

increases in outgo of fluorine from both untreated soils.

Fluorine recoveries from the first- and third-year inputs of 200 pounds per acre, as fluorides, were decreased by the liming materials in the Hartsells soil and increased in the Clarksville soil.

Fluorine retentions from potassium fluoride in Hartsells were 91 to 96% against 91 to 92% for Clarksville; minimal retention was from the wollastonite, at heavy rate. The high percentage retentions of fluorine were in contrast to the potassium retentions of 46 to 65% by Hartsells and 33 to 45% by Clarksville. Such differentials demonstrate the preferential fixation of the fluoride ion, the extent being higher in the soil of lower content of calcium and higher content of alumina (Table I).

Potassium recoveries per annum were greatest after the first- and third-year incorporations. The 28 comparisons demonstrated that all carriers of calcium caused decreases in recoveries of the potassium of the added fluoride.

Potassium fluoride incorporations caused decreases in calcium and magnesium outgo from both soils, whereas

calcium fluoride caused enhancements in the leachings of calcium and decreases in outgo of magnesium and potassium from both soils.

In general, wollastonite proved more conducive than limestone in causing fluorine outgo, and was less repressive upon potassium recovery and upon magnesium outgo.

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## FLUORIDES IN SOIL

# Fate and Effects of Hydrofluoric Acid Added to Four Tennessee Soils in a 4-Year Lysimeter Study

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Hydrofluoric acid emissions from thermal processing of rock phosphate have caused abnormal occurrences of fluorine in the atmosphere and vegetation in Maury County, Tennessee. Because of the uncertainty as to the effects of atmosphere-derived hydrofluoric acid upon soils, a dilute solution of that acid was used for applications and incorporations to four Tennessee soils in a 4-year lysimeter experiment, through which rain-water leachings of fluorine, calcium, magnesium, and potassium were determined. Fluorine leachings from the incorporations greatly exceeded those from the applications. Retentions of fluorine from the 200- and 800-pound additions ranged between 75.8 and 99.6% of the inputs. The fluorine retentions by the four soils were proportional to their contents of aluminum, and were postulated as due to the formation of aluminum silicofluoride,  $Al_2(SiF_6)_3$ . The hydrofluoric acid additions caused small decreases uniformly in the leachings of calcium and magnesium. When integrated with plant responses obtained in earlier pot culture experiments, the findings indicate that the fertility of a soil will not be impaired by hydrofluoric acid that may come to it from the atmosphere.

**H**YDROFLUORIC EMISSIONS occur in the thermal production of ortho- and metaphosphate fertilizers and in the preparatory nodulization of rock phosphate charges for reduction in electric furnaces (9). The emitted acid undergoes dispersion in the gaseous phase, as mists and as droplets, according to height of release, topography, atmos-

pheric moisture, and meteorological conditions. Emissions of hydrofluoric acid in the manufacture of aluminum also have been blamed for abnormal fluorine contents of vegetation in several states (7, 2, 6) and as a result of studies conducted at the experiment stations of Oregon (5), Washington (5, 17), and Tennessee (12, 13).

In bench experiments, Hurd-Karrer (10) incorporated "greatly diluted" hydrofluoric acid into a New Jersey soil, the fluorine content of which was only 11 p.p.m. She sought "to determine the extent to which fluorine can be absorbed from soils by plant roots, and the extent to which absorption can be controlled by liming." The effects of addi-

