

# The Persistence and Chemical Distribution of Arsanilic Acid in Three Soils

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The persistence and chemical distribution of 4-aminobenzenearsonic acid (arsanilic acid), in Lakeland sandy loam, Hagerstown silty clay loam, and Christiana clay loam, were examined at two application rates (158 and 790 ppm) and at two moisture levels in soils established under aerobic and anaerobic conditions in the laboratory. Flooding was used to establish anaerobic soil conditions. Arsanilic acid was determined spectrophotometrically (520 nm) as the *N*-(1-naphthyl)ethylenediamine derivative, and arsenic (840 nm) was determined as an arseno-molybdenum blue complex.

Total arsanilic acid, extracted sequentially by 1 *N* NH<sub>4</sub>Cl, 0.5 *N* NH<sub>4</sub>F, 0.1 *N* NaOH, and 0.5 *N* H<sub>2</sub>SO<sub>4</sub> at 0, 2, 4, 8, 16, 24, and 32 weeks, disappeared rapidly from all three soils, whereas total arsenic (As) remained constant in two soils and decreased some in Christiana clay loam. At the end of 32 weeks, less than 10% of the applied arsanilic acid could be extracted from any soil. It was concluded from extraction behavior that arsanilic acid formed salts with aluminum, iron, and calcium in the soil in the same manner as arsenate and phosphate.

Arsanilic acid (ARS) is added to feed either alone or with other drugs that promote growth or suppress bacterial and parasitic diseases. The use of arsenicals in animal medicine began in 1907 when sodium arsanilate (atoxyl) was found to be effective against spirochetosis in chickens. Arsanilic acid has been used since then and is currently registered as a feed additive for chickens, turkeys, and swine. Several reviews of arsanilic acid metabolism in animals have been published (Frost et al., 1955; Calvert, 1971; Frobish, 1971). In general, arsenic is eliminated unchanged from the animal system. Although body As residues increase during feeding, they decrease rapidly when arsanilic acid is removed from the feed.

Morrison (1969) found up to 29 ppm of arsenic in litter from commercial poultry house operations. After 20 years of soil application of the chicken litter, however, arsenic has not increased significantly in the soil or in crops grown on soil fertilized with this manure.

Arsanilic acid has been determined by paper chromatographic, paper electrophoretic, and ion exchange procedures (Overby et al., 1965) or by gas-liquid chromatographic (GLC) determination (Weston et al., 1971). The GLC determination and the recommended AOAC colorimetric method (AOAC, 1970) are based on the distillation of aniline after reduction of ARS. Aniline is determined directly or diazotized and a color complex formed.

The fate and chemical distribution of ARS in soil are unknown and need to be understood in much the same manner as the soil fate of other pesticides. The analytical methods previously used for ARS detection are time consuming and nonspecific. The objectives of this study were to develop or modify a rapid colorimetric method for ARS; to examine the chemical distribution of ARS into water-soluble (WS), iron (Fe), aluminum (Al), and calcium (Ca) fractions in three soils under aerobic and anaerobic conditions; and to determine its persistence in these soils.

## EXPERIMENTAL SECTION

**Methods and Materials.** Three soils (25 g each), Lakeland loamy sand, Hagerstown silty clay loam, and Christiana clay loam (Table I), were treated with ARS to give concentrations of 158 and 790 ppm of ARS. These are equivalent to 54 and 270 ppm of As, respectively, levels which are comparable to those used in experimental studies on behavior of other arsenicals in soils. The arsanilic acid was added to soil as a diethyl ether solution and thoroughly

mixed after solvent evaporation. Soils were contained in 50-ml foil-covered beakers. Aerobic soils in three replications were watered to 6.0, 21.8, and 14.0% H<sub>2</sub>O (equivalent to 75% of field moisture capacity), respectively, and incubated at 25° for up to 32 weeks.

