

THE USE OF PHOSPHATE MATERIALS AS AMELIORANTS FOR ACID MINE DRAINAGE

John J. Renton
Alfred H. Stiller
Thomas E. Rymer

WEST VIRGINIA UNIVERSITY
Morgantown, WV 26506

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INTRODUCTION:

In areas producing high sulfur coal (>1 wt% S) such as in the Illinois Basin, highly calcareous overburden materials or calcite rich surficial materials are readily available for reclamation purposes. As a result, acid mine drainage is rarely a problem. However, in high sulfur areas such as the northern Appalachian Basin where abundant calcareous rocks are not generally available, limestone has been routinely added to the toxic rock materials during reclamation to ameliorate the production of acid. The use of limestone has however, not always resulted in the elimination of acid waters.

Early in the research of the authors, experimental data indicated that the presence of calcite in a potentially toxic system could actually INCREASE acid production. In initial Soxhlet leach experiments designed to evaluate the acid producing potential of various coals and coal-associated rocks, a direct correlation was observed between the calcium content and INCREASING acidity of the leachates. Further observations had also been made that coals collected for study that eventually were shown not to have exceptionally high sulfur contents but were shown to contain iron disulphide minerals and calcite in direct contact invariably would rapidly decompose the cloth collection bags. Acid was obviously being produced at a rate disproportionate to the sulfur content of the coal. It soon became apparent from experimental data that when CaCO_3 was added to toxic rock material in concentrations comparable to those being used in reclamation, the rate of acid production actually INCREASED. Upon dissolution of the calcite by the acidic solutions, the calcium was reacting with the sulfate ion, precipitating gypsum and subsequently shifting the iron disulphide oxidation reaction in favor of the products which of course included acid. It was obvious that at the CaCO_3 application levels commonly used in surface mine reclamation, acid was being

produced faster than it could be neutralized.

With limestone being questioned as a potential ameliorant, a substitute was sought. It was obvious that any number of chemicals could be added to the system which would either neutralize any acid produced or which could stop acid production. Our objective, however, was to utilize a natural occurring material rather than a man-made chemical so as not to subject the environment to another source of unnatural pollution and preferably to utilize a material that would actually prevent the oxidation of the iron disulphide minerals rather than simply neutralize acid once produced. Apatite was chosen because it filled all the criteria. Apatite only dissolves when the conditions become acidic. It is therefore a time release material. Apatite eliminates acid formation by removing the major oxidizer of the iron disulphide minerals, Fe^{+3} , by precipitating the iron as a totally insoluble iron phosphate. Having chosen apatite as a potential AMD ameliorant, the purpose of this work was to systematically evaluate the effectiveness of a variety of available phosphate materials as acid ameliorants in all phases of reclamation.

INTRODUCTION

Phosphate materials were categorized for this study into three types: 1) sand to pebble sized rock phosphate, 2) fine grained rock phosphate and 3) dried phosphate slurry (slime). The sand to pebble sized rock phosphate, composed largely of the mineral apatite, is the material that is presently being used in the Appalachian Basin with varying amounts of success (or lack of success). The fine grained rock phosphate is simply the larger sized apatite rich material that has been ground into fine particle sizes in order to increase the available reactive surface area. In this research, two sizes of ground apatite were used, one designated CODE 30 that was 95% in the size range from 150 to 250 mesh and a second material designated CODE 31 that was about 65-70% less than 325 mesh. The 150-250 mesh material was considered the finest size that could be used on-site without problems of dust generation either during handling or by the blowing wind. The -325 mesh material was primarily considered as an additive to increase the apatite content and subsequent effectiveness of the dried slurry material.

Of all the phosphate materials, the utilization of the dried slurry (slime) was considered most important in that it was an attempt to utilize a costly refuse material of the phosphate industry to solve an equally costly problem of the coal industry. The composition of slurry (slime) material varies depending upon the geographic source. The dried slurry used in these experiments contained about 25 wt% apatite on the average; the remainder being smectite dominated clay minerals. The highly reactive clay sized apatite content, the ability of the dried material to be reslurried and hydraulically applied, its tendency to stick to applied surfaces and the fact that the apatite content could be increased by "spiking" with fine grained (-325 mesh) apatite were the main attributes of the material.

The toxic materials used in this work were of two varieties. The first was a common toxic "standard" material, a typical coal cleaning plant waste used with all of the various phosphate materials. The phosphate materials were intermixed with the toxic waste in a predetermined concentration range to allow relative comparisons of various application schedules to be made. The phosphate materials were also tested against a second suite of toxic materials which represented all of the various kinds of rock types encountered in mining and which also

provided a range of sulfur contents and acid producing potentials. The subsequently generated data using this suite of toxic materials would allow statistical testing of possible interrelationships between the various phosphate addition schedules and individual rock compositional and acid parameters.

The experiments conducted in this work were of two types: 1) bench scale experiments utilizing the oven oxidation/soxhlet leaching synthetic weathering procedure previously reported by the authors, and 2) small field scale (barrel) experiments which exposed mixtures of toxic and phosphate materials to conditions of natural weathering.

The bench scale experiments were designed to evaluate the effect of different addition schedules of each of the three basic phosphate materials on both the rate of acid production and on the ultimate acid load. The purpose of the small field scale experiments was to allow the evaluation of scaling factors which would in turn allow bench scale parameters to be translated to actual field conditions.

Four experimental parameters which are used to evaluate the effect of experimental treatments: 1) an acid production rate constant, α , which is the slope of the plot of the $\ln\%$ unreacted sulfur versus time 2) a sulfate production parameter, S300, which is the amount of sulfate produced from 1000 Tons of toxic material in 300 days (the S300 parameter is used as a comparison statistic) 3) the acid load which is the equivalent amount of CaCO_3 needed to neutralize the acid produced from 1000 Tons of toxic material and 4) a parameter η , which is the acid load divided by the total sulfur content of the toxic material.

In order to provide a basis of comparison for the phosphate data, a series of experiments were conducted which intermixed pure calcite with several different toxic rock materials at application schedules of 0.25, 0.50, 1.00, 2.00 and 4.00 wt%. The experiments showed that the addition of calcite in application schedules up to about 5 wt% had the effect of increasing acid production over that of the untreated controls. Acid loads reached a maximum at about 1.2 wt% calcite addition after which acid production dropped to about 5 wt% CaCO_3 addition at which point the acid production equaled that of the untreated controls. Beyond 5 wt% addition, acid production decreased relative to the controls, i.e. calcite became an effective ameliorant.

It is important to note that the use of limestone was never intended to eliminate the PRODUCTION of acid from the weathering of iron disulphide rich rocks, but rather was meant only to neutralize acid once formed. It should be pointed out that CaCO_3 will inhibit the oxidation of the iron disulphides if the application schedule is sufficiently large so as to raise the pH of the system to approximately pH 6-7. At this point, acid production would be reduced both by the precipitation of dissolved iron and by the inhibition of iron and sulfur oxidizing bacteria.

Normally, however, calcite is used simply to neutralize acid already generated. Because the neutralization reaction takes place on the surface of the calcite grains, the calcite grains will eventually become coated with precipitated iron oxy-hydroxides thereby reducing the effective calcite concentration. According to the experimental data, should the effective calcite concentration drop below 5 wt%, the system will once again become a net acid producer. This presumably explains the frequent lack of success using limestone as an AND

ameliorant. It was precisely because of these potential problems that another ameliorant was sought.

RESULTS OF INVESTIGATION-BENCH SCALE EXPERIMENTS

Table 1 summarizes the bench scale experiments which were conducted to evaluate the effect of intermixing the various phosphate materials with a suite of different toxic lithotypes. In each of the experiments, the respective phosphate material was added in 0.25, 0.50, 1.00 and 2.00 wt% apatite in addition to an untreated control. All experiments were run in triplicate. The table lists the coal bed association, the specific lithotype and the various acid evaluation parameters for each of the respective toxic materials. The CC#'s are laboratory identification numbers.

