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Arsenic Concentrations in Selected Soils and Parent Materials in Mississippi

David E. Pettry
Professor of Soil Science
Department of Plant and Soil Sciences
Mississippi State University

Richard E. Switzer
Senior Research Assistant
Department of Plant and Soil Sciences
Mississippi State University

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ABSTRACT

Arsenic concentrations were determined in representative parent materials and soils of major soil resource areas in the state. Analyses were conducted on 11 parent materials and 260 soil samples from 84 soil series representing all eight soil orders recognized in Mississippi. Mean arsenic concentrations in soil parent materials ranged from 33.76 parts per million (ppm) in the Winona Formation to 1.77 ppm in the Wilcox Group. The mean arsenic concentration of 260 soil samples was 8.25 ppm with a range of 0.26 to 24.43 ppm, and it was significantly correlated ($p = 0.001$) with clay content, cation exchange capacity (CEC), and pH. Cultivated surface horizons (Ap) had significantly ($p = 0.05$) higher concentrations than uncultivated horizons (A), reflecting cultural arsenic additions. Subsoil horizons had significantly ($p = 0.05$) higher arsenic concentrations than surface horizons, indicative of the influences of parent materials and pedogenesis. Water-soluble (bioavailable) arsenic levels in selected parent materials and soils were less than 1 ppm. Soil arsenic concentrations were highest in the Delta Soil Resource Area with the following relationship: Delta > Interior Flatwoods > Blackland Prairies > Loess > Upper Coastal Plain > Lower Coastal Plain > Coastal Flatwoods. Soil arsenic concentrations increased with increasing distance from the Gulf of Mexico.

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INTRODUCTION

Arsenic is generally considered an essential element for animals and humans. The daily required intake for adult humans is 12 to 25 micrograms, and the lethal intake is reported as 50 to 340 milligrams per day (Pais and Jones 1997). Animals may exhibit arsenic deficiency when rations contain less than 50 parts per billion (ppb) of the mineral. Trace levels of arsenic are essential to animals and humans, but threshold toxicity levels are very small, and it is considered carcinogenic. Arsenic is not essential for plants, and amounts greater than 2 parts per million (ppm) (dry weight) may be phytotoxic (Pais and Jones 1997) to some plants.

Compounds containing arsenic have been widely used as pesticides, insecticides, herbicides, soil sterilants, silvicides, and dessicants over the past century (Alloway 1970; Woolson et al. 1971; Pais and Jones 1997). Inorganic arsenicals including As_2O_3, $NaAsO_2$, $Pb_3(AsO_4)_2$, CaH_2AsO_4, and Paris green have been extensively used in agriculture and forestry. More recently, methylarsonic acids, dimethylcalciumpropylarsonate, calciummethylarsonate, and dimethyl arsenic acid have been applied to crops, orchards, turf, and used in silviculture (Woolson et al. 1971).

Some plants and crops are stimulated by small arsenic concentrations (Stewart and Smith 1922). Early researchers (Cooper et al. 1932) reported yield increases in corn (*Zea mays* L.), sorghum (*Sorghum bicolor* L. Marsh), soybeans (*Glycine max* L. Merr), and cotton (*Gossypium hirstum* L.) when 500 ppm of arsenic was added as $Ca_3(AsO_4)_3$ to a Davidson clay soil. Later research by Jacobs et al. (1970) indicated slight growth improvements to potatoes (*Solanum tuberosum* L.)and corn, but yields decreased in pears (*Pyrus Communis* L.)and snap beans (*Phaseolus vulgaris* L.) as arsenic additions increased.

Widespread arsenic usage has produced elevated soil accumulations that may be phytotoxic in some areas. Several studies indicated treated areas in North America contained 1.8 to 830 ppm, while untreated areas had 0.5 to 14 ppm (Benson 1953; Bishop and Chisholm 1962; Greaves 1913; Vandecaveye et al. 1936). Woolson et al. (1971) reported that arsenic residues averaged 165 ppm in 58 surface samples from fields with a history of arsenic applications, while nearby untreated soils averaged 13 ppm. Newton (1986) and Norris et al. (1983) reported arsenic levels in surface soil near and below treated trees were higher than native soil. Researchers (McLaren et al. 1998) recently studied soils surrounding cattle dips in Australia where arsenicals had been used several decades in the past. Surface soil contaminations with arsenic ranged up to 3,542 ppm. The arsenic also moved vertically in the soil with levels of 2,282 ppm at 20- to 40-centimeter depth. One of the sites had 14,000 ppm at 40 to 45 centimeters depth. Peryea and Creger (1994) also detected downward movement of arsenic through the soil profile in orchard soils contaminated with lead arsenate pesticide. Johnson and Hiltbold (1969) suggested downward movement of mobile arsenic in soils may change with depth as labile arsenic is transformed to relatively recalcitrant forms.

Arsenic is not highly mobile in soils, and it has a moderate bioaccumulation index (Pais and Jones 1997). The chemical behavior of arsenic in soils is apparently similar to phosphorus since both commonly form oxyanions in the +V oxidation state (O’Neill 1990). Early research demonstrated arsenic toxicity to plants decreased as clay and iron oxide contents of soils increased (Crafts and Rosenfels 1939; Dorman et al. 1939). The clay fraction and iron oxides have frequently been associated with arsenic-sorption in soils. Soils high in reactive iron components have been shown to sorb more arsenic than low-iron soils of similar texture (Keaton and Kardos 1940; Misra and Tiwari 1963). Jacobs et al. (1970) determined amorphous iron and aluminum components that are oxalate-extractable preferentially sorbed arsenic. These researchers reported organic matter contributed little to arsenic sorption. Jacobs et al. (1970) suggested a portion of the arsenic is mobile in soils that have low sorption capacity.

Public concern and increased awareness of environmental contamination by trace metals has resulted in governmental regulations and the establishment of soil levels deemed toxic. Arsenic accumulation is a particular concern because of its toxicity in small concentrations, carcinogen classification, and potential to impact surface and ground waters and soil-plant ecological systems. Natural background levels of arsenic concentrations in soils and parent materials should be understood to realistically assess contamination and develop remediation methodology. Background data serve as a foundation to determine the degrees of toxic accumulation and to understand the biogeochemical behavior of arsenic in the dynamic soil environment.

Knowledge of arsenic background levels in soils of the Southeastern U.S., including Mississippi, is very limited. Arsenic concentrations in uncontaminated surface soils worldwide have been reported to range from less than 0.1 to 95 ppm (Kabata-Pendias and Pendias 1992) with mean values generally less than 20 ppm. Studies in the U.S. indicate surface soil concentrations of 0.1 to 40 ppm (Allaway 1970) and average values of 7.5 ppm (Adriano 1986). Recently, Pais and Jones (1997) reported a mean range of 3.6 to 8.8 ppm. Lena et al. (1997) determined concentrations of 11 metals in 40 Florida soils and reported mean arsenic concentration of 1.1 ppm in the weathered, highly leached soils.

