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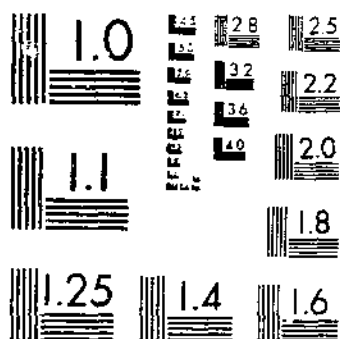
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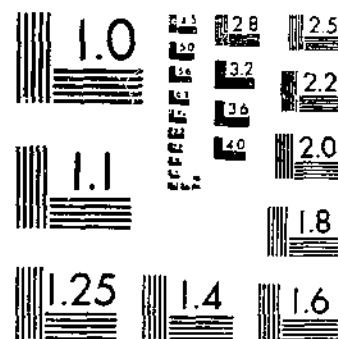
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THE USE OF A NEW RADIOGRAPHIC TECHNIQUE FOR THE DETERMINATION OF ARSENIC DISTRIBUTION IN SOILS AND ITS PRESENCE IN CERTAIN PLANTS  
WILLIAMS, K. L. - RHETSTONE, R. R. - 1 OF 12

# START



MICROCOPY RESOLUTION TEST CHART  
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MICROCOPY RESOLUTION TEST CHART  
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# Arsenic Distribution in Soils and Its Presence in Certain Plants<sup>1</sup>

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## INTRODUCTION

For some years the Division of Soil Chemistry and Physics has been interested in the occurrence and behavior of arsenic in soils, and numerous determinations of the quantities present in both normal soils and those treated with arsenicals have been made.

Slater, Holmes, and Byers reported (20)<sup>2</sup> the arsenic content of the soil profiles of the erosion experiment stations. From these data it appears that arsenic is present in definitely determinable quantities in all of the 11 profiles examined. These profiles include representative soil types from 4 of the great soil groups. It seemed probable that arsenic is a normal though quite variable component of all soils.

It seemed, therefore, of importance to make a cross-section examination of a large number of soils representative of a considerable diversity of soil types in order to determine the range of arsenic content of soils in general, and to discover if any relation could be found between parent material, climatic conditions, or soil properties and the arsenic content. A considerable number of the soils examined were those for which detailed data are available. The circumstances were particularly favorable for such examination because the methods used for the selenium investigations (1, 2, 3, 25) involve the quantitative isolation of the arsenic in the filtrate from the selenium precipi-

<sup>1</sup> Received for publication January 11, 1940.

<sup>2</sup> Italic numbers in parentheses refer to Literature Cited, p. 19.

tation. The determination of the arsenic in the samples was therefore relatively easy. (See section on Methods of Examination, p. 4.)

The fact that arsenic may be absorbed by plants has been known for about 100 years (5). It was, therefore, of interest to determine the extent to which plants in general absorb arsenic under field conditions from soils of known arsenic content and in particular whether any plants of general occurrence possess the property of arsenic concentration, such as is shown by numerous plants for selenium. A fairly large number of plant species growing on the soils analyzed were examined for arsenic.

These considerations have an added interest since arsenicals are used so extensively for insecticidal purposes. Because such use in limited areas is continued over many years, it is possible that arsenic may accumulate in quantities sufficient to produce toxic crops and crop injury. Therefore, the soils examined include not only virgin soils but also a number known to be affected by added arsenic compounds. In addition to samples examined for the specific purposes mentioned, a few miscellaneous analyses were made because of points of special interest, and the results are included in the data reported.

The term arsenic as used throughout this bulletin refers to the element As. The values published by other workers have been recalculated to this basis for ease of comparison.

### RÉSUMÉ OF PREVIOUS WORK

Although this résumé of the literature is by no means complete it includes the more important pertinent articles in this field.

Headden (14) examined virgin soils of Kansas and Colorado and found that the arsenic content ranged from 1.3 to 2.5 p. p. m. (parts per million). The parent materials of the soils contained from 2 to 7.5 p. p. m. of arsenic. The arsenic in the soils was found to be slightly soluble. Alfalfa and saltbush (*Atriplex confertifolia* (Torr. and Frem.) S. Wats.) growing on these soils contained small amounts of arsenic. Headden also examined samples of the surface few inches of soils from orchards that had been sprayed with arsenicals. The total amount of arsenic present ranged from 18 to 69 p. p. m. and the water-soluble arsenic from 0.35 to 0.70 p. p. m. Apples from widely separated portions of the United States were carefully pared and cored for analysis, and found to contain arsenic. The maximum content found was 1.4 p. p. m.

Zuccari (26) analyzed 20 soils of Italy and found the arsenic content ranged from 2 to 60 p. p. m. The soil samples were collected at various elevations on different geological formations and at various depths. The soils differed in physical and chemical character. The arsenic content was found to vary with the iron content of the soils.

Soils from different parts of Argentina were examined for arsenic by Reichert and Treilles (18). All except 1 of the 20 soils examined were found to contain arsenic, the amount ranging from 1 to 22 p. p. m.

Greaves (12) reports the analysis for total and water-soluble arsenic of 38 orchard soils, collected over the western portion of the United States. The total arsenic ranged from 5 to 102 p. p. m. and the water-soluble arsenic varied greatly and many soils having

a low total arsenic content gave higher water-soluble arsenic values than samples with high total content. For example, soils containing 5, 9, and 11 p. p. m. of arsenic had approximately 3 p. p. m. of water-soluble arsenic, and samples containing 102, 63, and 60 p. p. m. total content had approximately 1 p. p. m. of water-soluble arsenic. Greaves suggests that the kind of soil, its water-soluble salt content, and the form in which arsenic was applied to the soil are the factors governing arsenic solubility.

The cause of unproductiveness of certain soils in the Yakima Valley, from which old apple trees have been removed, was investigated by Vandecaveye and coworkers (23). The orchards had been sprayed over a period of years with lead arsenate. They found that the poor condition of young alfalfa and barley in the affected fields correlated roughly with the readily soluble arsenic. When the soluble arsenic was 1.8 p. p. m. or more, the growth of the alfalfa and barley was exceedingly poor. Pot experiments indicated that water-soluble arsenic was the cause of the poor growth and that lead was probably not involved.

Studies were made of the arsenic in orchard soils of Oregon by Jones and Hatch (15). The native arsenic content of orchard soils was found to range from 3 to 14 p. p. m. in the surface 8 inches. Orchard soils in which arsenical sprays had accumulated over a period of years ranged in arsenic content from 18 to 441 p. p. m. in the surface soil. The soil is cultivated to a depth of about 8 inches so that there is mechanical mixing to this depth. The arsenic content of the soils contaminated with spray decreased materially in the next 8 inches. For example, a clay adobe that contained 441 p. p. m. in the surface 8 inches contained but 19 p. p. m. in the next 8 inches. A silt loam contained 61 p. p. m. and 7.6 p. p. m. in the same respective depths. The average content of carefully pared and cored apples from 10 orchards that were never sprayed was 0.006 p. p. m., whereas similarly treated samples from 13 sprayed orchards contained 0.03 p. p. m.

Cooper and associates (6) found that the productivity of some soils was diminished when calcium arsenate had been used in cotton boll weevil control. In fact, on some soil types there was a marked reduction in the yield of certain crops. The red soils, which are high in iron oxide, seem to be much more tolerant of additions of calcium arsenate than gray soils. Light applications of calcium arsenate often stimulate the growth of certain crops on Davidson clay loam. Similar applications on the Durham soil proved toxic.