The first 12 experiments listed are the sand to pebble sized rock phosphate sized into the indicated categories. As previously indicated, the material indicated "CODE 30" is the rock phosphate in the size range from 150 to 250 mesh and the material indicated "CODE 31" is the same material ground to pass 325 mesh. The CODE 30 and CODE 31 materials were acquired from Texasgulf Sulfur at Aurora, North Carolina. The material termed "AGRICO" is a solar dried slurry (slime) acquired from the AGRICO Mining Co., Mulberry, Florida.

The results of the experiments were compared by plotting percent acid reduction relative to the control versus the wt% apatite addition. The data were extrapolated by computer to 5 wt% apatite addition.

TABLE 1

CC#	COAL BED ASSOC.	LITHIC TYPE	St	ALPHA	S ₃₀₀	ETA	TREATMENT	TREATMENT CC#
6434	U.FREE	REF.	2.970	-0.0003	2.56	48.00	1/4"-1/8"	5192
116	M.KITT	ROOF SHALE	1.410	-0.0012	7.578	22.495	1/4"-1/8"	5192
114	U.FREE	REF.	2.830	-0.0093	31.159	25.287	1/4"=18"	5192
22	L.KITT	REF.	2.742	-0.0012	10.778	12.405	1/4"-1/8"	5192
6434	U.FREE	REF.	2.970	-0.0003	2.56	48.00	1/8"-1/16"	5191
122	U.FREE	ROOF SHALE	7.271	-0.0075	37.347	23.894	1/8"-1/16"	5191
60	U.FREE	REF.	2.955	-0.0012	7.825	10.467	1/8"-1/16"	5191
53	U.FREE	REF.	6.501	-0.0046	26.680	25.871	1/8"-1/16"	5191
6434	U.FREE	REF.	2.970	-0.0003	2.56	48.00	<1/16"	5190
326	L.KITT	REF.	7.010	-0.0039	33.863	22.314	<1/16"	5190
35	U.FREE	REF.	1.140	-0.0019	9.957	32.649	<1/16"	5190
19	L.KITT	REF.	1.812	-0.0010	8.514	23.103	<1/16"	5190
330	U.FREE	SEAT-EARTH	2.680	-0.0068	20.415	6.263	CODE 30	5168
47	M.KITT	BONE COAL	5.263	-0.0007	19.544	23.987	CODE 30	5168
45	U.FREE	REF.	6.334	-0.0011	20.383	20.158	CODE 30	5168
40	L.KITT	PARTING	4.242	-0.0015	21.262	30.193	CODE 30	5168
6434	U.FREE	REF.	2.970	-0.0003	2.56	48.000	CODE 30	5168
337	L.KITT	REF.	9.114	-0.0051	35.064	21.617	CODE 30	5168
320	U.FREE	REF.	0.535	-0.0535	5.795	25.324	CODE 30	5168
123	U.FREE	REF.	3.186	-0.0080	19.570	16.660	CODE 30	5168
121	U.FREE	ROOF SHALE	9.740	-0.0082	13.737	24.710	CODE 30	5168
63	U.FREE	REF.	4.560	-0.0082	24.22	21.13	CODE 30	5168
55	U.FREE	ROOF SHALE	6.910	-0.0008	9.123	27.71	CODE 30	5168
24	U.FREE	OVERB. SHALE	0.652	-0.0050	4.83	5.00	CODE 30	5168
6434	U.FREE	REF.	2.197	-0.0003	2.56	46.000	AGRICO	5166
5070	U.FREE	REF.	3.150	-0.0050	17.06	58.36	AGRICO	5166
13	U.FREE	REF.	4.560	-0.0052	16.53	17.73	AGRICO	5166
12	L.KITT	ROOF SHALE	1.586	-0.0117	14.84	5.37	AGRICO	5166
19	L.KITT	REF.	1.812	-0.0010	4.777	23.103	AGRICO/C31	8348
26	U.FREE	ROOF SHALE	2.428	-0.0063	20.792	25.676	AGRICO/C31	8348
49	U.FREE	S.S.	1.740	-0.0003	1.359	45.210	AGRICO/C31	8348
62	U.FREE	REF.	5.525	-0.0050	43.102	20.943	AGRICO/C31	8348
64	U.FREE	REF.	3.312	-0.0061	27.847	15.911	AGRICO/C31	8348
119	L.FREE	PARTING	1.940	-0.0033	12.104	12.114	AGRICO/C31	8348

transfer; the effectiveness increasing with decreasing particle size

The results of the investigation are quite clear. The effectiveness of the rock phosphate is simply a question of mass and increasing magnitude of the application schedule. It is significant to note that the sand to pebble sized material is relative ineffective at acid reduction (see Figs. 1-3). Even the -1/1611 size does not reduce the acid load by 50% at projected application schedules of 5 wt%.

The CODE 30 material, as would be expected, is significantly more effective with 8 out of 12 experiments resulting in 50% acid reduction with an average application schedule of about 2.2 wt% apatite (see Figs. 4-6). Of the remaining 4 experiments which showed relatively low response, the sulfur content of the toxic material in two of the experiments was in excess of 9 wt%, thereby explaining the limited response.

Most encouraging, however, were the results of the experiments utilizing the dried slurry material. Because the material contained only about 25% by weight apatite, the effectiveness of the material used without any apatite addition was limited (see Fig. 7). However, with the addition of CODE 31 material, the slurry material showed significant improvement in performance. Based upon the success of these initial experiments, another series of experiments was designed utilizing the AGRICO slurry material with and without CODE 31 addition intermixed as a water slurry and run against a common toxic material. The experiments are summarized in Table 2. Each wt% apatite addition with the exception of 7.00 wt% apatite was conducted using two different slurry mixtures. All experiments were conducted in triplicate.

TABLE 2

TABLE 2

CC#	SOLID MIX			SLURRY MIX		WT% APATITE ADDITION
	gm AGRICO	gm CODE 31	ml/H ₂ O	gm SOLID MIX		
8342	5	0	50	5		0.25
8343	260	13	200	40		2.00
8344	260	13	750	225		1.25, 1.75, 3.25, 3.50, 3.75, 4.00
8345	300	60	300	60		0.75, 2.25, 2.75
8346	300	60	1000	300		2.75, 3.25, 4.00, 4.50
8347	450	225	750	75		0.25, 0.50, 1.00, 1.25, 1.50, 1.75, 2.50
8348	450	225	750	150		0.50, 1.00, 2.00, 2.50, 3.00, 3.50, 5.00
8349	450	225	1500	450		0.75, 1.50, 2.25, 3.00, 3.75, 4.50, 5.00, 7.00

The results of these experiments are summarized in figures 8 and 9 which plot acid load and alpha reduction versus wt% apatite addition respectively. The data show that approximately 0.9 wt% apatite must be added before acid reduction is initiated. Below 0.9 wt% apatite addition, the chemical effect of calcium on the system is the same as observed for calcite addition, namely, it results in an increase in acid production. Between 0.9 wt% and 4.0 wt% apatite addition, however, reduction in acid production is rapid. Note that on the average, an application schedule of 5 wt% apatite will reduce acid load and the rate of acid production by more than 90% relative to the untreated control. As previously indicated, calcite must be added at a 5 wt% addition schedule simply to INITIATE positive acid reduction which means that effective ameliorization using limestone will necessitate application schedules in excess of 5 wt% CaCO₃ on the average.

The initial slurry experiments intermixed the slurry material with a common toxic material. Based on the results of the above experiments, two final sets of experiments were designed and are still underway. The first set of experiments intermix slurry CC# 8348 with four different toxic materials at application schedules of 1, 2, 3 and 4 wt% apatite (see Table 3).

TABLE 3

AGRICO VS. 6 DIFFERENT TOXIC MATERIALS

CC#	COAL	ROCK TYP.	St	ALPHA	S300	ETA
26	U.FREE	ROOF SH.	2.418	0.0065	21.325	25.676
62	U.FREE	PREP.REF.	5.525	0.0050	28.397	20.943
64	U.FREE	PREP.REF.	3.312	0.0061	17.741	15.911
119	L.FREE	PARTING	1.940	0.0033	13.976	12.114

CC# 8348 SLURRY

450 gm AGRICO + 225 gm CODE 31
750 ml H₂O + 150 gm MIXTURE

APPLICATION SCHEDULE

CONTROL, 1 wt%, 2 wt%, 3 wt% and 4 wt% APATITE

Initially, the CODE 30 material was tested against a variety of toxic lithotypes. In the second set of experiments, the CODE 30 material is intermixed with the previously utilized common toxic lithotype in application schedules ranging from 0.50 wt% to 5.00 wt% at 0.25 wt% intervals.