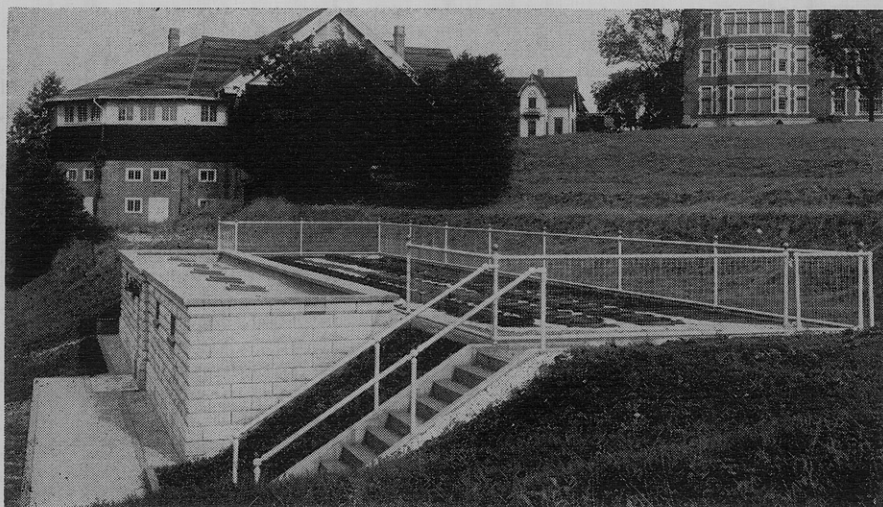


Figure 1. Outside view of lysimeter installation at Knoxville

tions of hydrofluoric acid upon soil reaction and uptake of fluorine by plants in pot cultures, and the ameliorative effects of liming, were reported by Leone and others (17), by Prince and others (18), and by workers at the Tennessee station (15).

However, no evidence has been advanced as to the fate of the fluorine of hydrofluoric acid added to soils that then were exposed to long-time rain-water leachings. Therefore, a 4-year lysimeter experiment was inaugurated to ascertain the chemical expectancy for composition of the rain-water leachings from four Tennessee soils that had received additions of a highly diluted solution of hydrofluoric acid at two rates at the beginning of the experiment.

#### Compositions and Properties of Soils

The four acidic soils used were screened in moist bulk and a charge equivalent to 100 pounds on a moisture-free basis was introduced into each asphalt-coated cylindrical galvanized iron lysimeter of  $\frac{1}{20,000}$ -acre area. The soil charge was underlain by a layer of quartz and flow of the rain-water drainage from the cone bottom was into a block tin tube, which was within a 1-inch galvanized iron pipe that passed through the walls of the building that housed the receptacles (Figures 1 and 2). The soils were maintained clean and fallow throughout the 4 years of the experiment.

Compositions of the four soils are given in Table I and their exchange properties and pH values are indicated in Table II. Three of the soils contained small percentages of calcium and meager occurrences of fluorine. In contrast, the Maury silt loam contained a relatively high percentage of apatite, which was responsible for the 3.76% content of calcium, the 5.46% of phosphorus pentoxide, and a fluorine content equivalent to 0.75% of calcium fluoride. The apatite was responsible for the high milliequivalent extraction of calcium

by the ammonium acetate; but, because of its meager solubility in water, the apatite did not neutralize the aqueous system in which the soil registered pH 5.3 electrometrically.

When apatite was extracted alone, the resultant ammonium acetate solution was of the apatite molecule. But when the apatite content of the soil charge underwent dissolution by the ammonium acetate, the resultant phosphate ions were retained by the soil and the extract was a solution of calcium acetate. This was demonstrated through the calcium extractions of 5.00 meq. from 10 grams of Etowah silt loam alone, 1.35 meq. from apatite alone, and 5.59 meq. from a combination charge of soil and apatite. Therefore, only 0.59 meq. of calcium was attributable to the apatite in its combination with the soil. The corresponding extractions for phosphorus were 0.2 meq. from the apatite alone, but only 0.03 meq. from the apatite plus soil. Consequently, when the summation of calcium, magnesium, and potassium was subtracted from ex-

change capacity, a conventional procedure for acidic soils, no room was left for indication of hydrogen content as in the third column of Table II. However, when the phosphatic soil was subjected to the AOAC calcium acetate procedure (20), it registered 9.5 meq. of hydrogen.

#### Hydrofluoric Acid Additions

A c.p. stock concentrate of hydrofluoric acid was diluted to a 2% solution. Aliquots were brought to 1-liter constant and the highly diluted acid was sprinkled upon the soil surfaces to supply fluorine at rates of 200 and 800 pounds per acre. The intent was to produce effects similar to those that result from the fluorine that passes from atmosphere into soil, without influence from plant growth. Obviously, it was not feasible to effect a precise simulation of the known increment of fluorine the rain waters brought to the lysimeter soils in the 4-year experiment at Knoxville. The rate of 200 pounds per acre for additive fluorine was deemed minimal to assure significant quantitative findings. That rate was paralleled by 800-pound additions, with hope that the range for additions would indicate the fate of the increments of hydrofluoric acid that have reached the soil from the atmosphere in certain locales in Tennessee (13).