Calcium arsenate used in the dusting of cotton was found by Reed and Sturgis (17) to have a toxic effect on succeeding crops of irrigated rice in certain soils of southwestern Louisiana. The rice either gave very low yields or blighted completely. The yield and quality of the straw were not harmfully affected, but the rice heads were empty and unfit for milling. Rice on Crowley very fine sandy loam was seriously affected by the application of 50 pounds per acre of calcium arsenate, although on Crowley silty clay loam 150 pounds per acre was not injurious. Less total arsenic was found in the soils at the conclusion of the test than was present at the beginning. An analysis of the rice heads and straw showed that the loss could not be accounted for by crop removal. It is suggested that the arsenic was reduced to arsine.



any frothing due to decomposition of carbonates had subsided, the still was connected so that the adapter was below the surface of 5 ml. of bromine water in the receiving flask. Heat was gradually applied to gentle boiling. If sufficient bromine was not added to the soil to give some in the distillate, the flame was removed and more bromine was added in hydrobromic acid solution through the thistle tube. Fifty to sixty milliliters of distillate were collected.

The distillate was slowly added to an excess of arsenic-free nitric acid to destroy the hydrobromic acid. This was best done by adding 5- to 10-ml. portions of the sample to the nitric acid in a casserole and expelling most of the bromine on the steam bath before adding the next portion. When the sample had all been added the mixture was evaporated to dryness on the steam bath. The sides of the casserole were washed down with distilled water and again evaporated to dryness. The sample was dissolved in water and was transferred to a 100-ml. volumetric flask and made up to volume.

A suitable aliquot was taken and the arsenic estimated by a method described by Truog and Meyer (22). Where possible an aliquot containing 0.05 to 0.10 mg. of arsenic was taken for analysis, as the color is more suitable for comparison at this concentration. To the aliquot in a 50-ml. flask 2 ml. of ammonium molybdate reagent were added<sup>3</sup>; the aliquot was made up to volume and mixed thoroughly. Exactly 3 drops of the stannous chloride solution<sup>4</sup> were added and the solution was again mixed thoroughly and allowed to stand 10 minutes. The color developed was compared in a suitable colorimeter with the color of a standard arsenic solution<sup>5</sup> similarly treated and of approximately the same color intensity. Standards must be prepared with each set of samples, as the blue color developed is not permanent.

When selenium is determined in the distillate, the filtrate is used for arsenic. The filtrate was treated in the manner described for the distillate, except that it was necessary to neutralize (phenolphthalein indicator) with sodium hydroxide the small amount of sulfuric acid remaining after the evaporation of the excess nitric acid.

The vegetation samples were prepared for distillation by a method used for selenium (24). The air-dried vegetation was ground in a Wiley mill to pass a 2-mm. mesh sieve and thoroughly mixed. Ten grams of the sample were stirred into a mixture of 50 ml. of sulfuric acid (specific gravity 1.84) and 100 ml. of arsenic-free nitric acid (specific gravity 1.42) in a 600-ml. Pyrex beaker. The mixture was stirred with a thermometer until it became homogenous. After the violence of the reaction was spent, the mixture was warmed on the hot plate to a temperature not to exceed 120° C. until all evolution of nitrogen peroxide had ceased. The end of the operation was marked also by an incipient carbonization of the mixture, which was then cooled and transferred to the distilling flask. The beaker was rinsed with 100 ml. of hydrobromic acid containing 1 ml. of bromine, then with 30 ml. of

<sup>3</sup> Dissolve 25 gm. of ammonium molybdate in 200 ml. of water heated to not more than 80° C. Dilute 280 ml. of arsenic and phosphorus-free sulfuric acid to 800 ml. After both solutions are cool add the molybdate to the acid solution, slowly with stirring, and when cool made up to exactly 1,000 ml. with water.

<sup>4</sup> Dissolve 2.5 gm. of stannous chloride ( $\text{SnCl}_2 \cdot \text{H}_2\text{O}$ ) in 100 ml. of dilute hydrochloric acid (1:10). Preserve under white mineral oil.

<sup>5</sup> Weigh out 0.767 gm. of dry arsenic pentoxide and dissolve in water. Make up to 500 ml. This solution contains 1.0 mg. of arsenic per milliliter. Working standards of 0.1 mg. and 0.01 mg. per milliliter are prepared by dilution.



distilled water. A distillate of 50 to 60 ml. was collected, chilled, and filtered through an asbestos pad in a Gooch crucible to remove the waxy material. The filtrate was treated as described for soils.

Duplicate analyses of soil or vegetation were found to agree within 10 percent on samples containing 15 p. p. m. or less. As the arsenic content became greater the percent of deviation became less. This method has been shown to give good recovery of arsenic added to soils (20). In samples of vegetation containing large amounts of selenium the selenium must be removed before the arsenic determination is made. In some types of organic matter, notably shrimp, a more drastic oxidation process may be required as preparation of the sample before distillation (?).

The samples of soil and soil material were for the most part collected by members of the Division of Soil Survey or by members of the Division of Soil Chemistry and Physics. The samples were collected for various purposes, but most of them were selected for complete chemical analysis and for selenium analysis. The plant samples, except where otherwise specified, consisted of the whole plant, except roots, and were growing in or adjacent to the soil. All examinations were made on air-dried samples of soil or vegetation or were calculated to air-dry basis except as noted.

The soil series and class name (soil type) are given where definitely known. When samples were collected in areas not yet surveyed for this information, or where for any other reason the series names are unknown, only the soil class name is given.

## EXPERIMENTAL RESULTS

### ARSENIC CONTENT OF SOILS AND VEGETATION

The study of the arsenic content of soils was designed to include widely divergent soil types. The samples used were for the most part profile samples. The great soil groups served as a general guide in their selection. Occasionally samples of soil parent rock were available. For the sake of completeness the data on arsenic from United States Department of Agriculture Technical Bulletin 552 (20) are included with those obtained by the authors. They are indicated by asterisks in table 1. The data in table 1 concern only soil relations.

TABLE 1.—Arsenic content of various soils and related materials  
PODZOLIC SOILS

Kind of material	Location	Laboratory No.	Depth	Arsenic content as As
			<i>Inches</i>	<i>P. p. m.</i>
Brassua sandy loam.....	North Groton, N. H.	C1437	5 - 0	0.1
		C1438	0 - 3	0.3
		C1439	3 - 4	3
		C1440	1 - 0	2
		C1441	0 - 19	2.4
		C1442	10 - +	7
		C3187	0 - 2	1
Kalkaska loamy sand.....	Kalkaska County, Mich	C3188	2 - 8	1.5
		C3189	8 - 14	1.2
		C3190	14 - 0	1.2
		C3191	20 - 18	1.4

\* Numbers indicated by asterisks are reported in Technical Bulletin 552 (20).