With the completion of these final two sets of experiments, we will have tested all of the various phosphate materials against both a common toxic lithotype and against a variety of rock materials which vary in toxic potential. The completed data set will allow relative effectiveness comparisons to be made and will also allow the effect of the individual phosphate materials on the various toxic parameters to be calculated.

The entire bench scale experimental effort consisted of a total of 3285 individual experiments with 65,700 analyses. This point is made to emphasize the fact that the database is sufficiently large to allow a reasonably high statistical reliability to be assigned to any effectivity comparisons that will be made.

SMALL FIELD SCALE (BARREL) EXPERIMENTS

The third phase of this work is described as barrel experiments or small field scale experiments. The primary objective of this study was to determine the effect of phosphate mine waste on acid production from bituminous mine waste rock. The fact that phosphate rock can eliminate AMD had already been established by previous experimentation. However, the effectiveness of phosphate is apparently not directly related to any stoichiometric formulation based on the percentage of pyrite in the rock sample. Therefore, the ameliorative property of phosphate must be mass transfer controlled. If this is correct, the sample with the smaller particle size, but equal weight percentage phosphate rock will be more effective as an ameliorant.

The soxhlet experiments tested the effectiveness of surface area and weight percent of phosphate on 100 gram samples of toxic material. Because of the simplicity of this experimental procedure, large numbers of experiments can be run and a large data base can be accumulated. The question that yet remained was how these soxhlet tests related to the real world. If no correlation could be found, then the data are helpful simply in that they point toward a useful product. No one would be able to evaluate the cost effectiveness of the procedure; therefore, it can not be used. Our effort to resolve this dilemma was incorporated

into the barrel experiments.

The study on phosphate slurries was enlarged to test the effect of surface area and weight percent of phosphate rock on the acid production from cleaning plant waste and toxic sandstones. Identical sets of samples and treatments were evaluated by the soxhlet extraction procedure in the lab, so that these data could be correlated to the soxhlet performance. The goal was to prepare surface area, weight percent, effectiveness relationships in the lab and scale them to the barrels. A mathematical relationship for accurately predicting acid production of sample between soxhlet, barrel and field has already been established. With the barrel derived corrections made to the soxhlet procedural data, it is felt that one could go directly from the soxhlet to the field.

Ninety barrel experiments were prepared. Each barrel is a 35 gallon plastic container. Just above the bottom of the barrel is a supported distribution plate consisting of a plastic plate with 135 - 1/811 holes symmetrically drilled about the center. Below is an exit orifice with a drain pipe which connects the barrel to a sealed collection vessel. This pipe is intercepted by an air trap. Thus, the liquid can only flow in one direction and air can only enter through the top of the barrel. Three hundred pounds of cleaning plant waste or sandstone is supported above the distribution plate. The barrels were placed on 8 benches at the West Virginia University Plant and Soil Science Farm. The placement of individual experiments was determined by random number generation and is listed in the Table 4.

TABLE 4

TABLE 4 AMELIORANT FIELD EXPERIMENTS REACTOR POSITION SCHEDULE FOR POSITION SCHEDULE FOR PHOSPHATE TREATMENTS

PROCEDURE PLAN

BENCH	NORTH						SOUTH					
I	82	24	01	87	38	14	43	57	72	50	78	96
II	88	66	85	75	93	51	71	17	22	21	30	63
III	81	31	13	34	56	28	32	41	12	67	42	64
IV	79	52	08	16	48	18	03	69	58	47	05	20
V	25	54	37	61	45	77	73	86	29	10	62	04
VI	80	35	15	19	94	60	46	59	44	49	53	90
VII	07	89	36	65	92	40	55	11	84	06	74	70
IIX	09	26	91	76	83	23	33	27	02	95	68	39

The Mixtures of phosphate material to rock material are seen in Table 5.

TABLE 5

TABLE 5 PHOSPHATE AMELIORANT FIELD EXPERIMENTS

<u>MATERIAL</u>	<u>AMELIORANT</u>	<u>PARTICLE MESH SIZE</u>	<u>APPLICATION RATE</u>	<u>REP</u>	<u>EXPER. NUMBER</u>
REFUSE	P-ROCK	18-35	1.20%	1	01
REFUSE	P-ROCK	18-35	1.20%	2	02
REFUSE	P-ROCK	18-35	1.20%	3	03
REFUSE	P-ROCK	18-35	0.40%	1	04
REFUSE	P-ROCK	18-35	0.40%	2	05
REFUSE	P-ROCK	18-35	0.40%	3	06
REFUSE	P-ROCK	18-35	0.13%	1	07
REFUSE	P-ROCK	18-35	0.13%	2	08
REFUSE	P-ROCK	18-35	0.13%	3	09

REFUSE	P-ROCK	18-35	0.04%	1	10
REFUSE	P-ROCK	18-35	0.04%	2	11
REFUSE	P-ROCK	18-35	0.04%	3	12
REFUSE	P-ROCK	35-60	1.20%	1	13
REFUSE	P-ROCK	35-60	1.20%	2	14
REFUSE	P-ROCK	35-60	1.20%	3	15
REFUSE	P-ROCK	35-60	0.40%	1	16
REFUSE	P-ROCK	35-60	0.40%	2	17
REFUSE	P-ROCK	35-60	0.40%	3	18
REFUSE	P-ROCK	35-60	0.13%	1	19
REFUSE	P-ROCK	35-60	0.13%	2	20
REFUSE	P-ROCK	35-60	0.13%	3	21
REFUSE	P-ROCK	35-60	0.04%	1	22
REFUSE	P-ROCK	35-60	0.04%	2	23
REFUSE	P-ROCK	35-60	0.04%	3	24
REFUSE	P-ROCK	60-120	1.20%	1	25
REFUSE	P-ROCK	60-120	1.20%	2	26
REFUSE	P-ROCK	60-120	1.20%	3	27
REFUSE	P-ROCK	60-120	0.40%	1	28
REFUSE	P-ROCK	60-120	0.40%	2	29
REFUSE	P-ROCK	60-120	0.40%	3	30
REFUSE	P-ROCK	60-120	0.13%	1	31
REFUSE	P-ROCK	60-120	0.13%	2	32
REFUSE	P-ROCK	60-120	0.13%	3	33
REFUSE	P-ROCK	60-120	0.04%	1	34
REFUSE	P-ROCK	60-120	0.04%	2	35
REFUSE	P-ROCK	60-120	0.04%	3	36
REFUSE	P-ROCK	LT 120	1.20%	1	37
REFUSE	P-ROCK	LT 120	1.20%	2	38
REFUSE	P-ROCK	LT 120	1.20%	3	39
REFUSE	P-ROCK	LT 120	0.40%	1	40
REFUSE	P-ROCK	LT 120	0.40%	2	41
REFUSE	P-ROCK	LT 120	0.40%	3	42
REFUSE	P-ROCK	LT 120	0.13%	1	43
REFUSE	P-ROCK	LT 120	0.13%	2	44
REFUSE	P-ROCK	LT 120	0.13%	3	45
REFUSE	P-ROCK	LT 120	0.04%	1	46
REFUSE	P-ROCK	LT 120	0.04%	2	47
REFUSE	P-ROCK	LT 120	0.04%	3	48