Samples (0.500 g dry weight) were taken at 0, 2, 4, 8, 16, 24, and 32 weeks and analyzed for chemical distribution of arsanilic acid into WS, Al, Fe, and Ca fractions (Petersen and Corey, 1966; Woolson et al., 1971a). This fractionation procedure is based on the assumption that arsanilic acid reacts in the same manner as phosphate because of the chemical similarity of arsenate and phosphate. The extracting solutions were 1 *N* NH<sub>4</sub>Cl, 0.5 *N* NH<sub>4</sub>F, 0.1 *N* NaOH, and 0.5 *N* H<sub>2</sub>SO<sub>4</sub>, respectively. Arsanilic acid was determined in all extracted fractions using the method described by Pease (1962). The method consists of diazotization of the phenylamine portion of the molecule and coupling with *N*-(1-naphthyl)ethylenediamine dihydrochloride and colorimetric quantitation at 520 nm.

The extracted fractions were also analyzed for total extractable arsenic by digestion with a HNO<sub>3</sub>-H<sub>2</sub>SO<sub>4</sub>-HClO<sub>4</sub> (20:4:1) mixture and arsenic was determined colorimetrically (Woolson et al., 1971b). Arsenate-As was determined by difference between total extractable As and extractable arsanilic acid. Arsenate-As also was determined on all soils after 32 weeks by direct distillation of soil (Melton et al., 1973). In addition, separate 1-g samples were taken at 0, 4, 16, 24, and 32 weeks for total arsenic analysis (Woolson et al., 1971b), which involves soil digestion with H<sub>2</sub>SO<sub>4</sub>-HClO<sub>4</sub> acids.

A duplicate set of soils was treated with ARS identically, but was flooded with 2.5 cm of water above the soil surface to maintain anaerobic conditions. Samples were taken at 0, 24, and 32 weeks for total As analysis. Chemical fractions (WS, Al, Fe, and Ca) were determined only at 32 weeks.

**Colorimetric Method for Arsanilic Acid.** Arsanilic acid was subjected to color development with the method described by Pease (1962) for the amine hydrolysis products of 3-(*p*-chlorophenyl)-1,1-dimethylurea (monuron) and 3-(3,4-dichlorophenyl)-1,1-dimethylurea (diuron). The complex follows Beer's law and has a molar absorptivity ( $\epsilon$ ) of 52,500 l. M<sup>-1</sup> cm<sup>-1</sup>. The complex is stable for at least 18 hr. Recovery was quantitative (Table II) when 10 or 50  $\mu$ g of ARS was added to the four extracting solutions. Recovery of ARS acid as arsenic after digestion of these same solutions was also determined (Table III). Recovery averaged 90% of that added, which indicated little loss during digestion. The NH<sub>4</sub>Cl solution gave the lowest recovery at 80%. The chloride present during digestion may have caused volatilization of some arsenic as the trichloride.

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**Table I. Physical and Chemical Properties of Experimental Soils**

Soil	pH	Water field capacity, %	Clay <0.002 mm, %	Organic matter, %	Available cations, mequiv/100 g			Total As, ppm
					Fe <sup>a</sup>	Al <sup>b</sup>	Ca <sup>c</sup>	
Hagerstown silty clay loam	5.5	29.1	30.0	2.50	933	6.3	6.0	4.5
Lakeland loamy sand	6.2	8.7	10.5	0.90	135	1.9	0.5	1.2
Christiana clay loam	4.4	19.7	24.4	0.99	1402	2.4	10.5	3.5

<sup>a</sup> Oxalate extractable (Schwertmann, 1964). <sup>b</sup> 1 N NaOH extractable (Yuan, 1959; Yuan and Fiskell, 1959). <sup>c</sup> 0.5 N NaC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> extractable (pH 8.2) (Woolson et al., 1970).

**Table II. Recovery of Arsanilic Acid from Soil Extraction Reagents**

Reagent	Arsanilic acid, $\mu\text{g}$		
	Added	Recovered <sup>a</sup>	%
1 N NH <sub>4</sub> Cl	10.0	10.5	105
	50.0	49.5	99
0.5 N NH <sub>4</sub> F	10.0	11.2	112
	50.0	49.5	99
0.1 N NaOH	10.0	11.0	110
	50.0	49.5	99
0.5 N H <sub>2</sub> SO <sub>4</sub>	10.0	11.0	110
	50.0	49.5	99

<sup>a</sup> Recovered as an *N*-(1-naphthyl)ethylenediamine complex (Pease, 1962).