In making full-depth incorporation, 1 liter of the diluted acid was poured into a large cavity of the full charge of soil that was in good "tilth," and a lapse of 30 minutes was allowed before the entire bulk of soil was mixed and placed in the lysimeter. This technique for the maximal input of the acid assured good friable condition of the soil charge.

The soils were maintained fallow and clean throughout the 4 years of the experiment and were wetted only by the rainfall. The drainages represented an annual mean of about 45% of the rain

Figure 2. Inside view of lysimeter



**Table I. Composition of Four Soils Used, as Indicated by Analyses of Nitric-Hydrochloric Acid and Sodium Hydroxide Extractions<sup>a</sup>**

Soil	Fluorine <sup>b</sup> %	Ca, %	Mg, %	Mn, %	K, %	Fe <sub>2</sub> O <sub>3</sub> , %	P <sub>2</sub> O <sub>5</sub> , %	Al <sub>2</sub> O <sub>3</sub> , %	
								Acid-soluble	NaOH <sup>c</sup> -soluble
Hartsells fine sandy loam	0.017	0.09	0.15	0.09	0.115	3.19	0.045	3.85	2.59
Clarksville silt loam	0.010	0.11	0.05	0.10	0.065	2.39	0.035	1.15	0.78
Maury silt loam	0.365	3.76	0.22	3.41	0.385	8.78	5.46	8.64	4.19
Baxter silt loam	0.023	0.13	0.10	0.18	0.110	5.59	0.19	2.26	1.31

<sup>a</sup> Charges of 2 grams digested in HNO<sub>3</sub>-HCl (4).

<sup>b</sup> By H<sub>2</sub>SO<sub>4</sub> and HClO<sub>4</sub> distillations (8, 14).

<sup>c</sup> Charges of 2.5 grams extracted in 100 ml. of 5% NaOH solution, with continuous mechanical agitation, 1 hour, at 65° C.

**Table II. Properties of Hartsells Sandy Loam and Maury, Clarksville, and Baxter Silt Loams into Which Hydrofluoric Acid Was Introduced**

Determinations <sup>a</sup>	Hartsells Sandy Loam	Clarksville Silt Loam	Maury Silt Loam	Baxter Silt Loam
	Meq. per 100 Grams of Dry Soil			
Exchangeable Cations				
Calcium	1.36	2.08	11.67 <sup>b</sup>	1.48
Magnesium	0.29	0.37	0.62	0.36
Potassium	0.27	0.09	0.29	0.14
Hydrogen <sup>c</sup>	10.68	3.36	0 (9.5) <sup>d</sup>	3.97
Exchange capacity at pH 7	12.60	5.90	11.05	5.95
Organic matter, % <sup>e</sup>	4.7	2.7	2.2	2.3
Initial pH values in water <sup>f</sup>	5.40	5.60	5.3	5.2

<sup>a</sup> Exchangeable Ca, Mg, and K were determined by means of neutral normal ammonium acetate extraction and leaching of 10 grams of soil with 250 ml. of solution.

<sup>b</sup> Apparent anomaly of high content of exchangeable Ca and H indicated by pH 5.3 is accounted for by solvent action of ammonium acetate upon unusual content of apatite with resultant enhancement in extraction of Ca without concomitant extraction of PO<sub>4</sub> and F. Apatite is but slightly soluble in aqueous system and does not preclude pH value 5.3.

<sup>c</sup> Values for H, other than <sup>d</sup>, determined as differences between summations of cations Ca-Mg-K and exchange capacity.

<sup>d</sup> 9.5 meq. value for exchangeable H determined through replacement with 250 ml. of 0.5M neutral Ca acetate and titration of engendered acidity with 0.1N Ba(OH)<sub>2</sub> to pH 8.8 (20).

<sup>e</sup> Organic matter determinations by method of Walkley and Black (21).

<sup>f</sup> pH readings made electrometrically.

Upon assumption that reaction products from the added acid were much the same for applications and incorporations, the fluoride solutes in the leachings from the upper zone of higher initial concentration underwent some stoppage during their gravitational passage through the full depth of soil.