REFUSE	P-SLURRY	-----	4.80%	1	49
REFUSE	P-SLURRY	-----	4.80%	2	50
REFUSE	P-SLURRY	-----	4.80%	3	51
REFUSE	P-SLURRY	-----	1.60%	1	52
REFUSE	P-SLURRY	-----	1.60%	2	53
REFUSE	P-SLURRY	-----	1.60%	3	54
REFUSE	P-SLURRY	-----	0.52%	1	55
REFUSE	P-SLURRY	-----	0.52%	2	56
REFUSE	P-SLURRY	-----	0.52%	3	57
REFUSE	P-SLURRY	-----	0.16%	1	58
REFUSE	P-SLURRY	-----	0.16%	2	59
REFUSE	P-SLURRY	-----	0.16%	3	60
REFUSE	CONTROL	-----	-----	1	61
REFUSE	CONTROL	-----	-----	2	62
REFUSE	CONTROL	-----	-----	3	63
SANDSTONE	P-ROCK	18-35	0.40%	1	70
SANDSTONE	P-ROCK	18-35	0.40%	2	71
SANDSTONE	P-ROCK	18-35	0.40%	3	72
SANDSTONE	P-ROCK	35-60	0.40%	1	73
SANDSTONE	P-ROCK	35-60	0.40%	2	74
SANDSTONE	P-ROCK	35-60	0.40%	3	75
SANDSTONE	P-ROCK	35-60	0.40%	1	76
SANDSTONE	P-ROCK	35-60	0.40%	2	77
SANDSTONE	P-ROCK	35-60	0.40%	3	78
SANDSTONE	P-ROCK	LT 120	0.40%	1	79
SANDSTONE	P-ROCK	LT 120	0.40%	2	80
SANDSTONE	P-ROCK	LT 120	0.40%	3	81
SANDSTONE	P-SLURRY	-----	4.80%	1	82
SANDSTONE	P-SLURRY	-----	4.80%	2	83
SANDSTONE	P-SLURRY	-----	4.80%	3	84
SANDSTONE	P-SLURRY	-----	1.60%	1	85
SANDSTONE	P-SLURRY	-----	1.60%	2	86
SANDSTONE	P-SLURRY	-----	1.60%	3	87
SANDSTONE	P-SLURRY	-----	0.52%	1	88
SANDSTONE	P-SLURRY	-----	0.52%	2	89
SANDSTONE	P-SLURRY	-----	0.52%	3	90
SANDSTONE	P-SLURRY	-----	0.16%	1	91
SANDSTONE	P-SLURRY	-----	0.16%	2	92
SANDSTONE	P-SLURRY	-----	0.16%	3	93
SANDSTONE	CONTROL	-----	-----	1	94
SANDSTONE	CONTROL	-----	-----	2	95
SANDSTONE	CONTROL	-----	-----	3	96

The toxic material used in this experiment was specifically chosen. The cleaning plant waste came from Grant County, West Virginia. Many toxic rock wastes have been studied over the past four years and the material from this site is of average toxicity, it is neither too reactive nor too unreactive. Sixteen tons of this material was obtained and hand screened to a size of <1.5" in order to guarantee that the water would not channel through the barrels but rather would travel downward in a uniform front.

The sandstone selected for the study was the overburden rock covering the Kittanning coal bed in central West Virginia. The Kittanning coal beds are some of the most extensive in the state. As a result, the mining community must contend with this rock very frequently. Sixteen tons of the material was obtained and hand screened as described above.

The barrels have been weathering since May 1986. Although the experiments are not yet complete and the data collected so far have not been statistically analyzed, the colors of the leachates have indicated quite clearly the progress of the study. Since the first leachate collection to the present, it is evident there has been a significant difference in the acid drainage produced from the various samples. Those samples with the highest weight percent of phosphate addition and largest surface areas produce leachates which are colorless with no significant acidity. The leachate samples then increase in red color intensity, a usual indicator of increasing acidity, as both weight percent and surface area of rock phosphate decrease. The leachate sample color intensity shows that the acidity decrease is more of a response to surface area than it is to weight percent of phosphate rock. This validates our original hypothesis that the ameliorative effect of apatite is dominated by mass transfer, not reaction stoichiometry. Neither the acidity/weight percent nor the acidity/surface area relationships appear to be linear. Their exact mathematical relationships will be determined upon completion of the experiments. After the completion of the year long weathering cycle and all leachate samples have been collected and analyzed, we will be able to define mathematical equations which will describe the influence of various experimental parameters on acid production and will also show how the barrel field tests relate to the soxhlet tests.

PHOSPHATE STUDY

Toxic Material I.D. - CC116

M. Kittanning Roof Shale

$S_T = 1.410$

$\alpha = -0.0012$

$S_{300} = 7.578$

$\eta = 22.495$

PO₄ Material I.D. - CC5192

1/8" - 1/4"

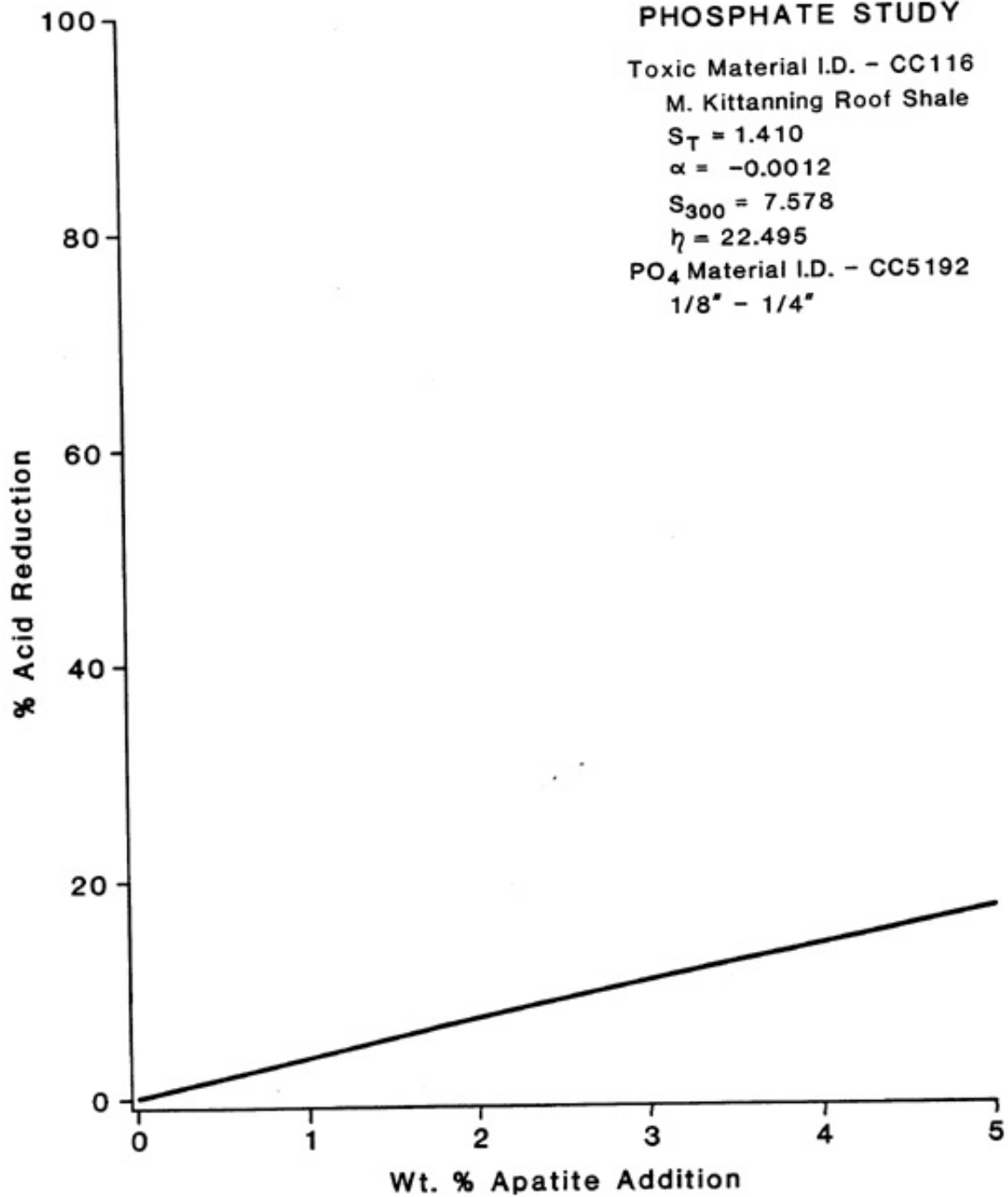


FIGURE 1. Percent Acid Reduction vs. Wt. % Apatite Application for 1/8" - 1/4" Granular Sized Rock Phosphate