Woolson et al. (1971) studied five Mississippi soils that had been treated with $Ca_3\ (AsO_4)_3$ around 1930. They reported total arsenic concentration of 21 to 96 ppm in untreated surface horizons. The high arsenic levels of the control soil samples were attributed to flooding and silting. Pettry and Switzer (1993) reported on the distribution of cadmium, copper, zinc, lead, nickel, iron, and manganese in selected soils and parent materials of Mississippi. They determined that heavy metal concentrations reflected the influence of parent materials, pedogenesis, weathering, and age.

This study had two objectives: (1) determine background arsenic levels of representative soil and parent materials in Mississippi; and (2) evaluate correlations between arsenic and selected soil properties.

METHODS AND MATERIALS

Representative soils and parent materials were sampled in 45 counties representing all major soil resource areas in the state (Figure 1). Eleven soil parent materials were carefully sampled at multiple locations by cutting back the surface and exposing fresh materials or from excavations. In all, 260 soil samples were obtained in 136 pedons from 84 series representing all eight soil orders recognized in the state. Ninety cultivated and 37 uncultivated surface horizons and 133 subsurface horizons were analyzed. Incremental vertical sampling of two pedons and underlying parent materials was conducted at locations in the Delta and Upper Coastal Plain to evaluate effects of pedogenesis on arsenic distribution. Soils were described and sampled using standard methods (Soil Survey Staff 1984).

Samples were air-dried and sieved to remove coarse fragments (more than 2 millimeters). Clay content was determined by the hydrometer method (Day 1965). Soil pH was measured in a 1:1 soil/water suspension. Organic matter was determined by wet combustion (Peech et al. 1947). Cation exchange capacity (CEC) was determined by summation of extractable cations and acidity. Cations were extracted with $\underline{M}$ NH_4OA_C (pH 7) and determined by atomic absorption spectrophotometry. Acidity was determined by the $BaCl_2$ - triethanolamine method (Peech 1965).

Arsenic Analysis

Air-dry samples were ground in an agate mortar pestle to pass a 60-mesh sieve (0 to 25 millimeters). A 0.5-gram sample was used for analysis unless high in $CaCO_3$ or organic matter, in which case a 0.10- or 0.25-gram sample was used. A separate sample was used to determine oven-dry (105^oC for 24 hours) weight. Environmental Protection Agency method 3051a (EPA 1995) was used to determine arsenic concentration. Samples were placed in 100-milliliter PFA HP-500 Plus digestion vessels; 9 milliliters of concentrated HNO_3 and 3 milliliters of concentrated HCL were added. Samples and reagents were mixed, sealed, and digested in a CEM MARS 5 microwave oven. Samples were heated to 175^oC within 5 minutes and held at 175^o for an additional 5 minutes. Samples were cooled, transferred to 200-milliliter volumetric flasks, and brought to volume with deionized water. Arsenic was determined by atomic absorption spectrophotometer using a graphite furnace and electrodeless discharge lamp (Perkin Elmer AAnalyst 700).

Water-soluble arsenic was extracted by shaking 5-gram soil samples (less than 2 millimeters) in 25 milliliters of distilled water for 16 hours, and filtering. The arsenic concentration was determined by atomic absorption using a graphite furnace (GFAAS) and an electrodeless discharge lamp (Perkin Elmer AAnalyst 700).

Quality Control

A reagent blank was digested with each set of samples, and the value was subtracted from the sample results. Two National Institute of Standards and Technology (NIST) standards were analyzed randomly to check percent recovery. The standards were NIST 2704, Buffalo River Sediment, 23.8 +/- 0.8 ppm arsenic; and NIST 2711, Montana Soil, 105 +/- 0.8 ppm arsenic. Recovery averaged 91.9% for 11 NIST 2704 determinations and 97.9% for four NIST 2711 determinations. In addition, a Perkin Elmer mixed standard (PE #N930-0244) at a concentration of 25 milligrams per liter was run as the last sample of each batch to check the operation of the GFAAS. Matrix interference was checked on each set of samples before analysis.

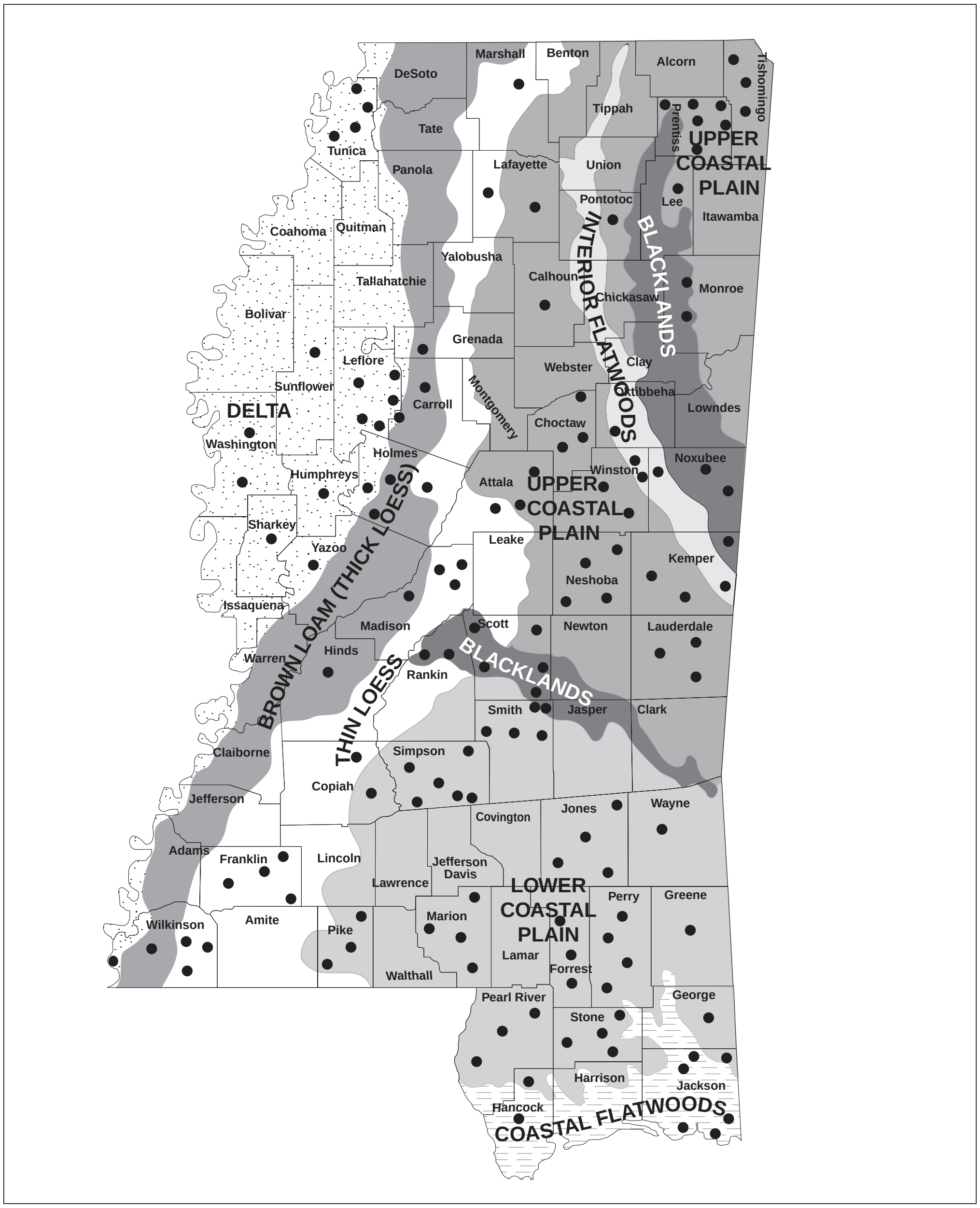

Figure 1. Locations of soil sampling sites in Mississippi.