Largest increase in fluorine outgo from the four fluoridated soils, and smallest retention, were registered by the Clarksville soil, which had the least content of acid-soluble and alkali-soluble alumina. The first-year outgo of fluorine from every 800-pound input was more than 50% of the corresponding 4-year total. The 133-pound mean of the first-year increases in fluorine outgo from the 800-pound incorporations represented 68% of the mean of total recoveries from the four soils. Because the proportions of the fluorine recoveries from those inputs in the three soils other than the Maury soil were without attendant increases in calcium outgo, it appears that hydrofluoric acid was present in the leachings of the first year.

From a comparison of the initial pH values, as in Table II, with the final values given in Table III, it is obvious that the acid additions caused increased acidity in all units at both rates in three of the four soils. The smallest change in pH was caused by the "carbanophosphate" in the Maury silt loam.

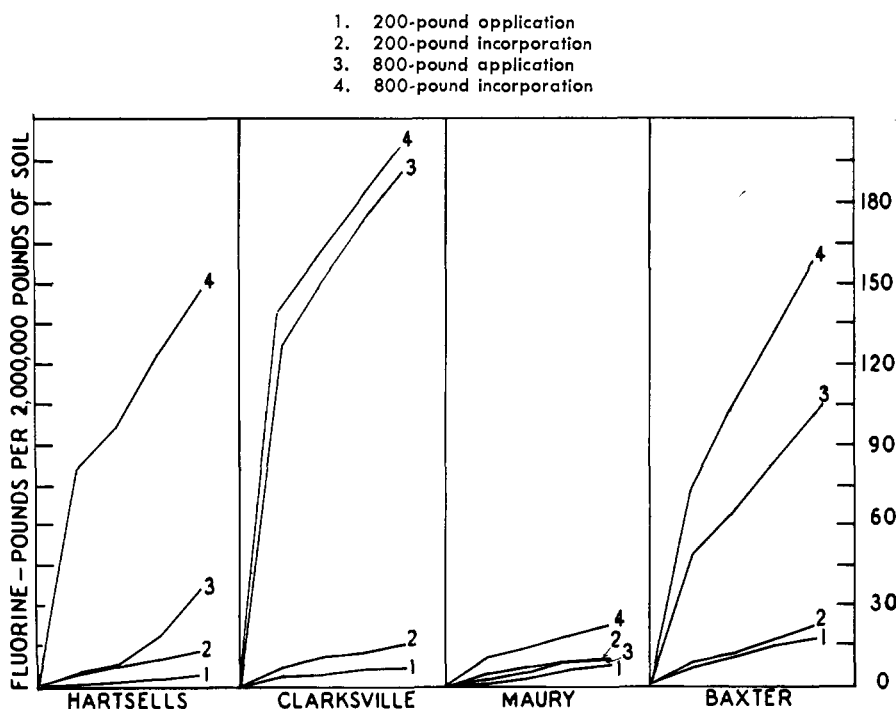
Although its natural content of fluorine in the Maury silt loam was 22 times the mean for the fluorine contents of the other three soils, that soil registered the smallest recovery and the largest retention of the added fluorine. Because the

waters. Fluorine contents of the periodic collections of the rain-water drainages were determined by means of the procedure prescribed by the American Public Health Association (3), and, whenever needed, the periodic leachings were clarified and decolorized for analysis by the technique developed by Shaw (19). Annual composites of the periodic collections were analyzed for their contents of calcium, magnesium, and potassium, and also for fluorine checks against the respective aggregates of periodic outgo.

**Fluorine Recoveries and Retentions**

The annual recoveries and corollary retentions of fluorine from the 200- and 800-pound additions are shown for the four soils in Table III. The 200-pound additions yielded small recoveries, as shown schematically in Figure 3. In every case, the largest annual outgo of fluorine occurred in the initial year and recoveries from surface application were decidedly less than those from the corresponding full-depth incorporations. The decided differences between total recoveries from the applications and incorporations are indicated in Figure 4.