**Table III. Recovery of Arsanilic Acid as Arsenic after Digestion of Amended Soil Extraction Reagents**

Reagent	Arsanilic acid added, $\mu\text{g}$	Arsanilic acid recovered as As, <sup>a</sup> $\mu\text{g}$	%
None	17.3	15.2	88
None	34.6	29.5	85
NH <sub>4</sub> Cl	17.3	13.8	80
NH <sub>4</sub> F	17.3	16.2	94
NaOH	17.3	16.0	92
H <sub>2</sub> SO <sub>4</sub>	17.3	16.1	93
			90

<sup>a</sup> Digested with HNO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>, and HClO<sub>4</sub> (Woolson et al., 1971a).

## RESULTS AND DISCUSSION

The chemical distribution of ARS and arsenate in extracts from three different soils is presented in Tables IV and V. Water-soluble ARS declined rapidly in all soils. Water-soluble ARS declined fastest in the Hagerstown soil, whereas in the Lakeland soil more remained in the available water-soluble form. Arsanilic acid found in the Al fraction decreased from the second week in all soils except at the high rate in Christiana clay loam, where Al arsanilate reached a maximum at 4 weeks, and then declined. Iron arsanilate formed between 2 and 4 weeks and decreased slowly after that. Very little Ca arsanilate was found in any soil except Christiana, and the amounts there were quite small. Total extractable ARS consistently decreased with time although the values at 24 weeks appear to be low.

With time, arsenate was formed from ARS in all soils

(Table V). The water-soluble arsenate ion formed was depleted by insoluble Fe-, Al-, and Ca-salt formation in soil and, as a result, generally declined after reaching a maximum amount in 8 to 16 weeks. In the Christiana soil, at the low application rate, very little water-soluble arsenate was found at any sampling period. Aluminum arsenate formed as ARS degraded, and reached a maximum at 4 to 8 weeks in all soils; it then declined in concentration. Iron arsenate, initially low in concentration, increased and reached a maximum in all soils at either 16 or 24 weeks; it also declined at 32 weeks. Very little Ca arsenate was found in any soil, but concentration increased somewhat with time. The total extractable arsenate reached a maximum at 8 or 16 weeks in all soils, except for the high treatment rate in Lakeland at which arsenate reached a maximum at 4 weeks. In all soils, total extractable arsenate decreased with further incubation. The percentage of arsanilate and arsenate recovered after 32 weeks, relative to the amount of ARS applied, is given in parentheses at the right of Tables IV and V. Less arsanilate remained at the low rate than at the high treatment rate on all three soils.

Application rate did not appear to affect the rate of ARS degradation to arsenate in the Hagerstown and Christiana soils. The percent conversion ranged from 13.5 to 21.1%. In Lakeland soil, however, the conversion was much slower at the high rate than at the low rate. At the high rate, only 1.5% of the arsenic applied was recovered as arsenate after 32 weeks. The total arsenic extracted from all soils was similar regardless of rate, ranging from 22.8 to 28.4% of that applied. This was recovered as both arsanilic acid-arsenic, and as arsenate-arsenic. Arsanilic acid is degraded through the splitting of the carbon-arsenic bond either chemically or biologically.

Arsanilic acid and arsenate follow much the same chemical distribution pattern in relation to the hydrous oxide species to which it may be adsorbed. In Hagerstown and Christiana soils, Fe arsenate and Fe arsanilate compounds were predominant. In Lakeland soil at the low rate, amounts of As and ARS in the Al and Fe fractions were nearly equal. At the higher rate, more arsanilic acid was found in the Al than in the Fe fraction, whereas the amounts of arsenate in those two fractions were nearly equal. The similar partitioning of ARS and arsenate between various chemical fractions indicates that they are bound at the same sites.