RESULTS AND DISCUSSION

Soil Parent Materials

The trace metal content of soils is strongly influenced by the parent materials in which they form (Esser et al. 1991). Research in Florida (Lena et al. 1997) and previous studies in Mississippi (Pettry and Switzer 1993) demonstrated the influence of parent materials on heavy metal concentrations in soils. Mississippi soils formed in alluvial, marine, and eolian parent materials ranging from Cretaceous to Holocene age. Episodic erosion, sedimentation, and sediment reworking by streams have resulted in complex distribution of the sedimentary parent materials of diverse origins. The age of soil parent materials decreases from east to west. The oldest materials, including Tombigbee sand and Selma chalk, are in the northeastern part of the state. The youngest major soil parent material is the Mississippi River alluvium, which is dominated by smectitic clay. Unconsolidated sediments are dominant in the state and include materials that were highly weathered before deposition.

A degree of uniformity exists in the soil resource areas (Figure 1) that have common parent materials and similar topography and climate (Pettry 1977). Annual precipitation in the state ranges from approximately 1,250 to 1,625 millimeters, and soil temperatures are in the thermic regime (15° to 22°C). The humid temperate climate produces an intense weathering environment.

Soil Resource Areas

The Coastal Plain soil resource areas (Upper and Lower) comprise approximately 41.8% of the state and contain several parent materials. Coastal Plain soils tend to be acidic and highly weathered with loamy and sandy textures inherited from the parent materials. The extensive Wilcox Group of the Upper Coastal Plain region consisted of sands, clays, and thin lignitic zones. The Neshoba sand was dominantly medium-grained quartz sand with glauconite and mica. The Tombigbee sand had quartz, calcite, and glauconite sand and silt fractions. The Winona parent material was medium-grained, poorly sorted silty, clayey, glauconitic sand. It had a very high glauconite content that weathered to form red soils with very high sesquioxide contents. The Basic City Shale, commonly referred to as Tallahatta silt stone, had high silt contents. Soils formed in this parent material contain cristobalite, a characteristic mineral of this formation. The Citronelle Formation is an extensive parent material of the Lower Coastal Plain. It was dominantly medium- to coarse-grained quartz sand, with silt and clay laminae. The Citronelle samples analyzed in this study had loamy textures and high iron oxide contents.

The Peoria loess (Upper and Lower Thick and Thin Loess) was dominantly silt (more than 90%) and consisted of quartz, feldspars, mica, and carbonates. The Thick Loess regions are distinguished from thin Loess by having 1.2-meter and greater loess thickness. The lower Loess regions have coastal influence from the Gulf of Mexico and receive higher precipitation. Loessial regions comprise approximately 28.9% of the state acreage.

The Delta region, which formed in rich sediments of the Mississippi River eroded from the heartland of America, makes up approximately 17% of the state. The clayey alluvium is dominated by montmorillonitic clay, and the clayey soils developed in it are rich in bases and exhibit little weathering.

Selma chalk underlies the northeastern Blackland Prairie and is composed dominantly of $CaCO_3$ (more than 70%) and contains montmorillonitic clay. Soils forming in this parent material commonly are clayey and montmorillonitic. Representative parent materials in the central Blackland Prairie are Yazoo Clay and calcareous materials. The Yazoo Clay is dominantly montmorillonitic and calcareous. The Blackland Prairie regions comprise approximately 6.1% of the state acreage.

The Interior Flatwoods region has Porters Creek Clay parent material. Commonly called “soapstone,” the Porters Creek material was dominantly silty montmorillonitic clay with lesser amounts of kaolinite and illite. This region makes up approximately 2.6% of the state.

Table 1. Mean elemental arsenic concentrations in selected soil parent materials.

Parent Material	Area [1]	Locations	Arsenic [2]	Minimum	Maximum
			ppm		
Citronelle Formation	LCP	2	10.28 (±4.92) [3]	6.80	13.76
Neshoba Sand	UCP	2	5.58 (±3.72)	2.95	8.22
Porters Creek	IF	2	8.98 (±6.90)	4.10	13.87
Peoria Loess	L	5	6.90 (±2.00)	5.02	9.82
Clayey Alluvium	D	5	21.05 (±5.81)	13.87	28.69
Selma Chalk	BP	3	6.68 (±3.44)	3.88	10.53
Basic City Shale	UCP	2	4.32 (±0.54)	3.94	4.71
Tombigbee Sand	UCP	2	2.55 (±0.21)	2.40	2.71
Wilcox Group	UCP	4	1.77 (±1.02)	0.32	2.69
Winona Formation	UCP	8	33.76 (±14.35)	19.70	54.76
Yazoo Clay	BP	2	16.57 (±0.14)	16.56	16.58
All Parent Materials		37	14.42 (±13.71)	0.32	54.76

[1] BP = Blackland Prairie; D = Delta; IF = Interior Flatwoods; L = Loess; LCP = Lower Coastal Plain; UCP = Upper Coastal Plain.
[2] Measured in milligrams of arsenic per kilogram of soil parent materials, which is expressed in this publication as parts per million (ppm).
[3] Standard Deviation.

Coastal Flatwoods soils formed in loamy and sandy marine sediments that are commonly acidic and low in natural fertility. This coastal region comprises approximately 3.5% of the state.

Average arsenic concentration of the 11 soil parent materials (37 samples) was 14.42 ppm and ranged from 33.76 ppm in the Winona Formation to 1.77 ppm in the Wilcox Group (Table 1). Both of these parent materials occur in the Upper Coastal Plain resource area and illustrate the large differences that can exist within one soil resource area consisting of different geological formations. The coarse-textured sandy silty materials (Tombigbee Sand, Neshoba Sand) had arsenic concentrations less than 7 ppm. In contrast, the materials with high clay contents (more than 50%) dominated by montmorrillonite (Clayey Alluvium, Yazoo Clay) had concentrations exceeding 15 ppm.

The Winona parent material had sandy loam textures and high iron oxide contents (more than 5%) associated with high glauconite content (Pettry and Switzer 1993). When the higher arsenic concentrations were detected in the Winona material, additional samples were collected and analyzed to verify the levels detected. The eight Winona samples had arsenic concentrations ranging from 54.7 to 19.7 ppm with an average value of 33.76 ppm.