TABLE 1.—Arsenic content of various soils and related materials—Continued

## BROWN PODZOLIC SOILS

Kind of material	Location	Laboratory No.	Depth	Arsenic content as As
			<i>Inches</i>	<i>P. p. m.</i>
Gloucester sandy loam.....	Norfolk County, Mass.....	C585.....	0 - 2	1.4
		C586.....	2 - 3	1.1
		C587.....	3 - 15	1.0
		C588.....	15 - 30	.8
		C589.....	30 - 40	.2

## GRAY-BROWN PODZOLIC SOILS

Miami silt loam.....	Fairmount, Ind.....	10341.....	0 - 1 1/2	4
		10342.....	2 1/2 - 9	6
		10343.....	11 1/2 - 23 1/2	14
		10344.....	27 1/2 - 48	9
		C3174.....	0 - 2	4
Russell silt loam.....	Morgan County, Ind.....	C3175.....	2 - 8	5
		C3176.....	8 - 13	8
		C3177.....	13 - 23	11
		C3178.....	23 - 36	11
		C3179.....	36 - 55	11
Frederick silt loam.....	Fairfield, Va.....	C3180.....	55+	10
		C807.....	0 - 2	4
		C808.....	2 - 11	4
		C809.....	11 - 16	3
		C810.....	16 - 36	21
Chester loam.....	Rockville, Md.....	C811.....	36 - 56+	25
		C1671A.....	0 - 2	4
		C1671.....	2 - 10	4
		C1672.....	10 - 34	5
		C1673.....	34 - 60	5
Clinton silt loam.....	La Crosse, Wis.....	*10362.....	0 - 8	5
		*10363.....	8 - 20	7
		*10364.....	20 - 32	5
		*10365.....	32 - 44	5
		*10366.....	44 - 60	5
Muskingum silt loam (lithosol of Gray-Brown Podzolic region).	Zanesville, Ohio.....	*B407.....	0 - 7	10
		*B408.....	8 - 13	15
		*B409.....	14 - 24	10
		*B410.....	25 - 46	4
		*B411.....	47 - 72	2

## RED AND YELLOW PODZOLIC SOILS

Appling sandy loam (yellow).....	Elbert County, Ga.....	C823.....	1 - 9	3
		C824.....	9 - 14	5
		C825.....	14 - 28	12
		C826.....	29 - 60+	4
		C294.....	0 - 12	1.3
Norfolk fine sandy loam (yellow).....	Wayne County, N. C.....	C295.....	12 - 34	6
		C296.....	36 - 60	5
		*6077.....	0 - 6	6
		*6078.....	6 - 32	9
		*6079.....	32 - 60	5
Cecl sandy clay loam (red).....	Statesville, N. C.....	C128.....	0 - 2	4
		C129.....	2 - 12	4
		C130.....	12 - 25	10
		C131.....	25 - 40	12
		C132.....	40 - 60	8
Maury silt loam (red).....	Maury County, Tenn.....	C133.....	60 - 90	7
		*6078.....	0 - 12	5
		*6079.....	12 - 24	9
		*6080.....	24 - 51	7
		*6081.....	51 - 63	1
Kirvin fine sandy loam (red).....	Tyler, Tex.....	*6082.....	63 - 75	5
		*9475.....	0 - 8	17
		*9476.....	8 - 18	21
		*9477.....	18 - 40	13
		*9478.....	40 - 60	6
Nacogdoches fine sandy loam (red).	do.....	*9479.....	60 - 72	8

PRAIRIE SOILS

		10082	0-3	8
		10083	7-13	7
Carrington loam	Buchanan County, Iowa	10084	13-22	9
		10085	22-43	11
		10086	43-70	8
		10087	70-81	6
		*B756	0-13	11
Marshall silt loam	Clarinda, Iowa	*B757	13-24	11
		*B758	24-45	11
		*B759	45-71	10
		*B797	0-7	7
		*B798	8-12	11
Shelby silt loam	Bethany, Mo	*B799	12-26	11
		*6800	20-24	13
		*B801	24-48	10
		*B802B	60-84	7
		*6096	0-3	6
Houston black clay (Rendzina)	Temple, Tex	*G097	14-20	5
		*G098	24-36	6
		*G099	36-50	5

## CHERNOZEM SOILS

		8068	0 - 2	2
		8089	2 - 6 1/2	1.5
		8090	6 1/2 - 16	6
Fillmore silt loam (Planosol of Chernozem region)	Adams County, Nebr.	8093	42 - 60	6
		8094	60 - 84	5
		8095	84 - 96	5
		*8642	0 - 10	7
		*8643	10 - 20	6
Hays silt loam	Hays, Kans.	*8644	20 - 33	0
		*8645	33 - 47	0
		*8646	47 - 60	8
		*8647	60 - 72	8
		*8069	0 - 20	4
		*8070	20 - 33	3.5
Palouse silt loam	Pullman, Wash.	*8071	33 - 62	6
		*8072	62 - 75	4.5
		*8073	75 - 84	4.6

## CHESTNUT SOILS

Canyon clay loam		B18175	0	-12	23
Shale	Logan County, Kans.	B18176			42
Do		B18177			9
		B18179	0	-6	8
		B18180	6	-12	10
Clay loam	do	B18181	12	-18	13
		B18182	18	-24	20
		B18183		24+	27
Smoky Hill chalk	do	B18184		36	41
		8749	0	-12	6
Phillips sandy loam (Solonetz of chestnut region).	Malta, Mont.	8781	4	-9	9
		8782	0	-19	8
		8783	19	-30	9
		8784	38	-36	9
Dark-gray clay containing gypsum.	6 miles south of Ingomar, Mont.	B21212	0	-6	10
		*6718	0	-3	3
		*6719	3	-10	4
		*6720	10	-27	7
		*6721	27	-38	6
Clay		B21347	0	-3	7
Do		B21349	3	-6	2
Bentonitic shale	Bighorn, Mont.	B21350	6	-18	2
Shale		B21351	18	-30	3
Clay	Fort Peck, Mont.	C3756			12
		C3757			11
		B14651	0	-8	8
		B14662	8	-12	8
Pierre clay	Dawes County, Nebr.	B14663	12	-20	0
		B14665	20	-30	9
Do	Chamberlain, S. Dak.	B858	0	-8	10
Pierre loam (Lithosol (arid-sub-humid) of Chestnut, Brown and Desert soil region).	Brozik farm, Medicine Butte, S. Dak.	B895	8	-18	8
Pierre shale		B15356	0	-6	28
Pierre clay loam	Niobrara County, Wyo.	B15358	0	-6	21

TABLE 1.—Arsenic content of various soils and related materials—Continued

## BROWN SOILS

Kind of material	Location	Laboratory No.	Depth	Arsenic content as As
			<i>Inches</i>	<i>P. p. m.</i>
Heavy silt loam	Sec. 23, T. 18 S., R. 51 W., Kiowa County, Colo.	B19510	0-6	4
Gritty clay loam		B19511	6-12	6
Stiff clay loam		B19512	12-24	6
Clay loam		B19513	24-36	6
Silt loam		B19514	36-48	6
Sandy loam		B19515	48-72	4
Gritty clay loam	Sec. 6, T. 10 S., R. 51 W., Kiowa County, Colo.	B19526	0-6	7
Do		B19527	6-12	6
Silty clay loam		B19528	12-24	8
Shaly clay loam		B19529	24-36	12
Apishapa shale	Sec. 6, T. 20 S., R. 51 W., Kiowa County, Colo.	B19530	36-48	11
Silt loam on Niobrara formation		B19544	0-8	10
Shaly soil	Near Pueblo, Colo.	B21144	0-6	5
Shale rich in gypsum		B21145	72	7