Degradation of arsanilic acid also appears to be a function of soil type. Lakeland soil, which is lowest in organic matter and available Fe and Al, degraded less ARS than either Hagerstown or Christiana soils. Hagerstown and Christiana soils degraded about the same percentage at both rates. However, the rate of degradation differed at the high treatment level. The pattern of soil degradation for these soils was similar to that reported for cacodylic acid (Woolson and Kearney, 1973). Cacodylic acid also was me-

**Table IV. Arsanilic Acid (ARS) in Four Extracts from Three Treated Soils Maintained at 75% Field Capacity Moisture**

Chem fraction	Weeks after ARS application					
	2	4	8	16	24	32
Hagerstown, 158 ppm <sup>a</sup>						
WS <sup>b</sup>	1.51	1.33	0.78	0.15	0.00	0.65 (1.2) <sup>c</sup>
Al	4.07	1.99	0.53	0.78	0.00	0.00 (0.0)
Fe	3.95	3.99	2.43	2.26	0.00	0.63 (1.2)
Ca	0.00	0.00	0.00	0.00	0.00	0.65 (1.2)
Σ	9.53	7.31	3.74	3.19	0.00	1.93 (3.6)
Total As		33.0		<i>d</i>	41.2	41.8
Hagerstown, 790 ppm						
WS	19.42	16.58	5.96	4.35	2.54	2.52 (0.9)
Al	24.57	21.21	14.75	7.16	3.39	3.67 (1.4)
Fe	29.37	20.51	17.72	17.89	12.38	12.26 (4.5)
Ca	0.00	0.00	0.00	0.00	0.20	0.20 (0.1)
Σ	73.36	58.30	38.45	29.40	18.51	18.65 (6.9)
Total As		249		256	252	242
Lakeland, 158 ppm						
WS	7.51	4.25	2.29	1.61	1.61	1.98 (3.7)
Al	6.66	4.85	2.39	2.49	0.00	0.88 (1.6)
Fe	2.76	2.86	1.76	1.98	0.58	1.13 (2.1)
Ca	0.45	0.75	0.00	0.65	0.00	0.78 (1.4)
Σ	17.38	12.71	6.44	6.73	2.19	4.77 (8.8)
Total As		36.3		<i>d</i>	37.1	43.0
Lakeland, 790 ppm						
WS	66.11	59.92	65.88	49.10	38.97	40.28 (14.9)
Al	34.22	31.18	24.10	33.09	16.03	20.20 (7.5)
Fe	7.69	7.74	7.64	6.64	5.02	7.99 (3.0)
Ca	1.41	1.46	0.55	0.90	0.33	1.94 (0.7)
Σ	109.43	100.30	98.17	89.73	60.35	70.41 (26.1)
Total As		196		238	<i>d</i>	214
Christiana, 158 ppm						
WS	4.17	2.71	2.51	0.88	1.21	1.41 (2.6)
Al	4.12	3.37	1.91	3.42	0.13	0.73 (1.4)
Fe	5.28	3.59	3.62	1.56	1.03	1.98 (3.7)
Ca	0.80	1.21	0.00	0.53	0.15	0.65 (1.2)
Σ	14.37	10.88	8.04	6.39	2.52	4.77 (8.8)
Total As		42.6		28.0	47.6	44.0
Christiana, 790 ppm						
WS	42.03	24.80	15.63	11.16	7.28	7.14 (2.6)
Al	21.99	23.42	14.30	10.17	4.57	7.54 (2.8)
Fe	21.71	20.05	16.63	12.31	13.02	17.21 (6.4)
Ca	2.44	2.84	2.41	2.89	2.26	3.62 (1.3)
Σ	88.17	71.11	48.97	36.53	27.13	35.51 (13.2)
Total As		337		275	230	174

<sup>a</sup> Low rate equivalent to 54 ppm of As; high rate equivalent to 270 ppm of As; expressed as As. All values expressed as ppm of As. <sup>b</sup> Fractions extracted sequentially with listed reagent: WS, 1 N NH<sub>4</sub>Cl; Al, 0.5 N NH<sub>4</sub>F; Fe, 0.1 N NaOH; Ca, 0.5 N H<sub>2</sub>SO<sub>4</sub> (Petersen and Corey, 1966; Woolson et al., 1971a). <sup>c</sup> Percent of arsanilic acid applied extracted as arsanilate. <sup>d</sup> Sample lost.

tabolized to arsenate more slowly in the Lakeland soil than in Hagerstown and Christiana soils.