Pettry and Switzer (1993) reported iron was the dominant heavy metal in parent materials and soils of Mississippi. They reported iron concentrations exceeding 30,000 ppm in the Winona Formation and Mississippi River Alluvium, and levels exceeded 19,000 ppm in the Citronelle Formation and Yazoo Clay. The higher arsenic concentrations in the Winona Formation, Clayey Alluvium, Yazoo Clay, and Citronelle Formation appear to be associated with sesquioxides and clay.

Boischot and Herbert (1948) stated soil texture was often related to arsenic fixation in that reactive iron and aluminum usually vary directly with soil clay content. The fixation (strong sorption) of arsenic added to soils has been demonstrated to be related to iron-aluminum oxides and clay content (Lena et al. 1997; Woolson et al. 1971; Jacobs et al. 1970). The elevated arsenic concentrations associated with sesquioxides and clay in

Mississippi probably reflect previous weathering of arsenic minerals and subsequent sorption-fixation by sesquioxides and clay. The arsenic form and concentration in parent materials have direct bearing on the soil content and redistribution within the solum by pedogenesis.

Research (Lena et al. 1997; Pettry and Switzer 1993) has demonstrated that metal distribution in soils reflects parent material and pedogenic factors that determine clay content variation between and within soil profiles. Arsenic, like other metals, exists as a structural component of layer silicates or absorbed or occluded by iron-manganese oxides and hydroxides (Lena et al. 1997). The heavy metal content in soils is strongly influenced by the parent material in which they form (Esser et al. 1991). Pedogenic factors (soil development) such as eluviation and illuviation affect clay and sesquioxide distribution in soils. Subsoil argillic horizons (Bt) represent zones of accumulated clay and associated sesquioxides. Young soils with limited pedogenic development have minimal eluviation and illuviation, and they are strongly related to the parent material in which they develop.

The strong influence of parent material is illustrated in Figure 2, which shows arsenic concentration with depth in a clayey Sharkey soil (Vertisol) in Holocene clayey alluvium parent material. Arsenic concentration in the subsoil cambic horizons (Bgss) with minimal pedogenic development is very similar to levels in underlying parent material. The higher arsenic concentrations in the cultivated surface horizon (Ap) reflect long-term herbicide and insecticide applications and accumulation.

The pedogenic influence on arsenic concentrations in the soil profile is illustrated in the deep, well-developed, forested Ultisol soil in Neshoba County (Figure 3). Illuviation and accumulation of arsenic in the strongly expressed subsurface argillic (Bt) horizons reflect the redistribution within the soil profile and weathering zone. Arsenic concentrations exceeding 55 ppm in the lower subsoil and underlying Winona Formation were the highest detected in the state.

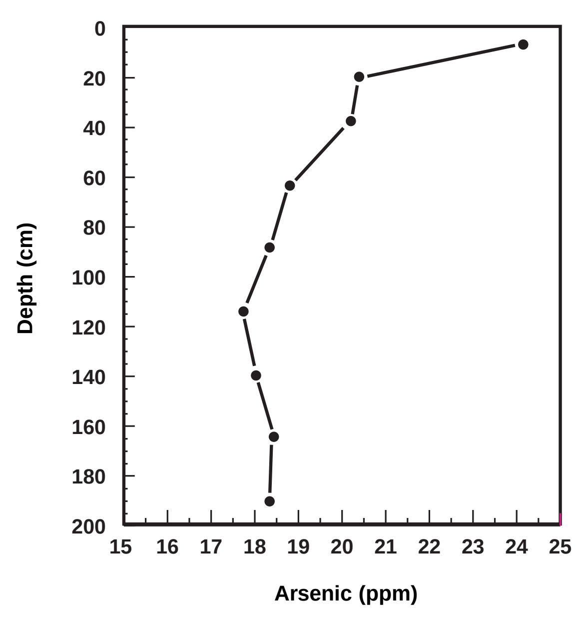

Figure 2. Arsenic concentration distribution in Sharkey soil and underlying parent material in the Delta.

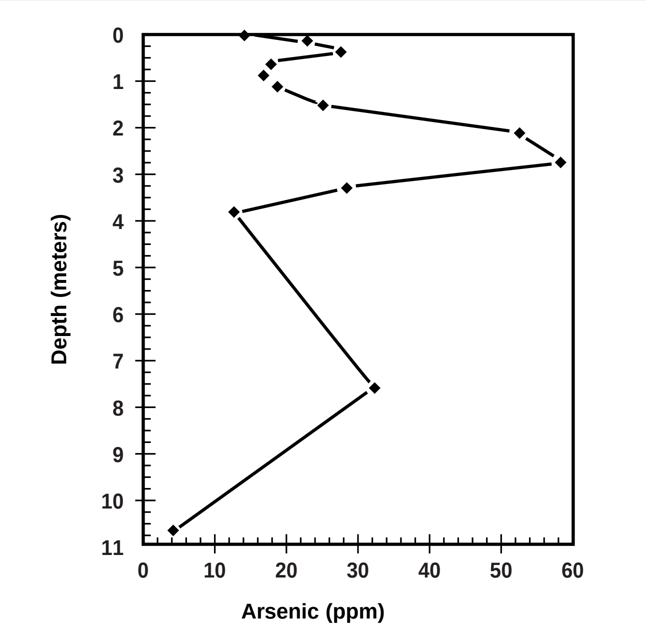

Figure 3. Arsenic concentration distribution in an Ultisol and underlying Winona Formation in the Upper Coastal Plain.

The study encompassed 136 pedons of 84 soil series representative of the soils in the state. All soil orders (Soil Survey Staff 1999) recognized in Mississippi were represented, including Alfisols, Entisols, Histosols, Inceptisols, Mollisols, Spodosols, Ultisols, and Vertisols. Organic matter contents, pH, clay contents, CEC, and arsenic concentrations of the 260 soil samples analyzed are presented in the Appendix.

The mean arsenic concentration of all samples (surface and subsurface) was 8.25 ppm with a range of 0.26 to 24.43 ppm (Table 2). Surface horizons had significantly ($p = 0.05$) lower arsenic concentrations than subsurface horizons. Soil organic matter contents were significantly higher in surface horizons, and clay contents were higher in the subsoils. Soil pH and cation exchange capacities did not differ significantly between surface and subsoil horizons. The higher arsenic concentrations in subsoil horizons may reflect higher clay contents and influence of underlying parent material.

Arsenic concentrations in cultivated surface horizons (Ap) were significantly higher ($p = 0.05$) than uncultivated horizons (Ap) as shown in Table 3. Cultivated soils contained more than twice the arsenic concentrations compared with uncultivated surface soils, reflecting historical arsenic applications in agricultural practices. Various researchers have reported elevated arsenic levels in agricultural soils (Woolson et al. 1971; McLaren et al. 1998; Johnson and Hiltbold 1969; Bishop and Chisholm 1962). Arsenic levels in cultivated surface horizons were not significantly ($p = 0.05$) higher than subsoil argillic (Bt) horizons with illuvial clay concentrations (Table 3). Cambic (Bw, Bg, Bgss) horizons exhibited the highest arsenic concentra-

Table 2. Mean arsenic concentration, organic matter content, pH, clay content, and cation exchange capacity (CEC) in surface and subsurface horizons averaged across all soils analyzed.