## MOUNTAIN SOILS OF NORTHEAST WASHINGTON

Loam	Austin Johnson farm, 3 miles south-east of Northport, Wash.	B18032	0-6	5
		B18033	6-18	12
	Trombetti farm, Northport area, Wash.	B18034	18-36	5
Sandy loam		B18035	0-6	5
		B18036	6-18	2
		B18055	18-36	4

## SOILS OF THE PACIFIC VALLEY

Maxwell clay adobe	Napa area, Calif.	C114	0-10	6
		C115	10-34	6
		C116	34-72	9

## ALLUVIAL SOILS

Yazoo very fine sandy loam	St. James Parish, La.	C1922	0-6	4
		C1923	10-24	7
		C1924	48-60	9
Sharkey silty clay	Terrebonne Parish, La.	C2106	0-6	7
		C2107	10-24	9
		C2108	48-60	5

## LATERITES

Columbiana clay	Costa Rica	9804	0-10	4
		9805	10-25	5
		9806	25-40	3
		9807	40-90	1
		9808	92-104	4
		9809	104-124	3
Nipo clay	Mayaguez, P. R.	9465	0-5	3
		9466	5-15	4
		9467	15-60	1
		9468	5 feet	3
		9469	12 feet	3
		9470	13 feet	3

TABLE 1.—*Arsenic content of various soils and related materials—Continued*  
RED DESERT SOILS

Kind of material	Location	Laboratory No.	Depth	Arsenic content as As
			<i>Inches</i>	<i>P. p. m.</i>
Surface mantle.....	Mojave Desert (from an alluvial fan).	C3395	0-3	4
Do.....		C3396	3-12	3
Compact claypan, pillared by lime.....		C3397	12-24	9
Brittle hardpan, moderately cemented.....		C3398	24-30	6
Do.....		C3399	30-36	4
C horizon.....	Mojave Desert (from granite)	C3400	36-56	3
Surface mantle.....		C3419	0-2	3
Claypan, upper, solid.....		C3420	2-5	9
Claypan, central, pillared.....		C3421	5-11	11
Claypan, lower, gritty.....		C3422	11-14	7
Rotten rock, colored pinkish brown.....		C3423	14-34	6
Rotten rock, uncolored.....		C3424	44-50	3

The data in table 1 reveal that all the soils examined contained arsenic. It is believed that all of these soils are free from any added arsenic through the use of arsenical insecticides. The quantity of arsenic varies between rather wide limits. The minimum amount found in soil was 0.3 p. p. m. and the maximum 38 p. p. m. The black forest mull C1437 on *Brassia* sandy loam, which contained 0.1 p. p. m., is not considered a part of the soil. Samples B16184 and B16176 which contained 41 and 42 p. p. m., respectively, are shales not yet weathered sufficiently to be called soil. About 30 percent of the samples contain less than 5 p. p. m.; about 50 percent contain 5 to 10 p. p. m., and about 20 percent more than 10 p. p. m.

There is no uniformity in the distribution within the profiles examined. The data in table 1 are arranged by great soil groups, which are determined presumably by climatic conditions, especially by temperature and precipitation. There is no observable relationship between climatic conditions and the arsenic content of the representatives of these groups. Likewise there is no clearly defined systematic relation between the arsenic content of the soils and the geological formations from which the soils are developed. In general, sandy soils and soils of high silicon-sesquioxide ratio in humid areas are relatively low in arsenic. Soils of the subhumid and arid regions are higher in arsenic. This relationship is not sufficiently defined to be more than a trend.

Samples of the vegetation growing on some of the soils were secured for analysis. Only a portion of these data are presented. The samples chosen as representative of the native and cultivated vegetation examined are given in table 2.

TABLE 2.—The arsenic content of soils and vegetation

Material and soil depth	Location	Laboratory No.	Arsenic as As in —	
			Soil	Vegetation
Chester clay loam, 0-8 inches	Falls Church, Va.	B24905	P. p. m.	P. p. m.
Chester clay loam, 8-12 inches		B24906	3	
Beets, tops		B24953	5	
Beets, roots				0.1
Turnips, tops				1.3
Turnips, roots		B24954		1
Tomato, vines				0.7
Tomato, fruit		B24955		0
Peanuts, tops				1
Peanuts, nuts		B24956		1
Rutabagas, tops				0.3
Rutabagas, roots		B24957		0.3
Parsnips, tops				0.8
Parsnips, roots		B24958		0
Carrots, tops				0.2
Carrots, roots		B24959		0.4
Sweet corn, tassels				0.8
Sweet corn, leaves		B24960		0.1
Sweet corn, grain				0
Lima beans, leaves				0.4
Lima beans, beans		B24961		0
Popcorn, grain				0.4
Hamburg parsley, leaves		B24962		0.1
Hamburg parsley, roots		B24963		0.1
Potatoes, tubers				0.3
Celery, leaves		B24964		0.2
Celery, stalks		B24967		0.1
Green beans, tops				0.6
Green beans, seeds and pods		B24968		0.2
Carrington loam, 0-8 inches				0.4
Carrots, tops		B24967	7	
Carrots, roots		B24932		1
Horseradish, tops				0.1
Horseradish, roots		B24933		0
Parsnips, tops				0.4
Parsnips, roots		B24934		0
Cabbage, tops				0.2
Cabbage, roots		B24935		0.1
Beets, roots				2
String beans, tops		B24936		0.1
String beans, roots		B24937		0.2
Radishes, seeds and pods				1.5
Radishes, roots		B24938		0.3
Corn, roots	Buchanan County, Iowa <sup>1</sup>			0.5
Corn, grain		B24939		2
Corn, leaves				0.3
Corn, stalk				10
Tomato, vines				0.3
Tomato, green fruit		B24940		0.2
Rhubarb, edible portion		B24941		0.1
Red clover, sample A tops		B24942		0.1
Red clover, sample B tops		B24943		0.5
Red clover, samples A and B roots				0.3
Onions, root		B24944		0.2
Potato, tuber		B24945		0.1
Apples, fruit		B24946		0.1
Tenmarq wheat, grain		B25062		0.2
Do.		B25064		0.3
Blackhall kafir, grain	Ellis County, Kans. <sup>1</sup>	B25066		0.3
Do.		B25068		0.2
Do.		B25065		2.7
Brown loam, 0-8 inches	Gove County, Kans.	B23416	6	
Wheat, grain		B23417		0.1
Yellow-brown silt loam, 0-8 inches		B23420	7	
Wheat, grain	Graham County, Kans.	B23421		0.2
Brownish-yellow clay		B23449	10	
Brown clay loam, 0-8 inches		B23450		0.1
Barley, grain	Logan County, Kans.	B23412	8	
Brown loam, 0-8 inches		B23413		0
Barley, grain		B23414	5	
Brown silt loam, 0-10 inches		B23415		0
Wheat, grain		B23399	5	
		B23400		0.1

<sup>1</sup> These samples were analyzed as received because decomposition had started in some portions of the samples, so that drying was not feasible. No decomposed material was used for analyses.

<sup>2</sup> For local soil analyses, see samples 6842-6847, table 1, p. 8.