Total As values are presented in Table IV. Total arsenic values in Lakeland sandy loam and in Hagerstown silty clay loam did not change significantly during the 32-week study. However, in Christiana clay loam, total arsenic in the system began to decrease at about 16 weeks. A garlic-like odor was detected first on flooded Christiana soils at about 12 weeks and about 4 weeks later on aerobic Christiana soils. Total As began declining at about this time on Christiana soil. The garlic-like odor is a characteristic of a volatile organo-arsenical gas and has been noted from caddylic acid treated soil (Woolson and Kearney, 1973). The decrease in total arsenic in Christiana soil, therefore, is real and due probably to the formation of a volatile organo-arsenical compound. Arsine gas and reduced arsanilic acid

are both odorless. Therefore, the odoriferous volatile compound is neither arsine nor an aminophenylarsine. This does not exclude loss of arsenic via an odorless gas.

The chemical distribution of arsanilic acid in the four chemical extracts under both moisture levels is compared in Table VI. At the low treatment rate, neither the amount nor distribution of arsanilic acid recovered at the two aeration states differed significantly. At the higher rate, differences were observed in the total extractable arsanilic acid. Under anaerobic conditions, 17.14 ppm of As was recovered; under aerobic conditions, 41.53 ppm of As was recovered. ARS may degrade more quickly anaerobically than it does aerobically or it may be bound more tightly to the soil colloids. Some minor differences in chemical distribution were observed with ARS under the two moisture regimes. The percentage of ARS in the Al fraction was greater under

**Table V. Arsenate (Parts per Million of As) in Four Extracts from Three Treated Soils Maintained at 75% Field Capacity Moisture**

Chem fraction	Weeks after ARS application					
	2	4	8	16	24	32
Hagerstown, 158 ppm <sup>a</sup>						
WS <sup>b</sup>	0.27	0.13	1.26	0.11	1.78	0.49 (0.9) <sup>c</sup>
Al	9.44	7.09	5.84	5.11	5.02	4.29 (7.9)
Fe	2.16	4.34	9.97	10.04	9.61	6.64 (12.3)
Ca	1.03	0.47	0.70	1.33	0.00	0.00 (0.0)
Σ	12.90	12.03	17.77	16.59	16.41	11.42 (21.1)
Hagerstown, 790 ppm						
WS	1.65	1.54	5.78	6.11	3.18	1.80 (0.7)
Al	2.17	19.33	23.25	19.73	17.64	16.09 (6.0)
Fe	13.33	31.32	36.09	41.92	44.89	19.73 (7.3)
Ca	3.40	2.70	3.63	4.66	4.74	5.39 (2.0)
Σ	20.55	54.89	68.73	72.42	70.45	43.01 (16.0)
Lakeland, 158 ppm						
WS	2.08	2.33	2.65	1.39	2.43	3.60 (6.7)
Al	2.85	5.98	8.83	2.32	6.89	2.64 (4.9)
Fe	2.06	1.57	3.70	2.32	2.46	2.26 (4.2)
Ca	0.00	0.00	0.00	0.11	0.78	0.48 (0.9)
Σ	6.99	9.88	15.18	6.14	12.56	8.98 (16.7)
Lakeland, 790 ppm						
WS	0.33	4.70	0.00	2.30	0.00	0.00 (0.0)
Al	5.85	14.65	6.73	1.76	10.63	1.71 (0.6)
Fe	1.73	3.89	4.40	8.28	3.68	2.30 (0.9)
Ca	0.00	0.57	1.75	3.14	0.93	0.00 (0.0)
Σ	7.91	23.81	12.88	15.48	15.24	4.01 (1.5)
Christiana, 158 ppm						
WS	0.00	0.79	0.00	0.00	0.00	1.85 (3.4)
Al	3.28	8.13	6.01	6.91	5.33	0.53 (1.0)
Fe	6.09	8.41	9.99	10.14	8.45	7.42 (13.7)
Ca	0.00	0.79	0.80	1.47	0.74	0.79 (1.5)
Σ	9.37	18.12	16.80	18.52	14.52	10.59 (19.6)
Christiana, 790 ppm						
WS	0.00	3.37	6.40	6.47	3.02	0.00 (0.0)
Al	21.67	25.08	20.99	18.72	19.50	13.40 (5.0)
Fe	8.29	17.08	33.37	31.10	30.61	19.55 (7.2)
Ca	1.66	1.13	1.57	2.66	0.30	3.52 (1.3)
Σ	31.62	46.66	62.33	58.95	53.43	36.47 (13.5)