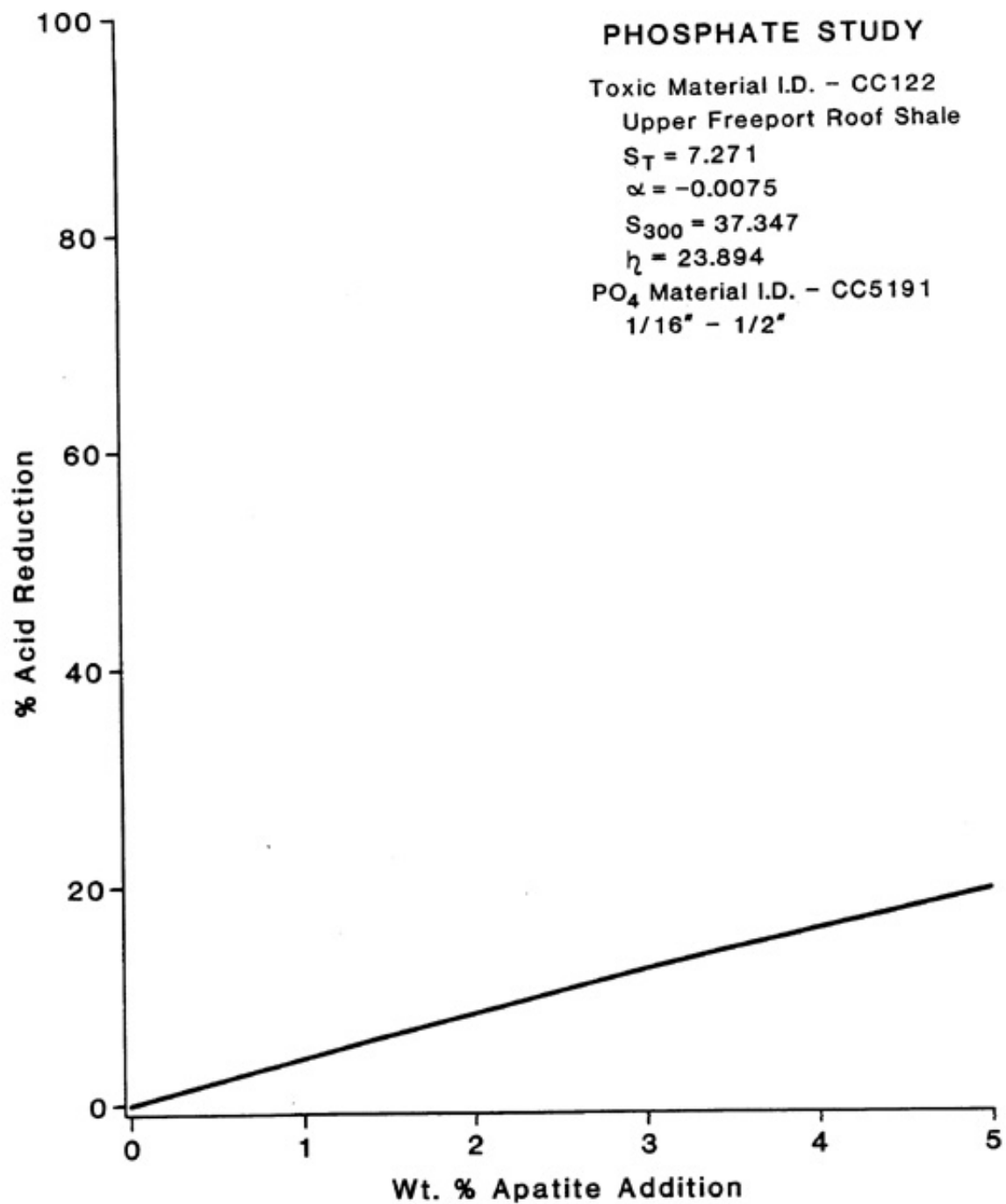


FIGURE 2. Percent Acid Reduction vs. Wt. % Apatite Application for 1/16" - 1/2" Granular Sized Rock Phosphate

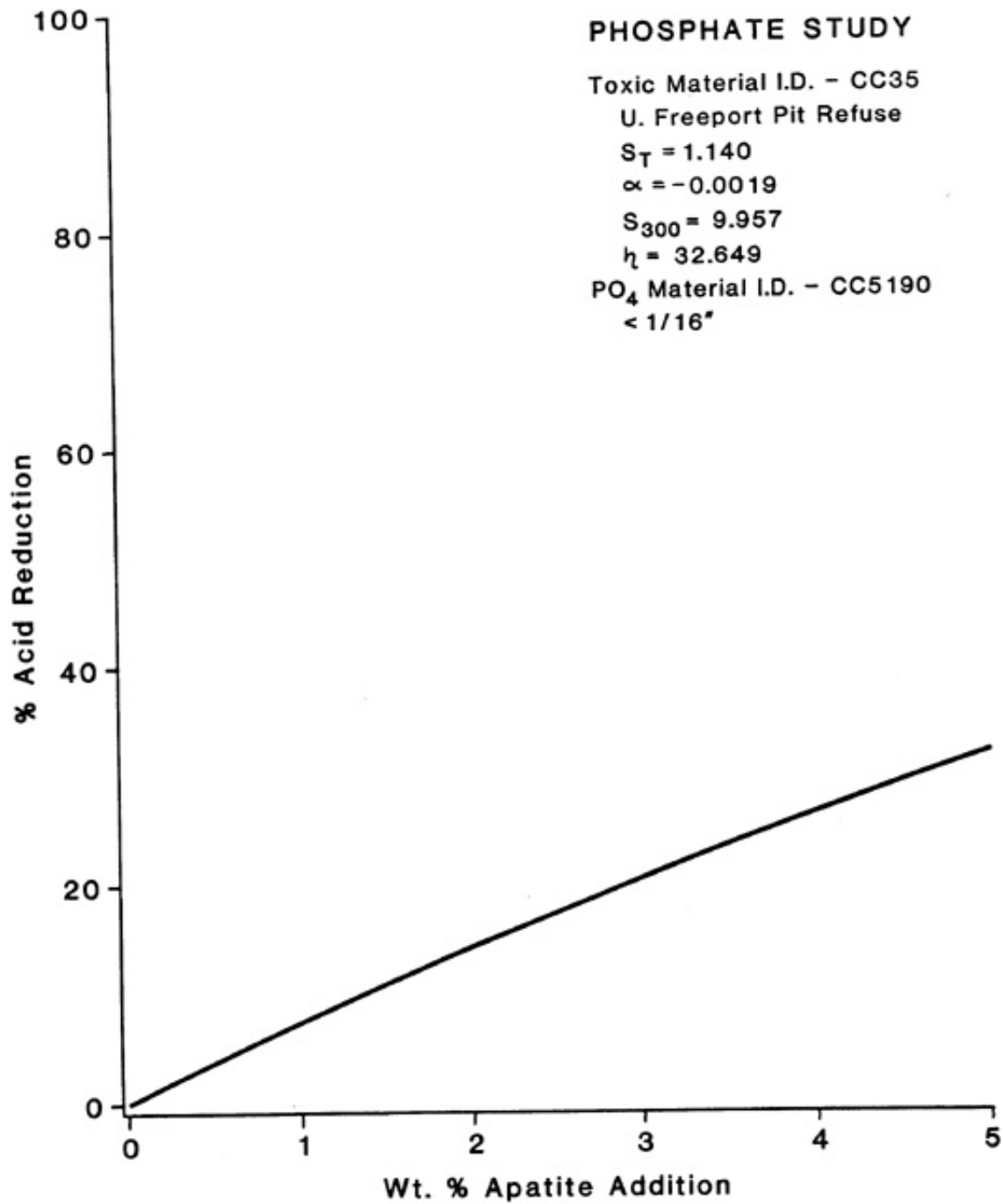


FIGURE 3. Percent Acid Reduction vs. Wt. % Apatite Application for < 1/16" Sand Sized Rock Phosphate