Component	Horizon	N	Mean [1]	Minimum	Maximum	Std. Dev.
Arsenic (ppm) [2]	surface	129	6.74 a	0.51	27.43	6.25
	subsoil	131	9.73 b	0.26	24.59	5.96
Organic matter (%)	surface	129	3.50 c	0.50	83.60	7.34
	subsoil	131	0.57 d	0.00	13.40	1.19
pH	surface	129	5.21 e	3.60	7.60	0.82
	subsoil	131	5.08 e	3.80	10.80	0.94
Clay (%)	surface	129	16.97 f	1.30	70.70	17.13
	subsoil	131	31.50 g	0.00	87.40	19.27
CEC ($\mathrm{cmol_c\ kg^{-1}}$)	surface	129	18.97 h	1.30	112.00	17.36
	subsoil	131	20.87 h	1.30	118.70	16.98
Arsenic (ppm) [2]	All samples	260	8.25	0.26	24.43	6.28

[1] Means with same letter are not significantly different ($p = 0.05$).
[2] Measured in milligrams of arsenic per kilogram of soil parent materials, which is expressed in this publication as parts per million (ppm).

Table 3. Mean arsenic concentrations in major horizons in the soil solution and statistical relationships.

Horizon	N	Arsenic [1]
		ppm
A (undisturbed surface)	39	3.63 a
Ap (cultivated surface)	90	8.09 b
Bt (subsoil argillic)	85	9.74 b
Bw (subsoil cambic)	23	13.92 c

[1] Means with same letter are not significantly different ($p = 0.05$). Measured in milligrams of arsenic per kilogram of soil parent materials, which is expressed in this publication as parts per million (ppm).

tions in the soil solum. Cambic horizons have minimal pedogenic development and strongly reflect influences of the parent materials. The cambic (Bgss) horizons of clayey Vertisols of the Delta exhibit slight alterations of the clayey alluvial parent materials.

Soil arsenic concentrations, averaged across all soils analyzed in the state, had the following relationships: Delta > Interior Flatwoods > Blackland Prairie > Loess > Upper Coastal Plain > Lower Coastal Plain > Coastal Flatwoods (Table 4). Clayey, montmorillonitic soils of the Delta, Interior Flatwoods, and Blackland Prairies had the highest arsenic levels, and lowest concentrations occurred in the coarser-textured Coastal Plain and Coastal Flatwoods soils. Soil arsenic concentrations increased with increasing distance from the Gulf of Mexico, reflecting effects of parent materials, weathering, and pedogenesis. Similar trends were reported in the distribution of seven heavy metals in the state in an earlier study (Pettry and Switzer 1993).

Table 4. Mean arsenic concentrations averaged across all soils analyzed in the Soil Resource Areas and statistical relationships.

Region	N	Arsenic [1]
		ppm
Delta	31	15.02 a
Interior Flatwoods	7	12.73 ab
Blackland Prairie	24	11.11 b
Loess	42	9.31 b
Upper Coastal Plain	61	6.58 c
Lower Coastal Plain	81	5.79 c
Coastal Flatwoods	14	4.42 c

[1] Means with same letter are not significantly different (p = 0.05). Measured in milligrams of arsenic per kilogram of soil parent materials, which is expressed in this publication as parts per million (ppm).

Correlation analyses of all samples across the sites revealed significant correlations (p = 0.001) between arsenic concentrations and clay, CEC, and pH (Table 5). The correlation coefficient for clay was highest (r = 0.72) with smaller values for CEC (r = 0.50), and pH (r = 0.25). Lena et al. (1997) reported clay content was significantly correlated with arsenic concentrations in 40 Florida soils, but pH, CEC, and organic carbon were not strongly correlated. Individual soil resource areas did not uniformly exhibit significant correlations with the three soil parameters.

Table 5. Linear correlation coefficients for the relationship among arsenic and selected soil properties for all sites and the major Soil Resource Areas.

Region	Organic matter	pH	Clay	CEC
	%		%	*$cmol_c$ kg^{-1}*
Blackland Prairies	NS	NS	NS	NS
Coastal Flatwoods	NS	NS	0.93***	NS
Delta	NS	NS	0.78***	0.81***
Interior Flatwoods	NS	0.81 *	NS	NS
Loess	-0.44 **	NS	0.56***	NS
Lower Coastal Plain	-0.32 **	NS	0.74***	0.34 **
Upper Coastal Plain	NS	NS	0.62***	0.46***
All sites	NS	0.25***	0.72***	0.50***

* = significant at the 0.05 level; ** = significant at the 0.01 level; and *** = significant at the 0.001 level, respectively.

Blackland Prairies

Soils in these regions were dominantly underlain by Selma Chalk and Yazoo Clay parent materials. The arsenic concentrations ranged from 27.4 ppm in the surface (Ap) horizon of a clayey Okolona soil in Monroe County to 3.8 ppm in the Ap horizon of a Kipling soil in Rankin County (see Appendix). The nine soil series analyzed were clayey with a mean clay content of 46.93% and a mean CEC of 43.91 cmol_c per kilogram (Table 6). The clayey soils strongly reflected the influence of the Selma Chalk and Yazoo Clay parent materials. The mean arsenic concentration was 11.11 ppm, and there were no significant correlations with organic matter, pH, clay, or CEC (Table 5).

Table 6. Clay and organic matter contents, pH, cation exchange capacity (CEC), and arsenic concentrations in representative soils of the Blackland Prairie Soil Resource Area.

Component	N	Mean	Minimum	Maximum	Std. Dev.
Clay (%)	24	46.93	14.1	87.4	16.34
Organic matter (%)	24	2.33	0.2	7.2	2.19
pH	24	5.94	4.5	8.0	1.36
CEC ($\text{cmol}_c\ \text{kg}^{-1}$)	24	43.91	15.8	118.7	20.18
Arsenic (ppm) [1]	24	11.11	3.8	27.4	5.65

[1] Measured in milligrams of arsenic per kilogram of soil parent materials, which is expressed in this publication as parts per million (ppm).

Coastal Flatwoods

The mineral soils in this area are typically highly weathered, leached, siliceous, and very strongly acidic. The mean arsenic concentration of 4.42 ppm was the lowest of the soil resource areas in the state. The mean soil pH level (4.4) in this area was the lowest among the soil resource areas. Inclusion of the organic Croatan soil (Histosol) tended to skew the mean organic matter content of the five soils analyzed (Table 7). Arsenic concentration was highly correlated with clay content (r = 0.93) as shown in Table 5.

Table 7. Clay and organic matter contents, pH, cation exchange capacity (CEC), and arsenic concentrations in representative soils of the Coastal Flatwoods Soil Resource Area.