**Figure 3. Progression in fluorine recoveries through 4-year leachings from 200- and 800-pound applications and incorporations as hydrofluoric acid in four soils**



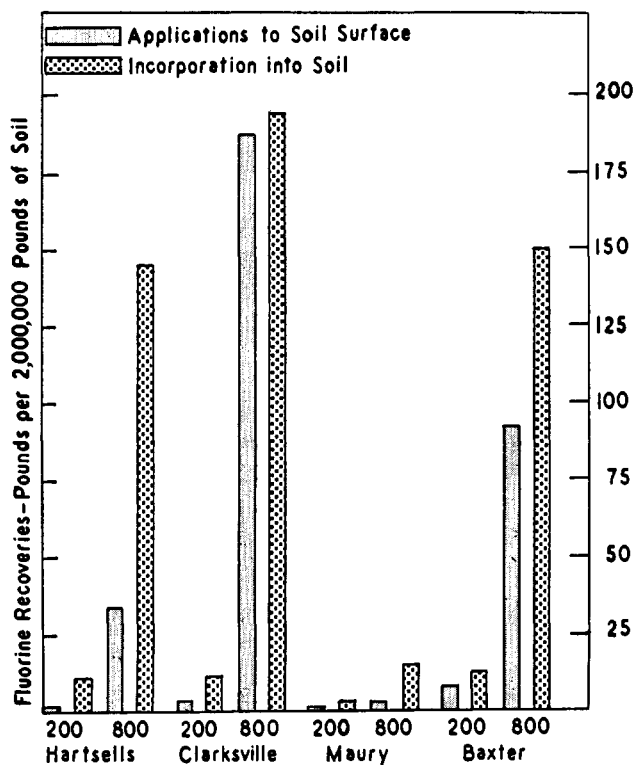


Figure 4. Total recoveries of fluorine through 4-year leachings from 200- and 800-pound applications and incorporations, as hydrofluoric acid in four soils

of fluorine to that soil cannot be attributed to such reaction. Calcium fluoride is but slightly soluble, and aluminosilico fluoride is decidedly less soluble. Only the Clarksville soil gave increases in the leachings of calcium in parallel with the large increases in outgo of fluorine in the initial year, and then only from the 800-pound inputs. In most cases, the leachings of calcium from the fluoridated

tents of the soil. Magnesium and potassium fluorides are relatively soluble and therefore have no part in the substantial fixations of the added fluorine.

Because of those observations and the preponderant proportion of alumina content to calcium content in all the soils and the small minus variations caused by the added acid in the leachings of calcium, magnesium, and potassium (Table IV), the small percentage recoveries of fluorine from the Maury silt loam of 8.64% alumina content are believed attributable to the fact that the added hydrofluoric acid reacted with aluminosilicate complexes and formed the relatively insoluble aluminum silicofluoride. This conclusion is supported by the fact that the largest recovery and smallest retention of added fluorine were induced by the Clarksville silt loam, which contained only 1.15% of alumina, 0.78% being dissolvable by sodium hydroxide (Table I), and the further fact that the order of the recoveries of fluorine corresponds to the order of the alumina contents of the four soils.

The conversion of the 200-pound applications of fluorine as hydrofluoric acid to a combination characterized by low degree of solubility serves to explain why such additions caused no detrimental effects upon plants grown on two of the soils of the present experiment in previous pot cultures (75).

apatite content in the Maury soil was naturally "saturated" with calcium fluoride, the added fluorine could not undergo fixation through a phosphate-fluoride reaction. Therefore, the meager recoveries from the 200-pound additions

soils were lessened and their totals for calcium outgo were less than outgo from the untreated soils. Hence, it seemed logical to attribute the retentions as effects of reactions between the added acid and the calcium and alumina con-

Table III. Fluorine Recoveries and Retentions from 200- and 800-Pound Applications and Incorporations as Hydrofluoric Acid in Four Soils