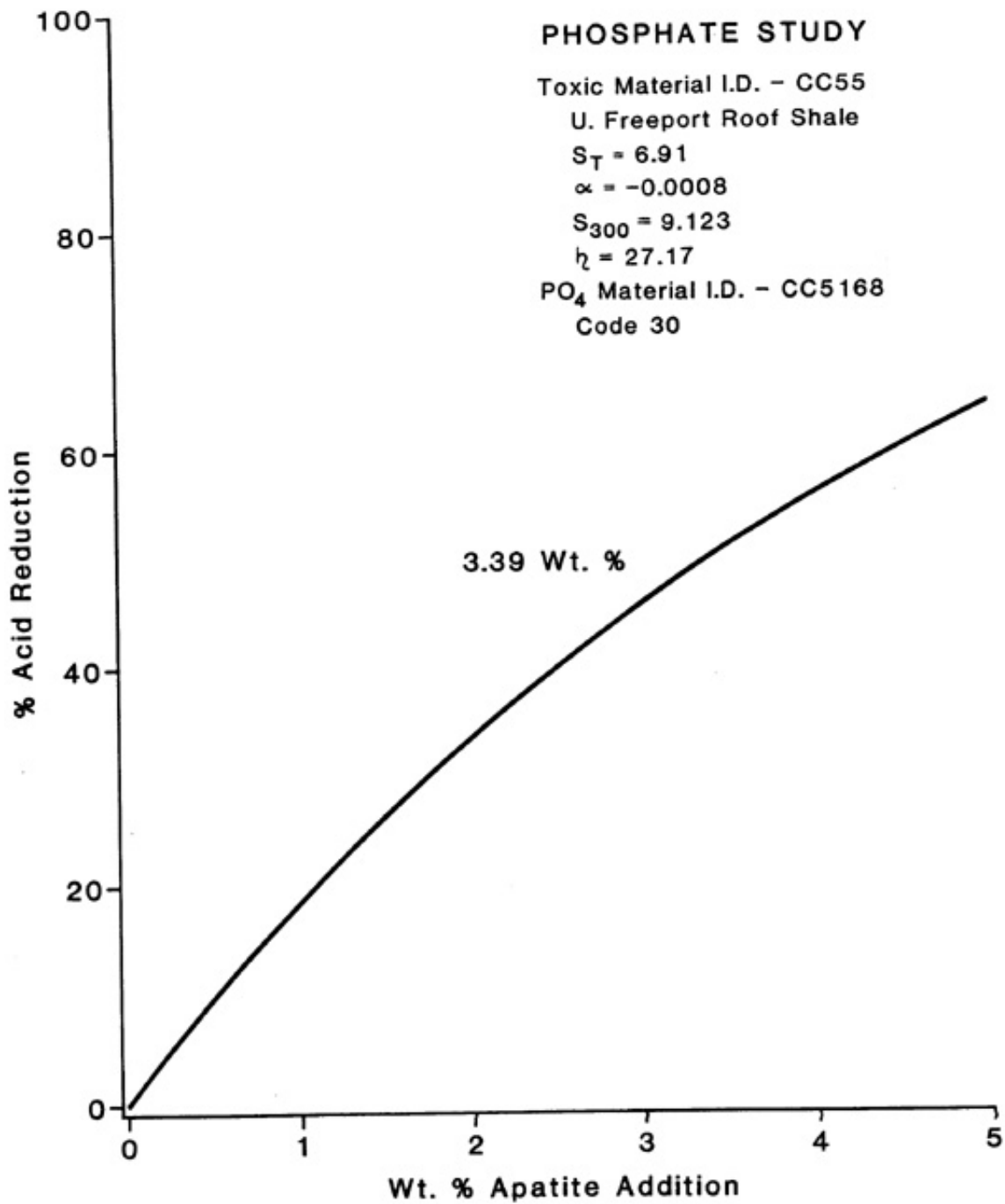


FIGURE 4. Percent Acid Reduction vs. Wt. % Apatite Application for Code 30 Fine Grained Rock Phosphate

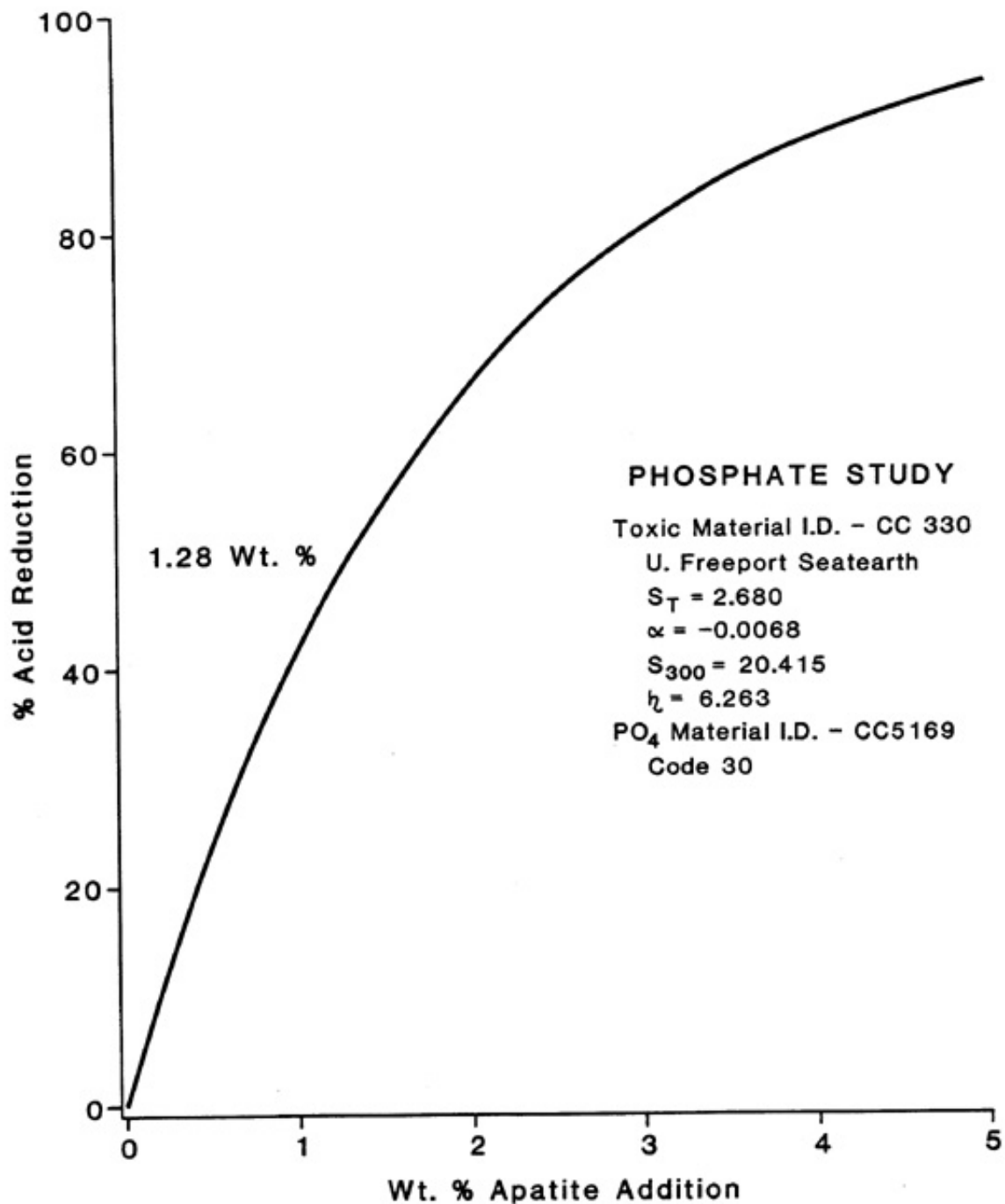


FIGURE 5. Percent Acid Reduction vs. Wt. % Apatite Application for Code 30 Fine Grained Rock Phosphate