Component	N	Mean	Minimum	Maximum	Std. Dev.
Clay (%)	14	16.23	2.00	54.20	17.20
Organic matter (%)	14	9.50	0.30	83.60	21.76
pH	14	4.39	3.60	5.00	0.41
CEC ($\text{cmol}_c\ \text{kg}^{-1}$)	14	23.32	2.90	112.00	27.99
Arsenic (ppm) [1]	14	4.42	0.37	14.78	5.02

[1] Measured in milligrams of arsenic per kilogram of soil parent materials, which is expressed in this publication as parts per million (ppm).

Delta

Soils in this area formed in Mississippi River Alluvium and are generally considered the youngest soils in the state. This area had the highest mean arsenic concentrations in the state. The arsenic levels ranged from 2.86 ppm in the coarse-textured, fluvial Bruno soil to 26.85 ppm in the cultivated surface (Ap) horizon of a Sharkey soil in Sharkey County (Table 8). These soils generally exhibit minimal pedogenic development and arsenic concentrations strongly reflect the influence of the clayey alluvium parent material. Arsenic concentrations were correlated with clay content and CEC (Table 5).

Table 8. Clay and organic matter contents, pH, cation exchange capacity (CEC), and arsenic concentrations in representative soils of the Delta Soil Resource Area.

Component	N	Mean	Minimum	Maximum	Std. Dev.
Clay (%)	31	45.58	4.80	84.2	24.42
Organic matter (%)	31	1.59	0.20	5.9	1.09
pH	31	5.70	4.30	7.7	0.99
CEC ($cmol_c$ kg^{-1})	31	35.66	6.50	56.4	17.18
Arsenic (ppm) [1]	31	15.02	2.86	26.85	7.58

[1] Measured in milligrams of arsenic per kilogram of soil parent materials, which is expressed in this publication as parts per million (ppm).

Interior Flatwoods

Soils formed in Porters Creek Clay sediments. The mean arsenic concentration (12.73 ppm) of the four soils analyzed was the second highest in the study (Table 9). The arsenic concentration ranged from 23.58 ppm in the cultivated surface horizon (Ap) of a Wilcox soil in Winston County to 5.48 ppm in a Mayhew subsoil (Btg) horizon in Kemper County. The soils had mean clay contents and CEC values greater than 30 $cmol_c$ per kilogram (Table 9). Parent material apparently had a strong influence on arsenic levels. Arsenic concentration was significantly ($p = 0.05$) correlated with pH (Table 5).

Table 9. Clay and organic matter contents, pH, cation exchange capacity (CEC), and arsenic concentrations in representative soils of the Interior Flatwoods Soil Resource Area.

Component	N	Mean	Minimum	Maximum	Std. Dev.
Clay (%)	7	34.50	23.10	64.70	14.56
Organic matter (%)	7	2.27	0.30	7.00	2.55
pH	7	4.60	3.90	5.30	0.45
CEC ($cmol_c$ kg^{-1})	7	33.25	23.00	44.50	7.64
Arsenic (ppm) [1]	7	12.73	5.48	23.58	6.90

[1] Measured in milligrams of arsenic per kilogram of soil parent materials, which is expressed in this publication as parts per million (ppm).

Loess

Soil formed in uniform wind-deposited Peorian loess silt, rich in unweathered minerals. The area is dominated by Alfisols, which have base saturation levels exceeding 35%. Clay contents in the 16 soils analyzed ranged from 52.5% to 4.2% with a mean value of 18.89% (Table 10). Arsenic concentrations varied from 19.35 ppm in a Loring subsoil (Bt) horizon to 1.95 ppm in a Kolin surface (A) horizon. Arsenic concentration was negatively correlated ($p = 0.01$) with organic matter and positively correlated ($p = 0.001$) with clay content (Table 5).

Table 10. Clay and organic matter contents, pH, cation exchange capacity (CEC), and arsenic concentrations in representative soils of the Loess Soil Resource Area.

Component	N	Mean	Minimum	Maximum	Std. Dev.
Clay (%)	42	18.89	4.20	52.50	10.93
Organic matter (%)	42	1.34	0.00	5.00	1.33
pH	42	5.21	3.90	6.70	0.63
CEC (cmol$_c$ kg^{-1})	42	14.66	6.50	45.50	7.42
Arsenic (ppm) [1]	42	9.31	1.95	19.35	4.32

[1] Measured in milligrams of arsenic per kilogram of soil parent materials, which is expressed in this publication as parts per million (ppm).

Lower Coastal Plain

Soils in this area formed in weathered, stratified deposits of sand, silt, clay, and gravel. The Citronelle Formation was parent material for many of the 30 soil series analyzed. The leached, siliceous soils exhibited strong pedogenic development with ochric epipedons and illuviated argillic subsoils. Arsenic concentrations ranged from 22 ppm in a clayey, iron-rich Lucedale subsoil containing 35.5% clay (see Appendix) to 0.26 ppm in a sandy, leached Lakeland subsoil (Table 11). Arsenic concentration was positively correlated ($p = 0.001$) with clay ($r = 0.62$) and CEC ($r = 0.46$) and negatively correlated ($p = 0.01$) with organic matter ($r = -0.32$) as shown in Table 5.

Table 11. Clay and organic matter contents, pH, cation exchange capacity (CEC), and arsenic concentrations in representative soils of the Lower Coastal Plain Soil Resource Area.

Component	N	Mean	Minimum	Maximum	Std. Dev.
Clay (%)	81	16.31	0.00	69.5	15.61
Organic matter (%)	81	1.56	0.10	7.8	1.64
pH	81	4.93	4.00	10.8	0.78
CEC (cmol$_c$ kg^{-1})	81	12.04	1.30	45.1	11.31
Arsenic (ppm) [1]	81	5.79	0.26	22.0	5.34

[1] Measured in milligrams of arsenic per kilogram of soil parent materials, which is expressed in this publication as parts per million (ppm).

Upper Coastal Plain

Soils formed in several geologic formations dominated by stratified deposits of sand, silt, and clays. Soils analyzed formed in the Wilcox Group, Tombigbee Sand, Neshoba Sand, Basic City Shale, and Winona Formation. Soils in this area had slightly higher mean clay contents, pH levels, CEC, and arsenic concentrations than Lower Coastal Plain soils. The mean arsenic concentrations of the 28 soil series analyzed in this area ranged from 22.47 ppm in the subsoil of an iron-rich Atwood soil containing 35.4% clay to 0.33 ppm in a siliceous Lakeland subsoil containing 0.5% clay (see Appendix, Table 12). Arsenic was correlated (p = 0.001) with clay (r = 0.62) and CEC (r = 0.46).

Table 12. Clay and organic matter contents, pH, cation exchange capacity (CEC), and arsenic concentrations in representative soils of the Upper Coastal Plain Soil Resource Areas.

Component	N	Mean	Minimum	Maximum	Std. Dev.
Clay (%)	61	19.57	0.50	58.20	13.20
Organic Matter (%)	61	1.48	0.10	6.40	1.64
pH	61	5.01	3.80	6.50	0.61
CEC ($cmol_c kg^{-1}$)	61	14.29	1.30	45.60	8.18
Arsenic (ppm) [1]	61	6.58	0.33	22.47	4.86

[1] Measured in milligrams of arsenic per kilogram of soil parent materials, which is expressed in this publication as parts per million (ppm).