TABLE 2.—*The arsenic content of soils and vegetation—Continued*

Material and soil depth	Location	Laboratory No.	Arsenic as As in—	
			Soil	Vegetation
			P. p. m.	P. p. m.
Gray-brown silt loam, 0-8 inches.....	Wallace County, Kans.....	B23407.....	5	
Wheat, grain.....		B23408.....		0
Barley, grain.....		B23409.....		.1
Brown loam, 0-8 inches.....		B23410.....	4	
Wheat, grain.....		B23411.....		.1
Clay loam, Niobrara formation, 0-6 inches.....		B16702.....	36	
Side-oats grama.....		B16703.....		2
<i>Astragalus bisulcatus</i> .....		B16704.....		1
Russian-thistle.....		B16705.....		2
Turpentineweed.....		B16706.....		2
Wild aster.....	Gove County, Kans.....	B16707.....		2
Ironweed.....		B16708.....		1
Sunflower.....		B16708a.....		2
Ragweed.....		B16709.....		1
<i>Tulipa</i> sp.....		B15710.....		2
Gritty clay loam, 0-6 inches.....		B19526.....	7	
Blue grama.....		B19531.....		1
Russian-thistle.....		B19532.....		1
Scarlet mallow.....		B19533.....		1
<i>Oreocarya</i> sp.....		B19534.....		1
Sunflower.....	Kiowa County, Colo.....	B19535.....		1
<i>Stanleya pinnata</i> .....		B19537.....		1
Cocklebur.....		B19538.....		1
Spurge.....		B19539.....		1
Turpentineweed.....		B19541.....		1
<i>Aplopappus fremontii</i> .....		B19542.....		1
<i>Astragalus pectinatus</i> .....		B19543.....		1
Yellow-brown silt loam, 0-8 inches.....		B21519.....	5	
<i>Astragalus pectinatus</i> , seeds.....		B21520.....		1
<i>Astragalus pectinatus</i> , roots.....		B21523.....		1
Yellow-brown clay loam, 0-8 inches.....	Teton County, Mont.....	B21570.....	5	
<i>Astragalus pectinatus</i> .....		B21571.....		1
Yellow-brown clay, 0-8 inches.....		B21566.....	8	
<i>Astragalus pectinatus</i> .....		B21597.....		1

\* For analysis of the complete profile, see samples B19526-B19530, table 1, p. 9

The arsenic content is calculated on the air-dry basis for the samples given in table 2. The vegetable samples from Falls Church, Va., were collected and analyzed at once, the moisture content being determined on another sample. By dividing the arsenic content of the vegetables by 10 an approximate value for the fresh material can be obtained. The air-dry residue of the edible portion of the beets, turnips, tomatoes, rutabagas, parsnips, carrots, sweet corn, lima beans, Hamburg parsley, potatoes, celery, and green beans was found to average 15 percent of the fresh material. The maximum residue was 32 percent for the lima beans and the minimum 5 percent for tomatoes. The data include vegetation grown on soil of relatively high arsenic content and on several soils of average content. In no case did the arsenic content of the vegetation exceed 10 p. p. m. and the highest content of the vegetables was 1.3 p. p. m. in the roots of the beets. The data obtained for the Chester and Carrington loams are similar. Carrington soil on which they grew contained 7 p. p. m. of arsenic in the first 6 inches and was located a half mile from the profile samples 10082-10087 given in table 1.

The samples of grain examined were grown on soils of average arsenic content. The amount of arsenic found in the grain was small, in no case exceeding 2.7 p. p. m. The examination of other

vegetation samples also failed to reveal any marked absorption of arsenic.

Samples of soil and vegetation from Mexico were examined for arsenic. The data are given in table 3.

TABLE 3.—*Arsenic content of Mexican soils and of vegetation growing on them*

Material and soil depth	Location	Laboratory No.	Arsenic as As in—	
			Soil	Vegetation
			<i>P. p. m.</i>	<i>P. p. m.</i>
Dark-gray clay loam, 0-8 inches.....	Sonaja ranch, Irapuato.....	B20887.....	40	
Black clay, 0-10 inches.....		B20890.....	7	
Dark grayish-brown clay, 10-23 inches.....		B20897.....	7	
Fine sandy loam, 23-28 inches.....		B20898.....	9	
Dark stiff clay, 28-35 inches.....	½ mile south of Irapuato.....	B20899.....	7	
Black stiff clay, 35-55 inches.....		B20900.....	11	
Black stiff clay, 55-97 inches.....		B20901.....	9	
Light-gray stiff clay, 97 inches-12 feet.....		B20902.....	2	
Dark-red smooth clay, 12-18 feet.....		B20903.....	5	
Manure and soil from barnyard.....		B20904.....	3	
Fine sandy loam, 0-8 inches.....	Garrida ranch, Irapuato.....	B20905.....	10	
Sweetclover.....		B20907.....		<1
Immature wheat heads and leaves.....		B20911.....		1
Lambquarters growing in wheat.....		B20912.....		1
Dark-gray clay loam, 6-12 inches.....	1 mile north of Irapuato.....	B20927.....	11	
Common mustard, flowers and leaves.....		B20928.....		1
Deep reddish-brown clay, 0-3 inches.....		B20973.....	26	
Red heavy clay, 3-20 inches.....	Tamazunchale.....	B20974.....	36	
Red heavy clay, 20-48 inches.....		B20975.....	38	
Limestone, 48+ inches.....	40 miles north of Torreon.....	B20976.....		1
Light-gray silt loam, 12-20 inches.....		B20801.....	30	
Red shale.....	24 km. west of Saltillo.....	B20855.....	4	
Light-gray silt loam, 0-6 inches.....	1 mile west of Los Reyes.....	B20938.....	2	

All of the soils examined contained arsenic and the quantities ranged from 2 to 40 p. p. m. The soils are similar to the soils of the United States in arsenic content. The four samples of vegetation contained arsenic only to the extent of 1 p. p. m. or less.

#### SOILS CONTAMINATED WITH ARSENICALS

Because of the extensive use of arsenicals in insect pest control and weed eradication, it is of importance to know more about the fate of the added arsenic and of its effect upon the vegetation growing upon such soils. Considerable data are available.<sup>6</sup> Supplemental data were obtained from contaminated soils by the authors.

Soils that had received arsenic either through sprays or direct applications were examined. The arsenic content of a profile from an orchard near Winchester, Va., was compared with an uncontaminated profile of similar soil collected nearby. Soil and alfalfa from an orchard near Orondo, Wash., were examined for arsenic. Test plots used in experimental work on arsenical treatment of soils at Princeton and Moorestown, N. J., were examined. The arsenic content of

<sup>6</sup> BAKER, FRANCIS E. REPORT ON THE EFFECT ON TRUCK CROPS OF LEAD ARSENATE IN THE SOIL. 1937. [Unpublished.]

FLEMING, WALTER E. EFFECT OF ACID LEAD ARSENATE ON DIFFERENT PLANTS WHEN APPLIED TO SOIL ABOUT THEIR ROOTS FOR DESTRUCTION OF LARVAE OF THE JAPANESE BEETLE. U. S. Bur. Ent. and Plant Quar. Rpt. E418, 32 pp. 1937. [Mimeographed.]



vegetation grown on the contaminated soils was determined. These data are given in table 4.