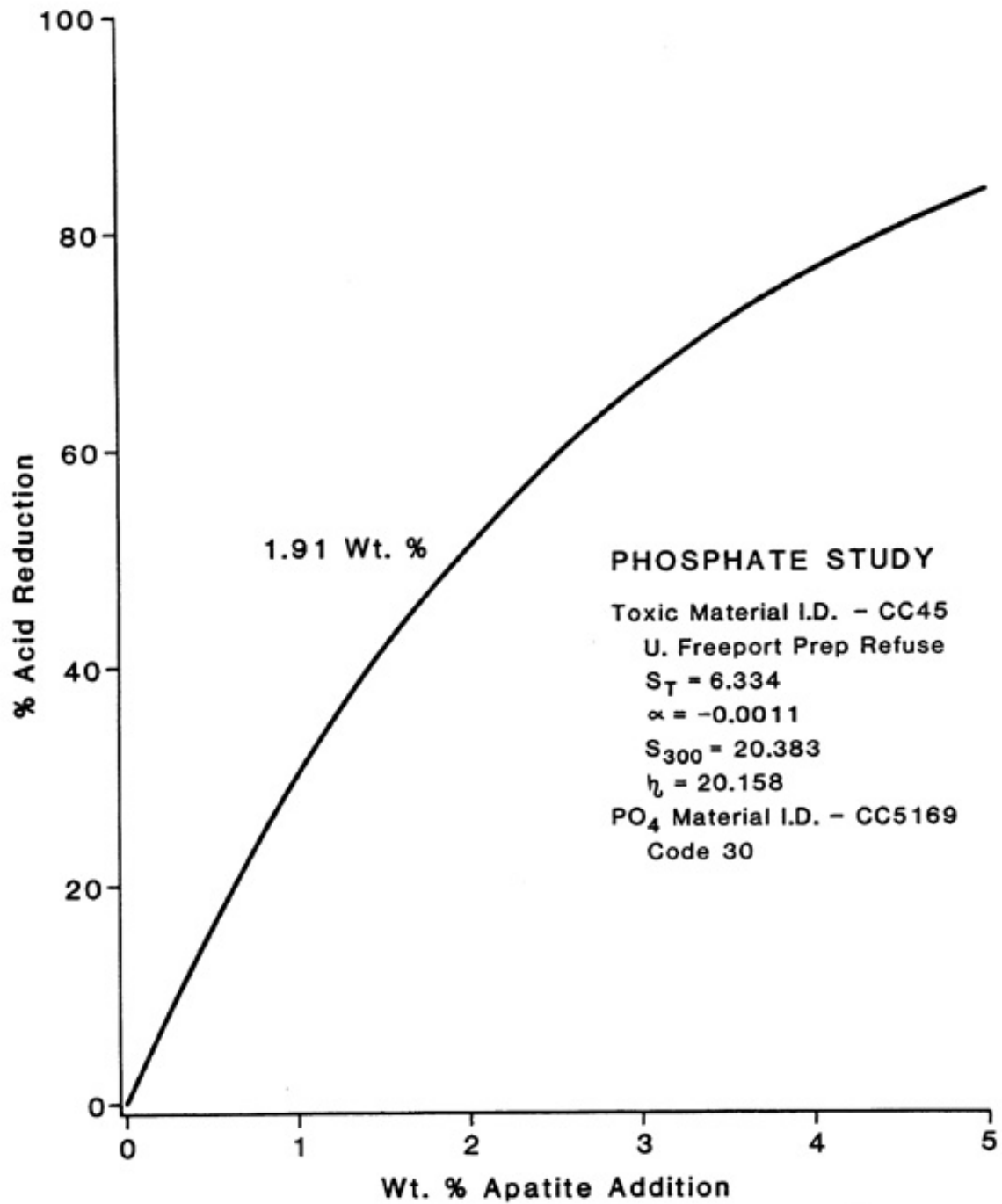


FIGURE 6. Percent Acid Reduction vs. Wt. % Apatite Application for Code 30 Fine Grained Rock Phosphate

PHOSPHATE STUDY

Toxic Material I.D. - CC6434

Aerico Dry PO₄

PO₄ Material I.D. - CC5166

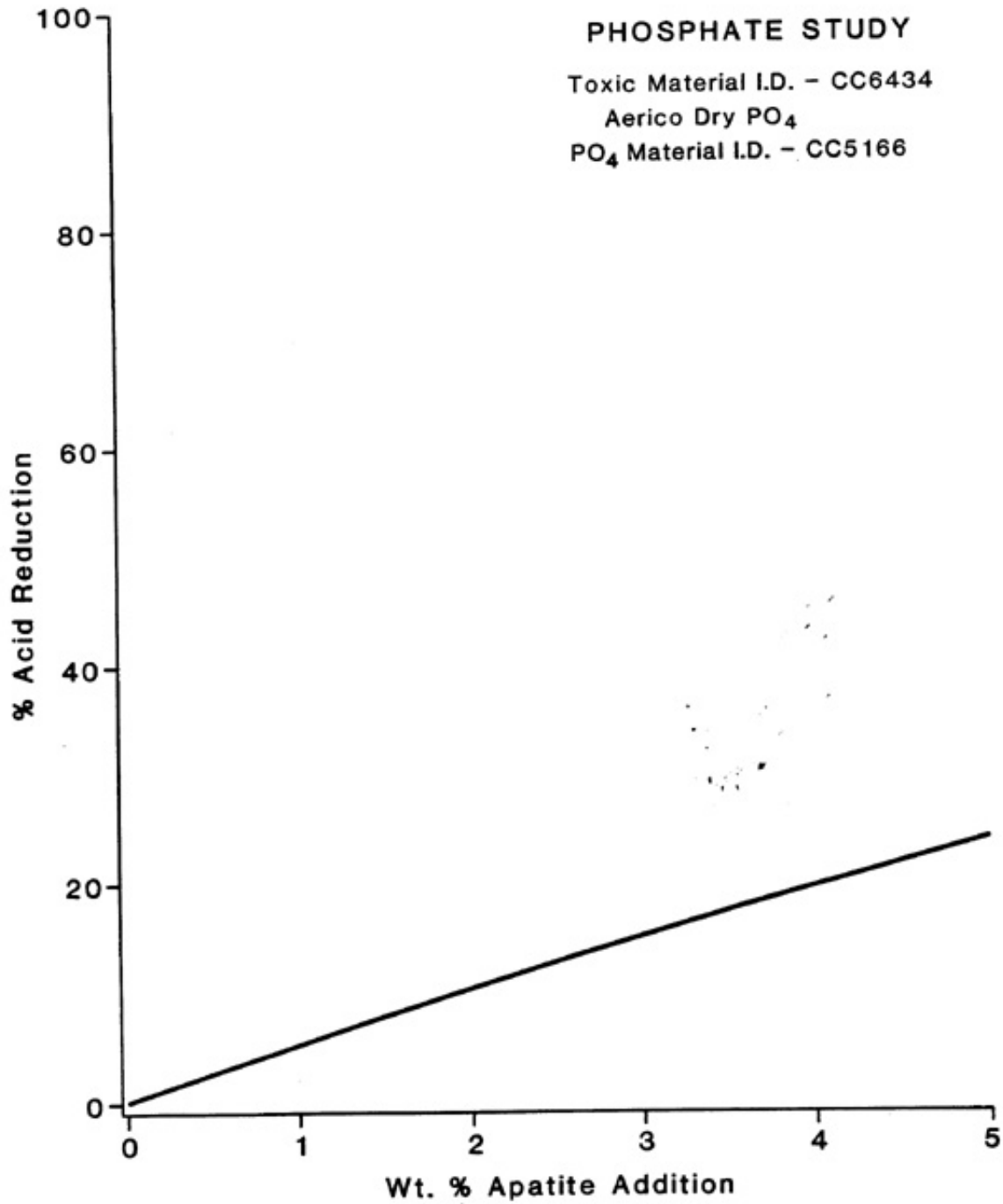


FIGURE 7. Percent Acid Reduction vs. Wt. % Apatite Application for Dried Slurry - No Code 31 Spike