Water-Soluble Arsenic

Background arsenic concentrations provide essential data to indicate the extent of anthropogenic arsenic accumulation from cultural activities. However, total arsenic concentration may not be the most reliable indicator of phototoxicity to plants or potential leaching and movement in the soil. The phytotoxicity of arsenic may be influenced more by the chemical form than total amount. Woolson et al. (1971) determined that soils with water-soluble arsenic generally were more phytotoxic than those with no detectable water-soluble arsenic. Johnson and Hiltbold (1969) showed arsenic was tightly bound in soils and unlikely to be bioavailable or mobile.

Selected parent materials and soils were analyzed to determine potential arsenic emission naturally occurring in the soil system. Water-soluble arsenic in the 10 samples analyzed ranged from 0.66 ppb in Wilcox Group to 13.02 ppb in the cultivated surface (Ap) horizon of a Sharkey soil from the Delta (Table 13). The literature (Pais and Jones 1997) indicates that arsenic content of fresh water ranges from 0.1 to 800 ppb with a reference value of 0.5 microgram per liter. Although the Winona Formation had the highest arsenic concentrations of the parent materials analyzed in this study, the water-soluble fraction is very small (2.02, 4.24, and 1.83 ppb). Soils and parent materials with the highest total arsenic concentrations may not have the greatest bioavailable (water-soluble) arsenic. The bioavailable arsenic levels detected in the soils and parent materials are in the low range of values reported to occur globally in fresh water.

Table 13. Water-soluble arsenic (bioavailable) levels in selected parent materials and soils of Mississippi.

Material	Water-soluble arsenic [1]
	ppb
Sharkey Ap Horizon	13.02
Byram C Horizon	3.27
Selma Chalk Parent Material	10.36
Yazoo Clay Parent Material	2.18
Winona Formation Parent Material	4.24
Winona Formation Parent Material	2.02
Winona Formation Parent Material	1.83
Citronelle Formation Parent Material	0.68
Wilcox Group Parent Material	0.66

[1] Measured in nanograms of arsenic per gram of soil and parent materials, which is expressed in this publication as parts per billion (ppb).

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Appendix Table. Organic matter contents, pH, clay contents, CEC, and arsenic concentrations of 260 soil samples.

Series	Classification	Horizon	Depth	Organic matter	pH	Clay	CEC	Arsenic [1]	County	Region [2]
			inches	*%*		*%*	*cmol kg^{-1}*	*ppm*		
Adler	Aquic Udifluvents	Ap	0-5	1.4	4.9	6.5	6.6	2.86	Leflore	D
Adler	Aquic Udifluvents	C	20-33	0.2	5.5	7.5	6.5	3.78	Leflore	D
Alligator	Alic Dystraquerts	Ap	0-5	2.2	4.9	57.3	42.1	12.61	Carroll	D
Alligator	Alic Dystraquerts	B21g	5-19	0.8	4.3	62.3	45.2	12.58	Carroll	D
Alligator	Alic Dystraquerts	Ap	0-5	5.9	4.7	67.7	52.6	13.23	Leflore	D
Alligator	Alic Dystraquerts	Bg2	21-30	0.9	4.6	84.2	56.4	15.43	Leflore	D
Alligator	Alic Dystraquerts	Ap	0-6	2.4	7.0	35.3	30.9	16.27	Humphreys	D
Alligator	Alic Dystraquerts	Bg	10-20	1.0	5.8	56.6	41.3	19.36	Humphreys	D
Alligator	Alic Dystraquerts	A	0-6	2.5	4.3	60.0	45.3	20.03	Holmes	D
Alligator	Alic Dystraquerts	Bg2	12-20	0.7	4.8	64.4	47.4	19.54	Holmes	D
Alligator	Alic Dystraquerts	Ap	0-6	2.0	6.4	58.6	45.8	26.80	Sunflower	D
Alligator	Alic Dystraquerts	Bg	10-20	1.3	6.6	67.9	50.7	22.62	Sunflower	D
Annemaine	Aquic Hapludults	A	0-6	3.2	4.7	20.5	17.4	4.79	Jones	LCP
Annemaine	Aquic Hapludults	Bt2	14-25	1.2	4.4	55.9	29.9	16.10	Jones	LCP
Ariel	Fluventic Dystrochrepts	Ap	0-8	1.8	4.2	10.6	12.7	3.80	Franklin	L
Ariel	Fluventic Dystrochrepts	Bw1	8-28	0.6	4.3	16.7	12.5	4.56	Franklin	L
Ariel	Fluventic Dystrochrepts	Ap	0-8	1.5	5.7	12.6	11.2	6.22	Choctaw	UCP
Ariel	Fluventic Dystrochrepts	B22	19-26	0.2	5.1	20.2	9.0	4.73	Choctaw	UCP
Arundel	Typic Hapludults	A1	0-4	4.0	4.3	6.4	15.4	5.91	Lauderdale	UCP
Arundel	Typic Hapludults	B22t	10-30	0.6	4.1	58.2	45.6	16.76	Lauderdale	UCP
Atmore	Plinthic Paleaquults	A	0-8	3.8	4.0	7.0	11.1	1.15	Stone	LCP
Atmore	Plinthic Paleaquults	Bt	16-32	0.6	4.4	9.5	5.4	1.24	Stone	LCP
Atwood	Typic Paleudalfs	Ap	0-1	5.7	5.2	9.2	12.9	5.42	Pontotoc	UCP
Atwood	Typic Paleudalfs	Bt2	11-49	0.4	5.4	35.4	13.3	22.47	Pontotoc	UCP
Bassfield	Typic Hapludults	A1	0-4	1.2	5.3	4.5	5.1	1.51	Perry	LCP
Bassfield	Typic Hapludults	Bt2	14-27	0.2	5.1	14.9	6.2	5.27	Perry	LCP
Bassfield	Typic Hapludults	Ap	0-4	3.6	5.5	5.6	11.3	4.19	Forrest	LCP
Bassfield	Typic Hapludults	Bt1	7-13	0.5	4.9	14.5	6.5	6.42	Forrest	LCP
Bassfield	Typic Hapludults	Ap	0-6	1.4	5.6	3.8	6.1	1.03	Marion	LCP
Bassfield	Typic Hapludults	A2	6-10	0.5	5.2	6.2	5.2	1.35	Marion	LCP
Benndale	Typic Paleudults	Ap	0-5	2.7	4.4	4.5	6.8	1.09	Stone	LCP
Benndale	Typic Paleudults	Bt2	22-32	0.1	4.8	12.5	4.2	3.51	Stone	LCP
Bibb	Typic Fluvaquents	Ap	0-5	1.6	4.8	5.4	4.5	1.12	Neshoba	UCP
Bibb	Typic Fluvaquents	C	15-28	0.2	4.7	14.8	5.3	2.01	Neshoba	UCP
Bigbee	Typic Quartzipsamments	Ap	0-9	1.2	4.6	5.2	4.5	1.19	Jones	LCP
Bigbee	Typic Quartzipsamments	C1	9-38	0.2	4.3	5.4	2.5	0.90	Jones	LCP
Bonn	Glossic Natraqualfs	A	0-7	2.9	4.7	17.0	14.1	5.03	Grenada	L
Bruno	Typic Udifluvents	Ap	0-4	2.2	7.1	13.4	17.5	5.72	Tunica	D
Bruno	Typic Udifluvents	AC	17-22	0.3	7.7	4.8	7.4	3.56	Tunica	D
Bude	Glossaquic Fragiudalfs	Ap	0-5	3.7	5.7	14.4	18.3	5.75	Franklin	L
Bude	Glossaquic Fragiudalfs	Bw2	11-19	0.3	4.8	28.8	13.9	11.74	Franklin	L
Bude	Glossaquic Fragiudalfs	Ap	0-7	2.0	4.9	10.7	10.9	4.10	Pike	LCP
Bude	Glossaquic Fragiudalfs	Bt	7-20	0.3	4.9	15.2	7.9	4.91	Pike	LCP
Bude	Glossaquic Fragiudalfs	Bt2	7-20	0.1	5.1	10.7	13.6	8.61	Copiah	L
Byram	Typic Fragiudalfs	Ap	0-5	1.5	5.3	16.9	13.2	8.64	Madison	L
Byram	Typic Fragiudalfs	B22t	14-20	0.3	5.4	27.3	17.1	13.77	Madison	L
Cahaba	Typic Hapludults	Ap	0-5	1.6	5.1	2.5	7.4	2.31	Simpson	LCP
Cahaba	Typic Hapludults	Bt2	18-29	0.1	5.1	14.9	5.4	6.93	Simpson	LCP
Calhoun	Typic Glossaqualfs	A	0-5	2.7	4.7	10.6	9.9	4.97	Attala	UCP
Calhoun	Typic Glossaqualfs	Btg	20-32	0.5	5.4	18.0	11.1	6.82	Attala	UCP