TABLE 4.—Arsenic content of soils contaminated with arsenicals and of vegetation growing on them

Material and soil depth	Location	Laboratory No.	Arsenic as As in—	
			Soil	Vegetation
Sassafras sandy loam, 0-6 inches.....	Princeton N. J. plot 76A-2-3, nurseries.	C3839	P. p. m. 92	
Common mustard, tops.....		C3837		<1
Common mustard, roots.....		C3838		34
Dandelion.....		C3440		7
Wild leek.....		C3841		8
Buckhorn plantain.....		C3842		16
Sour grass.....		C3843		18
Light-green succulent weed.....		C3844		<1
Daisy.....		C3845		12
Young high grass.....		C3846		1
Milkweed, tops.....	Princeton, N. J., plot 66 D-1.	C3847		1
Sassafras sandy loam, 0-6 inches.....		C3848	130	
Rhododendron leaves.....	Princeton, N. J., plot 66 D-2.	C3849		2
Sour dock, tops.....		C3850		1
Sour dock, roots.....	Moorestown, N. J., plots south of railroad.	C3851		7
Burdock, leaves.....		C3852		<1
Sassafras sandy loam, 0-3 inches.....		C3853	270	
Sassafras sandy loam, 5-8 inches.....		C3854	4	
Sassafras sandy loam, 10-12 inches.....		C3855	7	
Orchard grass, tops.....		C3856		2
Baptisia, false indigo.....		C3857		1
Wild carrot, tops.....		C3858		<1
Wild carrot, roots.....		C3859		2
Iris, German, roots.....		C3860		10
Iris, German, tops.....	Bell orchard, Winchester, Va.	C3861		<1
Orchard grass, roots.....		C3863		<1
Uncontaminated Sassafras sandy loam, 0-3 inches.....		C3864		
Uncontaminated Sassafras sandy loam, 10-12 inches.....		C3865	10	
Under trees sprayed with arsenic, Hagerstown silt loam, 0-3 inches.....		B22603	60	
Under trees sprayed with arsenic, Hagerstown silt loam, 3-7 inches.....		B22604	12	
Under trees sprayed with arsenic, Hagerstown silt loam, 7-15 inches.....		B22605	11	
Leaves of clover from orchard.....		B22606		12
Stems of clover from orchard.....		B22606		2
Leaves and stems of alfalfa.....		B22607		14
Roots of alfalfa.....		B22607		2
Uncontaminated Hagerstown silt loam, 0-3 inches.....	Woods near Bell orchard, Winchester, Va.	B22608	7	
Uncontaminated Hagerstown silt loam, 4-7 inches.....		B22609	6	
Uncontaminated Hagerstown silt loam, 10-13 inches.....		B22610	13	
Sandy soil, 0-6 inches.....		B22412	240	
Very sandy soil, 0-6 inches.....	Orondo, Wash.	B22413	140	
Alfalfa.....		B22414		860
Alfalfa, roots.....		B22415		83
String bean, leaves.....		C1562		19
Red beet, tops.....	Long Island, N. Y.	C1563		10
Cucumber, vines and leaves.....		C1564		12
Corn, leaves.....		C1565		5

<sup>1</sup> High arsenic content due to spray dripping from sprayed trees.

<sup>2</sup> Soil contaminated with arsenic from the use of arsenical insecticide.

A comparison of the Sassafras soil profiles, one contaminated with arsenic, samples C3853, C3854, and C3855, the other normal, samples C3864 and C3865, shows that the added arsenic has penetrated but a very few inches. This same relationship is shown in a comparison of the Hagerstown contaminated soil samples B22603,

B22604, and B22605, and normal soil samples B22608, B22609, and B22610.

Although the soils contained relatively large amounts of arsenic, the plants examined contained but little in their aerial portions. The roots, however, may have contained considerably more (23). The roots of alfalfa, sample B22415, contained 83 p. p. m. The aerial portion of the alfalfa, sample B22414, had received drippings when the trees were sprayed. The arsenic content of this alfalfa was 860 p. p. m. Animals consuming considerable quantities of hay with this arsenic content might be expected to suffer some physiological disturbances. A sample of alfalfa, sample B22607, which had not received spray drippings, contained 14 p. p. m. of arsenic. The highest arsenic content of the other plants was 18 p. p. m. in sour grass, sample C3843, and 34 p. p. m. in mustard roots, sample C3838.

F. E. Baker, of the Bureau of Entomology and Plant Quarantine,<sup>7</sup> grew a variety of vegetables in soil containing 1,000, 1,500, and 2,000 pounds of lead arsenate per acre in the upper 3 inches of soil (approximately 200, 300, and 400 p. p. m. of arsenic). Although most of the vegetables included in the experiments did not absorb significant quantities of arsenic, lettuce grown on these soils was found to contain (on a fresh-weight basis) 1.9, 2.1, and 2.3 p. p. m. of arsenic, respectively; turnips contained 0.6, 1.2, and 1.1, and radishes 1.8, 1.8, and 2.1 p. p. m., respectively. Where the lead arsenate was mixed with the top 3 inches the early growth of the vegetables was definitely retarded, but after the roots had penetrated below the zone of arsenic contamination, the plants appeared to develop normally. Lima beans did not grow and string beans had to be replanted to get a uniform stand. With respect to yield, however, only the onion was markedly and consistently below normal. In the following year, when the quantities of lead arsenate in the same plots were about doubled and mixed to a depth of 6 inches, the beans did not grow at all, and only a few other crops were able to produce approximately normal yields. The quantities of arsenic absorbed by nearly all the vegetables, however, were still negligible, although (on a fresh-weight basis) the radishes were found to contain 2.1, 3.0, and 3.2 p. p. m. and the onions 2.9, 4.6, and 6.5 p. p. m. of arsenic, respectively.

Soils of lawns and golf grounds are frequently treated with arsenicals to control grub injury of grass (10, 16). Experimental plots used in the study of grub control by this means were sampled and the arsenic determined in both the soil and grass. The soil samples were taken to a depth of 3 inches. The data are given in table 5.

The soils treated with different amounts of lead arsenate and arsenic pentoxide contained from 130 to 550 p. p. m. of arsenic. One grass sample contained 4 p. p. m. and the others 2 p. p. m. or less of arsenic.

<sup>7</sup> See footnote 6. p. 13.

TABLE 5.—Arsenic content of soils treated with various arsenicals and of the lawn grass growing on them<sup>1</sup>

Laboratory No.		Treatment given, 1,000 square feet plots	Arsenic as As in—	
Soil	Grass		Soil	Grass
C3760	C3807	24 pounds arsenic pentoxide in 3 applications 1935-36	P. p. m.	P. p. m.
C3761	C3808	12 pounds arsenic pentoxide in 4 applications 1935-36	210	2
C3762	C3809	do	150	1
C3772	C3817	12 pounds arsenic pentoxide in 6 applications 1934-37	160	< .5
C3765	C3812	5 pounds arsenic pentoxide in 4 applications 1936	180	1
C3769	C3815	do	140	1
C3766	C3813	5 pounds arsenic pentoxide in 3 applications 1936	140	4
C3763	C3810	40 pounds lead arsenate in 4 applications 1933	130	1
C3764	C3811	40 pounds lead arsenate in 1 application 1936	550	2
C3771	C3816	9 pounds arsenic pentoxide in 6 applications 1934-37	500	2
C3767	C3814	Check plot	210	2
C3768		Check plot, nitrogen applied	13	< .5
C3770		do	12	12
			12	

<sup>1</sup> Samples collected in April 1938.

Millet was grown in sand and sand-soil mixtures to determine the effect of soil on the absorption of arsenic. The plants were grown in 1-gallon glazed earthenware pots, which hold about 4,500 gm. of sand. Kirvin, a reddish soil, was used with pure white sand. The data on yield and the arsenic content of plants are given in table 6. The data show that the soil, even in relatively small amounts, inhibits the absorption of arsenic. The toxicity of a given amount of arsenic is reduced by increasing amounts of soil.