HF Additions		Annual Outgo of Fluorine, Lb. per 2,000,000 Lb. of Soil					Increase		Retention		Final pH <sup>c</sup>
Rate <sup>a</sup>	Depth	1st	2nd	3rd	4th	Total	Lb.	% <sup>b</sup>	Lb.	% <sup>b</sup>	
Hartsells Sandy Loam											
None	...	1.1	0.7	0.8	0.5	3.1	...	...	...	...	4.1
200	To surface	1.1	1.0	1.6	1.2	4.9	1.8	0.9	198.2	99.1	4.2
200	In full depth	4.5	2.3	4.0	3.7	14.5	11.4	5.7	188.6	94.3	4.1
800	To surface	3.5	4.4	12.4	16.6	36.9	33.8	4.2	766.2	95.8	4.3
800	In full depth	79.4	17.2	28.2	23.4	148.2	145.1	18.1	654.9	81.9	4.4
Clarksville Silt Loam											
None	...	1.2	0.8	0.9	0.5	3.4	...	...	...	...	4.5
200	To surface	3.8	1.9	1.3	0.6	7.6	4.2	2.1	195.8	97.9	4.8
200	In full depth	7.3	3.1	2.7	2.3	15.4	12.0	6.0	188.0	94.0	4.6
800	To surface	126.3	23.9	23.6	17.5	191.3	187.9	23.5	612.1	76.5	4.8
800	In full depth	139.6	20.3	20.0	16.6	196.5	193.1	24.1	606.9	75.8	4.9
Maury Silt Loam											
None	...	3.5	1.1	1.7	0.7	7.0	...	...	...	...	5.2
200	To surface	2.5	1.2	3.6	0.8	8.1	1.1	0.6	198.9	99.6	5.2
200	In full depth	5.0	2.0	2.4	1.1	10.5	3.5	1.8	196.5	98.3	5.2
800	To surface	3.0	2.0	4.5	0.8	10.3	3.3	0.4	796.7	99.6	5.0
800	In full depth	10.0	4.3	4.6	3.6	22.5	15.5	1.9	784.5	98.1	5.1
Baxter Silt Loam											
None	...	4.9	1.3	1.7	0.8	8.7	...	...	...	...	4.9
200	To surface	6.6	4.4	3.6	2.9	17.5	8.8	4.4	191.2	95.6	4.8
200	In full depth	7.7	4.1	5.6	4.3	21.7	13.0	6.5	187.0	93.5	4.6
800	To surface	48.0	15.9	19.8	17.9	101.6	92.9	11.6	707.1	88.4	4.5
800	In full depth	73.1	31.1	27.6	26.7	158.5	149.8	18.7	650.2	81.3	4.5

<sup>a</sup> Pounds of fluorine per 2,000,000 pounds of soil.

<sup>b</sup> Respective to 200- and 800-pound additions of fluorine.

<sup>c</sup> Initial pH values were: Hartsells, 5.40; Clarksville, 5.6; Maury, 5.3; Baxter, 5.2; as in footnote to Table II.

Rain waters per annum for the four successive years were 57.5, 39.9, 44.0, and 40.7 inches, respectively. Drainage waters were in range of 45 to 50% of precipitation.

**Table IV. Effects of 200- and 800-Pound Additions of Fluorine as Hydrofluoric Acid upon Outgo of Potassium, Calcium, and Magnesium from Four Tennessee Soils**

HF Additions		Outgo lb. per 2,000,000 lb. of Soil per Annum																
Rate <sup>a</sup>	Depth	Potassium <sup>b</sup>					Calcium <sup>a</sup>					Magnesium <sup>a</sup>					Variation <sup>c</sup>	
		1st	2nd	3rd	4th	Total	1st	2nd	3rd	4th	Total		1st	2nd	3rd	4th	Total	
Hartsells Sandy Loam																		
None	...	25	7	13	10	55	168	38	68	62	336	...	37	9	19	14	79	...
200	Surface	22	7	13	12	54	166	45	48	65	324	-12	34	9	19	16	78	-1
200	Full depth	23	4	13	10	50	145	44	64	62	315	-21	31	10	22	15	78	-1
800	Surface	19	10	13	8	50	138	62	54	32	286	-50	33	12	17	7	69	-10
800	Full depth	17	5	11	9	42	118	34	53	44	249	-87	21	8	21	9	59	-20
Clarksville Silt Loam																		
None	...	40	13	10	11	74	82	105	50	76	313	...	22	28	21	16	87	...
200	Surface	48	10	10	11	79	151	61	49	77	338	25	38	14	21	16	89	2
200	Full depth	36	13	10	10	69	85	95	42	57	279	-34	26	27	20	13	86	-1
800	Surface	44	8	9	10	71	139	26	40	47	252	-61	30	4	19	10	63	-24
800	Full depth	25	12	10	10	57	71	62	47	49	229	-84	15	18	21	14	68	-19
Maury Silt Loam																		
None	...	8	3	4	3	18	80	50	64	73	267	...	15	7	16	6	44	...
200	Surface	6	2	5	4	17	83	39	56	68	246	-21	11	6	15	4	36	-8
200	Full depth	8	3	5	4	20	85	50	64	68	267	0	15	6	18	16	55	11
800	Surface	9	2	5	3	19	79	41	59	72	251	-16	9	6	18	18	51	7
800	Full depth	8	3	5	4	20	90	57	62	69	278	11	13	8	17	16	54	10
Baxter Silt Loam																		
None	...	27	11	13	10	61	153	158	63	65	439	...	59	46	28	25	158	...
200	Surface	23	16	18	12	69	123	125	93	92	333	-106	44	37	42	35	158	0
200	Full depth	21	17	19	9	66	100	131	105	95	431	-8	35	39	42	34	150	-8
800	Surface	27	8	16	14	65	187	56	75	81	399	-40	61	19	34	28	142	-16
800	Full depth	24	12	18	15	69	141	77	79	80	377	-62	43	26	33	28	130	-28

