	44±22
Ferric Biosolids	100	63.1	87±36	176±6	88±76	55±22
	200	126.2	100±38	141±23	44±26	27±8
Rare Earth Biosolids	100	83.1	79±30	129±14	57±12	43±27
	200	166.2	62±25	153±41	61±59	36±20

Table VI. Kernel Fe Content

Material	P application Rate		Site			
	Proposed	Actual	TH	TA	B	C
	lb P/acre		Fe Content (ppm)			
None	0	0	-	-	45±4	176±44
Fertilizer	100	100	-	-	55±1	107±17
	200	200	-	-	54±7	122±69
Ferric Biosolids	100	63.1	-	-	54±4	163±66
	200	126.2	-	-	61±5	174±80
Rare Earth Biosolids	100	83.1	-	-	65±17	186±57
	200	166.2	-	-	53±7	200±91

The Fe content in the corn kernel (Table VI) shows that at site B, all samples are slightly higher than the control. At site C, only the 100 lb fertilizer sample is statistically different and it is lower than the control.

The rare earth content in the soil was measured and is in Table VII. At site TH, TA, and C only the 200 lb rare earth sample is statistically different from the control and show an increase in rare earth content. At site B both rare earth samples had higher rare earth concentrations than the control.

The rare earth content measured in the corn plant is in Table VIII. Of these results only the samples from site TH have higher rare earth content than the control.

The rare earth content in the corn kernels is in Table IX. None of these samples are statistically different from the control.

Table VII. Total Rare Earth Content in Soil

Material	P application Rate		Site			
	Proposed	Actual	TH	TA	B	C
	lb P/acre		Fe Content (ppm)			
None	0	0	58±21	201±116	88±4	157±34
Fertilizer	100	100	86±73	100±44	93±20	166±49
	200	200	49±5	309±164	130±39	160±21
Ferric Biosolids	100	63.1	106±67	252±127	169±101	436±357
	200	126.2	57±13	120±47	142±66	325±283
Rare Earth Biosolids	100	83.1	65±14	192±55	164±34	210±93
	200	166.2	154±67	435±88	183±18	250±71

Table VIII. Whole-Plant Total RE Content

Material	P application Rate		Site			
	Proposed	Actual	TH	TA	B	C
	lb P/acre		Fe Content (ppm)			
None	0	0	17±4	168±13	106±63	80±37
Fertilizer	100	100	10±0.3	185±39	44±42	24±13
	200	200	34±12	150±79	65±58	39±19
Ferric Biosolids	100	63.1	38±19	111±53	93±56	29±18
	200	126.2	41±25	155±101	111±31	68±22
Rare Earth Biosolids	100	83.1	67±30	100±50	88±66	49±21
	200	166.2	41±21	102±20	80±70	60±37

Table IX. Kernel Total RE Content

Material	P application Rate		Site			
	Proposed	Actual	TH	TA	B	C
	lb P/acre		Fe Content (ppm)			
None	0	0	-	-	31±16	39±5
Fertilizer	100	100	-	-	35±5	29±1
	200	200	-	-	36±13	27±6
Ferric Biosolids	100	63.1	-	-	34±11	37±9
	200	126.2	-	-	28±2	32±5
Rare Earth Biosolids	100	83.1	-	-	52±18	30±4
	200	166.2	-	-	28±2	24±1

This research shows that the test rare earth biosolids produced soil with P availability between P fertilizer and ferric biosolids as measured by the change in soil test P. The corn whole-plant dry matter yield either increased or was unaffected by the rare earth biosolids at the four sites. Thus, the application of rare earth biosolids is not expected to affect the growth and yield of corn when applied at normal rates that supply the corn N requirement. Furthermore the amount of Fe in the soil, the corn plant and the corn kernel was only higher than the control in a few cases which were mostly for samples where ferric biosolids had been applied. The rare earth content in the soil, the corn plant and the corn kernel had less variation from the control. The presence of rare earths in the control samples is confirmation of the ubiquitous presence of rare earths and an indication that the application of rare earth biosolids is not adding foreign metals to the soil. Furthermore, the lack of significantly higher rare earth concentrations in the plant material is an indication that the rare earths are not bioavailable. Thus, the application of rare earth biosolids at normal rates is not expected to increase the content of rare earths found in corn beyond what is naturally present.