TABLE 6.—Arsenic content of millet grown on sand and Kirvin soil mixtures contaminated with calcium arsenate<sup>1</sup>

Laboratory No.	Weight of millet	Culture medium	Arsenic as As in millet
	Gm.		P. p. m.
B22762	5.20	Sand only 0.01 gm. arsenic pentoxide	13
B22763	3.33	Sand only 0.02 gm. arsenic pentoxide	23
B22764	9.57	Sand + Kirvin soil sufficient to give 25 gm. colloid 0.02 gm. arsenic pentoxide	12
B22765	6.18	Sand + Kirvin soil sufficient to give 25 gm. colloid 0.04 gm. arsenic pentoxide	21
B22766	1.29	Sand + Kirvin soil sufficient to give 25 gm. colloid 0.08 gm. arsenic pentoxide	53
B22767	6.57	Sand + Kirvin soil sufficient to give 50 gm. colloid 0.04 gm. arsenic pentoxide	13
B22768	3.51	Sand + Kirvin soil sufficient to give 50 gm. colloid 0.08 gm. arsenic pentoxide	27

<sup>1</sup> The plants for this experiment were grown by P. L. Gille.

### ARSENIC IN MARINE ALGAE

Chapman (4) analyzed a large number of shellfish and crustaceans from the coastal waters of the British Isles. The arsenic content ranged from a minimum of 2.3 p. p. m. in an oyster sample to a maximum of 132 p. p. m. in one sample of prawns. The sea water from which his samples were taken contained arsenic in concentrations ranging from 0.13 to 0.76 p. p. m. Coulson, Remington, and Lynch (7) found that shrimp grown in certain localities con-

tain relatively large quantities of arsenic. They found as high as 130 p. p. m. of arsenic in the edible portion of shrimp, and they concluded that there was a seasonal variation within a locality and that there were large variations from locality to locality. This suggests a variation in the arsenic content of marine plant life and preponderance of certain plants in certain localities.

Five samples of marine algae were secured through the kindness of T. G. Thompson, director of the oceanographic laboratory of the University of Washington. The arsenic contents of these algae are given in table 7.

There is a marked variation in the arsenic content of the different algae. Other plants may contain even more than these few that were examined. Certainly this should be a fertile field for biologists interested in marine life.

TABLE 7.—Arsenic content of different marine algae from Puget Sound, Wash.

Laboratory No.	Alga	Arsenic as As
		P. p. m.
B20617	<i>Pterygophora californica</i>	12
B20618	<i>Maerccysetis pyrifera</i>	4
B20619	<i>Agarum fimbriatum?</i>	4
B20620	<i>Rhodemia pertusa</i>	1
B20621	<i>Codium castella</i>	1

## GENERAL DISCUSSION

Arsenic was found in all of the soil samples examined. The samples were widely distributed geographically and were chosen to represent the great soil groups. Data on such soils led to the conclusion that arsenic is a common constituent of soils. The quantity of arsenic found varied from a fraction of a part per million to about 40 p. p. m. in the normal soils.

The maximum arsenic content of the vegetation examined from the untreated soils was 10 p. p. m., based on air-dry weight. Although no extensive examination of plant species was made, no indications have been found of the existence of plants capable of high concentration of arsenic, such as have been found for selenium (3).

Soils contaminated with arsenicals contained many times as much arsenic in the surface few inches as did the untreated normal soils. The maximum quantity found was 550 p. p. m.

Vegetables grown on highly contaminated soils may contain appreciably more arsenic than those grown on soils with only naturally occurring arsenic. For example, by calculating the values given in table 2 for turnips and radishes to the fresh material basis and comparing with the values obtained by Baker<sup>a</sup> it is found that the turnips and radishes grown on uncontaminated soils contained 0.07 p. p. m. and 0.05 p. p. m., whereas those grown on the contaminated soils contained 1.2 p. p. m. and 2.1 p. p. m., respectively.

Large quantities of arsenicals should not be added to soils used for the cultivation of food crops. In addition to the possibility of

<sup>a</sup> See footnote 6, p. 13.

producing toxic foodstuffs, a serious reduction in yield may result. Contamination of soils with arsenicals certainly reduces the growth of some plants. It has been reported that cotton, cowpeas, wheat, barley, oats, corn, soybeans, and sorghum were so affected (6). Alfalfa and barley are also seriously affected (23). A serious reduction in the yield of rice has been noted (17). Fleming<sup>9</sup> lists many plants that are either killed or have their growth seriously retarded by arsenic-contaminated soils. Reduction in the yield does not always follow when the soil is contaminated, since many kinds of plants are not apparently affected. An increase of 64 percent in the growth of rye on Cecil sandy loam to which 750 pounds per acre of calcium arsenate had been added and a 6-percent increase when as much as 6,000 pounds per acre had been added has been reported (6).

The differences in behavior of arsenicals with various soils is of considerable interest and importance. Field observations and controlled experiments have brought out certain pertinent facts.

It has been observed that relatively small applications of calcium arsenate to the acid sandy soils of the coastal plains will very seriously reduce the yield of certain crops (6). This is not the case with the heavy clay soils in Louisiana. Here relatively large applications seem to have no effect on such crops (17). Davidson and Cecil soils, high in reactive iron, prevented relatively large applications of calcium arsenate from being harmful (6). The examination of Oregon orchard soils showed that practically no arsenic from approximately 20 years of spraying had penetrated below the 8-inch depth to which the soil was cultivated and mechanically mixed (15). The authors made a similar observation in two eastern soils (table 4). It is probable, however, that arsenic would be leached down through an acid sandy soil.

Quantitative experiments were made on the growth of millet, in soil-sand mixtures, to which various amounts of calcium arsenate were added (11). The quantity of arsenic necessary to produce half injury was determined for 36 different soils. Marked variations in reduction of growth were noted and in general the reduction became less as the iron oxide increased in the soil colloid. Reduction in growth is a function of the kind of soil, the amount of arsenic present, and the kind of plant. All three must be taken into strict account.<sup>10</sup>

## SUMMARY

A method for determining arsenic in soils and vegetation is described. Arsenic is separated from interfering elements by distillation with hydrobromic acid and determined colorimetrically by the molybdenum blue method.

Profile samples as well as surface soils alone from various great soil groups were examined. These soils, representative of widely separated areas, all contained arsenic in quantities varying from 0.3 to nearly 40 p. p. m.

<sup>9</sup> See footnote 6, p. 13.

<sup>10</sup> Subsequent to the submission of the manuscript of this report two articles have appeared (8, 9) that report the results of studies upon the effect of added calcium arsenate upon crop production in certain coastal plains soils. These reports are in harmony with the above discussion and in particular emphasize the influence of soil character upon crop growth as affected by arsenic addition.

Soils from Mexico were examined and their arsenic content was found to be similar to that of soils of the United States.

The arsenic content of widely varied vegetation growing on diverse soils was determined. Maximum values were about 10 p. p. m. under normal conditions. Many samples contained less than 0.1 p. p. m. Some plants contain more than others growing on the same soil. Also, as a rule, roots contain more than tops of plants.

No clearly defined relationship was found between arsenic content of soils and climatic conditions or geological formations on which the soils were developed.