<sup>a</sup> In CaCO<sub>3</sub> equivalence.

<sup>b</sup> As K.

<sup>c</sup> As increase or decrease from outgo from untreated soil.

Rain waters per annum for four successive years were 57.5, 39.9, 44.0, 40.7 inches, respectively. Drainage waters were in range of 45 to 50% of precipitations.

Because the 200-pound per acre addition of fluorine was about 50 times the quantity that would come from atmosphere to the soil per annum (13), it seems obvious that, in humid areas, the fertility of similar soils would not be impaired by accumulations of hydrofluoric acid from the atmosphere.

### Companion Leachings of Potassium, Calcium, and Magnesium

The effects of additions of hydrofluoric acid upon leachings of potassium, calcium, and magnesium are recorded by the data of Table IV. In most cases, the added acid caused decreases in the outgo of those three bases.

Although the potassium content of the hydrochloric-nitric acid digestion product of the Maury silt loam was four times the mean of the contents of the digestion products of the other three soils, and although the Maury soil had the largest content of exchangeable potassium, the outgo of potassium from the Maury soil was decidedly the least of the leachings of that element from the four soils. The mean for the 12 totals for potassium outgo from fluoridated Hartsells, Clarksville, and Baxter soils was 62 pounds against a mean of but 19 pounds from the four totals from the acid-treated Maury soil. It may be that the hydrolytic decomposition of the soil's content of "carbanoapatite" developed transitory

calcium solutes that repressed potassium outgo from the untreated Maury soil. The passages of potassium from the Hartsells and Clarksville soils were affected alike, because larger repressions in outgo were induced by the full-depth larger inputs of the acid. The four soils functioned alike as to first-year leachings of potassium, which were more often a third to half of the totals.

In most cases, the leachings of calcium per annum were largest within the first year and were least from the Maury soil of highest calcium content. However, in 15 of the 16 comparisons the total leachings of calcium from the acidulated soils were less than the outgo totals from the untreated soils. Apparently, these disparities mean that the bicarbonate fractions of the drainage waters were converted to the less soluble calcium fluoride. The additions of hydrofluoric acid may have caused a partial sterilization of the soil systems and hence smaller quantities of bicarbonate were engendered.

Repressions upon outgo of magnesium were registered in 11 of the 16 cases for acid additions to the four soils. As in the case of the additions of hydrofluoric acid upon calcium outgo, the relatively small variations in totals for magnesium outgo are not rated as significant.

The leaching data established the fact that the increments of hydrofluoric acid from the atmosphere do not cause

substantial diminutions in the quantities of the native supplies of calcium, magnesium, and potassium in the soils of the type used in the present experiment.

When the 4-year lysimeter findings for fallow soils are integrated with plant responses in the earlier pot culture experiments on the same soils (15, 16), it appears certain that the fertility of soils of the types studied will not be affected adversely by atmosphere-derived hydrofluoric acid.

### Summary

Because hydrofluoric acid reaches the soil from the atmosphere in Maury County, applications and incorporations of a highly diluted solution of that acid were made to four Tennessee soils in a 4-year lysimeter experiment.