<sup>a</sup> Low rate equivalent to 54 ppm of As; high rate equivalent to 270 ppm of As; expressed as As. <sup>b</sup> The following fractions were extracted sequentially with the listed reagent: WS, 1 N NH<sub>4</sub>Cl; Al, 0.5 N NH<sub>4</sub>F; Fe, 0.1 N NaOH; Ca, 0.5 N H<sub>2</sub>SO<sub>4</sub> (Petersen and Corey, 1966; Woolson et al., 1971a). <sup>c</sup> Percent of arsanilic acid applied extracted as arsenate.

**Table VI. Arsanilic Acid (ARS) Remaining in Soil after 32 Weeks of Incubation at Two Moisture Levels**

Chem fraction	Treatment, ppm of ARS	ppm of As							
		Soil						Average	
		Lakeland		Hagerstown		Christiana		Aero.	Anaero.
		Aero. <sup>a</sup>	Anaero.	Aero.	Anaero.	Aero.	Anaero.	Aero.	Anaero.
WS-ARS <sup>b</sup>	158	1.98	1.63	0.65	0.88	1.41	0.33	1.35	0.95
Al-ARS		0.88	1.10	0.00	1.31	0.73	0.00	0.54	0.80
Fe-ARS		1.13	0.88	0.63	3.39	1.98	0.00	1.25	1.42
Ca-ARS		0.78	0.00	0.65	0.00	0.65	1.71	0.69	0.57
Σ extractable		4.77	3.61	1.93	5.58	4.77	2.04	3.83	3.74
WS-ARS	790	40.28	6.13	2.52	2.84	7.14	4.87	16.65 (40) <sup>c</sup>	4.61 (27)
Al-ARS		20.20	1.51	3.67	0.55	7.54	3.42	10.47 (25)	1.83 (11)
Fe-ARS		7.99	2.03	12.26	9.87	17.21	13.49	12.49 (30)	8.46 (49)
Ca-ARS		1.94	0.35	0.20	0.25	3.62	6.13	1.92 (5)	2.24 (13)
Σ extractable		70.41	10.02	18.65	13.51	35.51	27.91	41.53	17.14

<sup>a</sup> Aero., 75% field capacity; anaero., flooded with 2.5 cm of water. <sup>b</sup> Determined colorimetrically as arsanilic acid. <sup>c</sup> Percent of extracted in each fraction.

Table VII. Arsenate Present in Arsanilic Acid Treated Soils after a 32-Week Incubation Period at Two Moisture Levels