Soils contaminated with arsenic may, in some cases, produce vegetation of higher arsenic content than that found on any natural soil. However, in general it appears that plant growth is limited by the presence of arsenic in soils before injurious quantities are absorbed.

A few marine algae samples were examined and the arsenic content was found to range from 1 to 12 p. p. m.

### LITERATURE CITED

- (1) BYERS, HORACE G.  
1935. SELENIUM OCCURRENCE IN CERTAIN SOILS OF THE UNITED STATES, WITH A DISCUSSION OF RELATED TOPICS. U. S. Dept. Agr. Tech. Bul. 482, 48 pp., illus.
- (2) ———  
1936. SELENIUM OCCURRENCE IN CERTAIN SOILS IN THE UNITED STATES, WITH A DISCUSSION OF RELATED TOPICS. SECOND REPORT. U. S. Dept. Agr. Tech. Bul. 530, 79 pp., illus.
- (3) ——— MILLER, JOHN T., WILLIAMS, K. T., and LAKIN, H. W.  
1938. SELENIUM OCCURRENCE IN CERTAIN SOILS IN THE UNITED STATES, WITH A DISCUSSION OF RELATED TOPICS. THIRD REPORT. U. S. Dept. Agr. Tech. Bul. 601, 75 pp., illus.
- (4) CHAPMAN, A. CHASTON.  
1926. ON THE PRESENCE OF COMPOUNDS OF ARSENIC IN MARINE CRUSTACEANS AND SHELL FISH. Analyst 51: 548-563.
- (5) CHATIN, AD.  
1845. ÉTUDES DE PHYSIOLOGIE VÉGÉTALE FAITES AU MOYEN DE L'ACIDE ARSÉNIEUX. [Paris] Acad. Sci. Compt. Rend. 20: 21-29.
- (6) COOPER, H. P., PADEN, W. R., HALL, E. E., ALBERT, W. B., et al.  
1931. EFFECT OF CALCIUM ARSENATE ON THE PRODUCTIVITY OF CERTAIN SOIL TYPES. S. C. Agr. Expt. Sta. Ann. Rpt. 1931: 28-37, illus.
- (7) COULSON, E. J., REMINGTON, ROE E., and LYNCH, KENNETH M.  
1935. METABOLISM IN THE RATE OF THE NATURALLY OCCURRING ARSENIC IN SHRIMP AS COMPARED WITH ARSENIC TRIOXIDE. Jour. Nutr. 10: 255-270, illus.
- (8) DORMAN, CLARENCE, and COLEMAN, RUSSELL.  
1939. THE EFFECT OF CALCIUM ARSENATE UPON THE YIELD OF COTTON ON DIFFERENT SOIL TYPES. Amer. Soc. Agron. Jour. 31: 966-971.
- (9) ——— TUCKER, FREDERICK H., and COLEMAN, RUSSELL.  
1939. THE EFFECT OF CALCIUM ARSENATE UPON THE PRODUCTIVITY OF SEVERAL IMPORTANT SOILS OF THE COTTON BELT. Amer. Soc. Agron. Jour. 31: 1020-1028.
- (10) FLEMING, WALTER E.  
1936. PREVENTING INJURY FROM JAPANESE AND ASIATIC BEETLE LARVAE TO TURF IN PARKS AND OTHER LARGE AREAS. U. S. Dept. Agr. Cir. 403, 12 pp., illus.
- (11) GILE, PHILIP L.  
1936. THE EFFECT OF DIFFERENT COLLOIDAL SOIL MATERIALS ON THE TOXICITY OF CALCIUM ARSENATE TO MILLET. Jour. Agr. Res. 52: 477-491, illus.
- (12) GREAVES, J. E.  
1913. THE OCCURRENCE OF ARSENIC IN SOILS. Biochem. Bul. 2: 519-523.

- (13) GREAVES, J. E.  
1922. AGRICULTURAL BACTERIOLOGY. 437 pp., illus. Philadelphia and New York.
- (14) HEADDEN, W. P.  
1910. THE OCCURRENCE OF ARSENIC IN SOILS, PLANTS, FRUITS, AND ANIMALS. Colo. Sci. Soc. Proc. 9: 345-360.
- (15) JONES, J. S., and HATCH, M. B.  
1937. THE SIGNIFICANCE OF INORGANIC SPRAY RESIDUE ACCUMULATIONS IN ORCHARD SOILS. Soil Sci. 44: 37-63, illus.
- (16) MONTEITH, JOHN, JR.  
1937. TURF-DESTROYING GRUBS. Natl. Golf Rev. 1 (4): 36-38.
- (17) REED, J. FIELDING, and STURGIS, M. B.  
1936. TOXICITY FROM ARSENIC COMPOUNDS TO RICE ON FLOODED SOILS. Amer. Soc. Agron. Jour. 28: 432-436.
- (18) REICHERT, FEDERICO, and TRELLES, ROGELIO A.  
1921. SOBRE LA PRESENCIA DEL ARSÉNICO COMO ELEMENTO NORMAL EN LAS TIERRAS VEGETALES. Asoc. Quím. Argentina An. 9: 89-95. Also Buenos Aires Univ. Nac., 3: 281-284. Facult. de Agron. y Vet. Rev.
- (19) ROBINSON, W. O., DUDLEY, H. C., WILLIAMS, K. T., and BYERS, H. G.  
1934. DETERMINATION OF SELENIUM AND ARSENIC BY DISTILLATION IN PYRITES, SHALES, SOIL AND AGRICULTURAL PRODUCTS. Indus. and Engin. Chem., Analyt. Ed. 6: 274-276, illus.
- (20) SLATER, C. S., HOLMES, R. S., and BYERS, H. G.  
1937. TRACE ELEMENTS IN THE SOILS FROM THE EROSION EXPERIMENT STATIONS, WITH SUPPLEMENTARY DATA ON OTHER SOILS. U. S. Dept. Agr. Tech. Bul. 552, 24 pp.
- (21) THOM, CHARLES, and RAPER, KENNETH B.  
1932. THE ARSENIC FUNGI OF GOSIO. Science 76: 548-550.
- (22) TRUOG, EMIL, and MEYER, A. H.  
1929. IMPROVEMENTS IN THE DENIGES COLORIMETRIC METHOD FOR PHOSPHORUS AND ARSENIC. Indus. and Engin. Chem., Analyt. Ed. 1: 136-139, illus.
- (23) VANDECAVEYE, S. C., HORNER, G. M., and KEATON, C. M.  
1936. UNPRODUCTIVENESS OF CERTAIN ORCHARD SOILS AS RELATED TO LEAD ARSENATE SPRAY ACCUMULATIONS. Soil Sci. 42: 203-215, illus.
- (24) WILLIAMS, K. T., and LAKIN, H. W.  
1935. DETERMINATION OF SELENIUM IN ORGANIC MATTER. Indus. and Engin. Chem., Analyt. Ed. 7: 409-410.
- (25) ——— LAKIN, H. W., and BYERS, H. G.  
1940. SELENIUM OCCURRENCE IN CERTAIN SOILS IN THE UNITED STATES, WITH A DISCUSSION OF RELATED TOPICS. FOURTH REPORT. U. S. Dept. Agr. Tech. Bul. 702.
- (26) ZUCCARI, GINO.  
1913. SULLA PRESENZA DELL' ARSÉNICO COME ELEMENTO NORMALE NELLE TERRE. Gaz. Chim. Ital. 43 (P. 2): 398-403.

**END**