The fluorine leachings from the untreated control soils were less than the increments from rain waters. Fluorine recoveries from the 200-pound and 800-pound applications as hydrofluoric acid in the phosphatic Maury silt loam were equivalent to only 0.6% of the additions. The recoveries from the 200-pound applications and the other three soils were from 0.9 to 4.4%; recoveries from the corresponding 200-pound incorporations were from 5.7 to 6.5%. Maximal recoveries from the 800-pound additions were 23.5% from applications and 25.2% from incorporations.

Maximal outgo of fluorine in the first year was not accompanied by increase in calcium outgo and the acid inputs caused decreases in total leachings of calcium and of magnesium, without significant effect upon potassium outgo.

Because of those effects and minimal retention of fluorine in the soil of least alumina content *vs.* decidedly small recoveries and high retentions in the soils of highest contents of alumina (Table I), the soil retentions of fluorine from the additions of hydrofluoric acid are attributed in part to the development of calcium fluoride but chiefly to the less soluble aluminum silicofluoride.

The lysimeter results supplement findings from the pot culture experiment, in which 200-pound additions of fluorine exerted no harmful effects upon plant response on two soils (74).

Practical applications of the findings are: Soils of the type studied will absorb and inactivate the additive fluorine of effluent hydrofluoric acid in amounts far beyond those brought by rain waters. Atmosphere-derived fluoric effluents will not diminish a soil's fertility and will not enhance the fluorine content of its drainage waters.

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## SWEET POTATO DEHYDRATION

### Effects of Processing Conditions and Variety on Properties of Dehydrated Products

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THE EFFECTS OF CONDITIONS OF STORAGE of raw materials on the chemical properties of dehydrated sweet potato products have been reported (7). It was shown that a storage temperature of 60° F. was superior for maintenance of raw materials. A second phase of the problem of sweet potato dehydration, as indicated by the Quartermaster Food and Container Institute for the Armed Forces, was to determine the effects of conditions of processing of the raw materials on the chemical properties of dehydrated products. A third phase was to determine the effects of selected, commercial varieties on the chemical properties of dehydrated products.

The purpose of these investigations was, therefore, to determine the effects of processing and of selected, commercial varieties (1) on carotene, ascorbic acid, starch, total and reducing sugars, and the color and rehydration characteristics of freshly dehydrated products and (2) on the losses of raw materials during processing.

#### Methods

**Moisture.** A 2-gram, ground sample, passing through 20-mesh screen but held on 40-mesh screen, was weighed into tared, dry, aluminum weighing dishes (approximately 2 inches in diameter and 3/4 inch in depth) with tightly fitting covers. The dishes, with cocked lids, were placed in a vacuum oven, and the samples were dried for 6 hours at 70° C. at a pressure of less than 100 mm. The dishes were covered and allowed to cool in a desiccator before weighing. The percentage of moisture in the original sample was calculated (6).

**Ascorbic Acid.** The visual titration method based on the reduction of 2,6-dichlorophenolindophenol by an acid solution of ascorbic acid was used (4). A 50-gram sample of dehydrated sweet potatoes was steeped under nitrogen for 15 minutes in a blender with 100 grams of 3% metaphosphoric acid. Then 150 grams of 6% metaphosphoric acid were added, and the mixture was blended

until a homogeneous slurry was obtained. Thirty grams of the slurry were quantitatively transferred to a 100-ml. volumetric flask and 20 ml. of acetone were added to eliminate the effect of sulfite used during dehydration. Then the sample was diluted to 100 ml. with 3% metaphosphoric acid. The solution was clarified by centrifugation, and an aliquot was titrated with 0.025% 2,6-dichlorophenolindophenol solution to a pink end point which persisted for 15 seconds. The dye solution was standardized each day by titrating against a freshly prepared ascorbic acid standard. When analyzing raw sweet potatoes, the initial slurry was composed of 150 grams of sample and 150 grams of 6% metaphosphoric acid. The content of ascorbic acid was reported as milligrams per 100 grams.

**Carotene.** The carotene was extracted from 2 grams of ground dehydrated sweet potatoes (or 5 grams of raw sweet potatoes) which had been saturated with water at room tempera-