Chem fraction	Treat- ment, ppm of ARS	ppm of As							
		Soil							
		Lakeland		Hagerstown		Christiana		Average	
Aero. <sup>a</sup>	Anaero.	Aero.	Anaero.	Aero.	Anaero.	Aero.	Anaero.		
WS-As <sup>b</sup>	158	3.60	0.14	0.49	1.60	1.85	2.70	1.98	1.48
Al-As		2.64	5.00	4.29	2.60	0.53	4.94	2.49	4.18
Fe-As		2.26	5.10	6.64	4.64	7.42	9.12	5.44	6.29
Ca-As		0.48	2.26	0.00	2.00	0.79	0.44	0.42	1.57
Σ extractable		8.98	12.50	11.42	10.84	10.59	17.20	10.33	13.51
Distillable AsO <sub>4</sub> <sup>3-</sup> <sup>c</sup>		8.7	15.2	10.2	11.9	8.3	12.1	9.1	13.1
WS-As	790	0.00	4.49	1.80	2.49	0.00	0.85	0.60 (2) <sup>d</sup>	2.61 (5)
Al-As		1.71	19.84	16.09	15.16	13.40	13.27	10.40 (37)	16.09 (31)
Fe-As		2.30	11.62	19.73	34.83	19.55	42.73	13.86 (50)	29.73 (57)
Ca-As		0.00	1.07	5.39	7.02	3.52	2.05	2.79 (10)	3.38 (7)
Σ extractable		4.01	37.02	43.01	59.50	36.47	58.90	27.83	51.81
Distillable AsO <sub>4</sub> <sup>3-</sup>		10.1	38.2	26.3	33.9	28.2	31.5	21.5	34.5

<sup>a</sup> Aero., 75% capacity; anaero., flooded with 2.5 cm of water. <sup>b</sup> Determined colorimetrically as As. <sup>c</sup> Distilled directly as arsine (Melton et al., 1973). <sup>d</sup> Percent of extracted recovered in each fraction.

aerobic conditions, whereas percentages in the Fe and Ca fractions were higher under anaerobic conditions.

A comparison of arsenate present after 32 weeks at the two moisture levels is presented in Table VII. Arsenate concentration was higher under anaerobic conditions than under aerobic conditions at both treatment rates. Thus, ARS degraded more rapidly under anaerobic conditions. The average chemical distribution after 32 weeks indicates that nearly equivalent amounts, on a percentage basis, were found in each fraction regardless of the moisture level. This distribution compares favorably with the distribution of arsenic from cacodylic acid treated soils (Woolson and Kearney, 1973). In the cacodylic acid study, more water-soluble arsenate was found in the anaerobic soil, amounts of Fe and Ca arsenate were nearly equal under both moisture levels, and more Al arsenate was present under aerobic conditions.

Some interesting comparisons between soils can be made for total arsenic and arsanilic acid in the system. In Lakeland soil much more WS-ARS was present under aerobic conditions than under anaerobic conditions. This might be due to most of the WS-ARS in Lakeland soil being present in the aqueous phase rather than being loosely adsorbed to the soil. In the other two soils, more WS-ARS was present under anaerobic conditions since more ARS was loosely adsorbed to the soil particles. Few differences exist between total arsenic of the other three forms present under aerobic and anaerobic conditions on any of the soils. The amount of arsanilic acid recovered was almost always much less under anaerobic conditions than under aerobic conditions. The significant exceptions were Ca-ARS on the Christiana soil and on the Hagerstown soil at the low treatment rate. The reason for these discrepancies is unknown.

As a further test for arsenate formation, soils were distilled directly without digestion. The As recovered as arsenate is presented as distillable arsenate (Table VII). Arsanilic acid does not give arsenate upon direct distillation. In most instances, the amount distilled is quite close to the sum extracted. Smaller amounts were recovered from Hagerstown and Christiana soils by distillation than by extraction, but more was recovered from Lakeland soil at the high application rate. In any event, this is further proof that inorganic arsenate is a product of ARS degradation in soil.

In conclusion, arsanilic acid is degraded to arsenate and an organic moiety. Degradation occurs more rapidly under anaerobic conditions than under aerobic conditions. Some reduction to a volatile organic arsenic occurred in the Christiana soil, but no significant decrease in total arsenic in either Lakeland or Hagerstown soil was observed. The sum of total extractable arsenic and extractable arsanilic acid decreased with time in all three soils, but extractable arsenate passed through a maximum in the Hagerstown and Christiana soils.

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