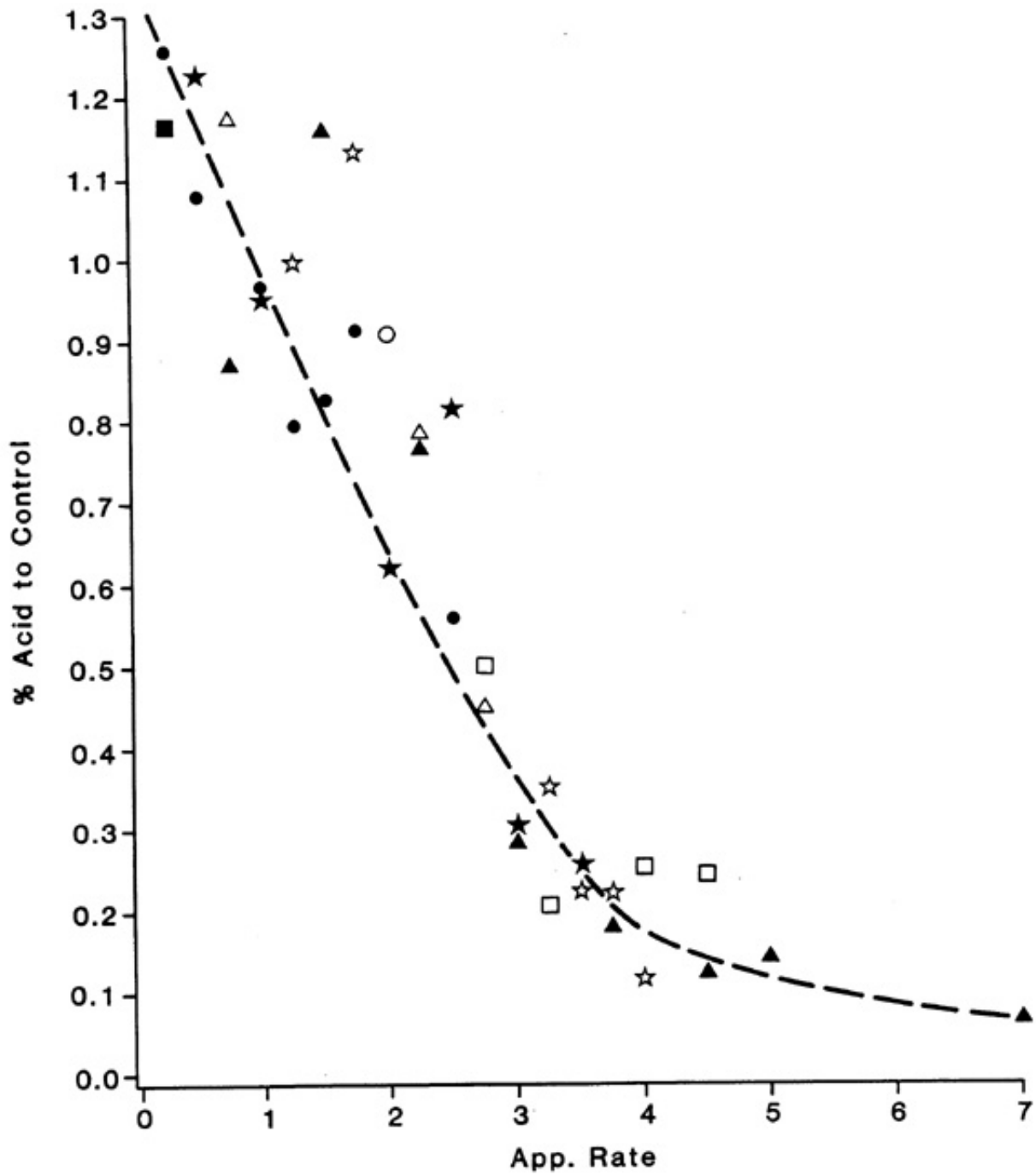


FIGURE 8. Percent Acid Reduction vs. Wt. % Apatite Application for Dried Slurry with Code 31 Spike

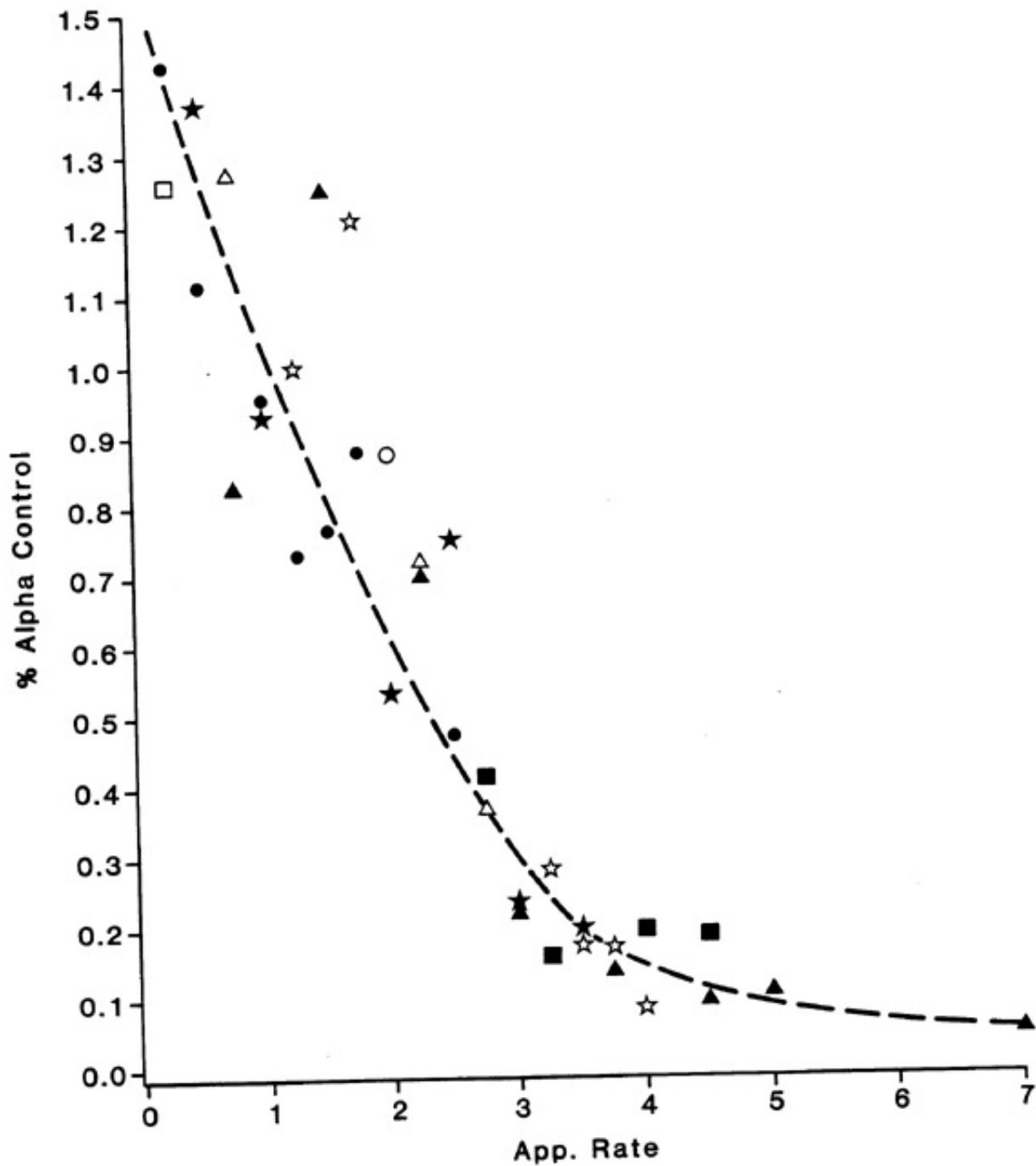


FIGURE 9. Percent Alpha Reduction vs. Wt. % Apatite Application for Dried Slurry with Code 31 Spike