[1] Measured in milligrams of arsenic per kilogram of soil parent materials, which is expressed in this publication as parts per million (ppm).

[2] Region: BP = Blackland Prairie; CF = Coastal Flatwoods; D = Delta; IF = Interior Flatwoods; L = Loess; LCP = Lower Coastal Plain; and UCP = Upper Coastal Plain.

Appendix Table (continued). Organic matter contents, pH, clay contents, CEC, and arsenic concentrations of 260 soil samples.

Series	Classification	Horizon	Depth	Organic matter	pH	Clay	CEC	Arsenic [1]	County	Region [2]
			inches	*%*		*%*	*cmol kg^{-1}*	*ppm*		
Calhoun	Typic Glossaqualfs	Ap	0-7	1.7	5.3	12.4	12.5	9.89	Madison	L
Calhoun	Typic Glossaqualfs	Bt	15-23	0.9	4.7	16.9	12.4	4.74	Madison	L
Calloway	Glossaquic Fragiudalfs	Ap	0-7	1.3	6.1	10.4	10.7	11.86	Attala	UCP
Calloway	Glossaquic Fragiudalfs	Bw2	11-17	0.2	4.8	18.2	13.4	16.39	Attala	UCP
Chastain	Typic Fluvaquents	Ap	0-6	5.5	4.7	42.2	33.4	14.78	Jackson	CF
Chastain	Typic Fluvaquents	C	10-15	0.7	4.5	31.1	18.0	9.97	Jackson	CF
Columbus	Aquic Hapludults	Ap	0-5	2.3	4.4	17.1	14.2	4.90	Simpson	LCP
Columbus	Aquic Hapludults	Bt2	18-28	0.3	4.8	23.1	11.8	6.44	Simpson	LCP
Commerce	Aeric Fluvaquents	Ap	0-4	3.1	5.7	58.4	45.8	24.55	Tunica	D
Commerce	Aeric Fluvaquents	C	21-26	1.4	7.3	37.2	32.0	13.13	Tunica	D
Croatan	Terric Medisaprists	Oa1	0-8	83.6	4.2	9.4	112.0	3.32	Jackson	CF
Croatan	Terric Medisaprists	2Ag	16-50	13.4	4.1	21.8	38.3	2.07	Jackson	CF
Daleville	Typic Paleaquults	A	0-4	1.6	4.5	17.8	15.5	4.53	Kemper	UCP
Daleville	Typic Paleaquults	Btg1	9-18	0.4	4.4	21.9	15.4	3.05	Kemper	UCP
Deerford	Glossic Natraqualfs	Ap	0-7	2.1	6.5	11.6	9.2	6.46	Attala	L
Deerford	Glossic Natraqualfs	BE	11-28	0.1	5.0	32.6	24.9	12.41	Attala	L
Dubbs	Typic Hapludalfs	Ap	0-7	1.3	5.7	17.4	15.0	7.21	Leflore	D
Dubbs	Typic Hapludalfs	Bg2	23-36	0.3	5.1	23.3	20.0	9.01	Leflore	D
Dundee	Aeric Ochraqualfs	Ap	0-5	2.1	3.9	23.1	22.4	8.13	Carroll	L
Dundee	Aeric Ochraqualfs	B22t	15-23	0.3	4.7	30.4	24.4	6.63	Carroll	L
Dundee	Aeric Ochraqualfs	Ap	0-8	0.9	6.5	20.5	17.1	7.74	Leflore	D
Dundee	Aeric Ochraqualfs	Bt	16-26	0.4	4.8	31.5	27.7	9.38	Leflore	D
Eustis	Psammentic Paleudults	A1	0-6	2.7	6.1	4.0	7.5	1.04	Hancock	LCP
Eustis	Psammentic Paleudults	B21t	26-44	0.6	5.5	6.2	3.5	1.35	Hancock	LCP
Falaya	Aeric Fluvaquents	Ap	0-11	1.3	6.3	7.9	9.6	8.05	Leflore	D
Falaya	Aeric Fluvaquents	Cg1	16-30	1.4	4.6	8.0	7.7	3.98	Leflore	D
Falaya	Aeric Fluvaquents	Ap	0-7	0.7	5.8	4.5	18.0	6.37	Calhoun	UCP
Falaya	Aeric Fluvaquents	C	12-20	0.4	4.3	15.3	11.1	4.75	Calhoun	UCP
Falkner	Aquic Paleudalfs	Bt2	13-28	0.4	4.5	36.9	27.6	17.10	Noxubee	IF
Falkner	Aquic Paleudalfs	Ap	0-5	3.3	5.2	15.4	15.3	3.31	Scott	UCP
Falkner	Aquic Paleudalfs	Bt2	11-22	0.3	4.8	27.4	16.4	4.50	Scott	UCP
Freest	Aquic Paleudalfs	A	0-5	0.7	4.4	11.5	21.5	2.06	Kemper	UCP
Freest	Aquic Paleudalfs	Bt1	9-23	0.3	3.8	23.2	21.8	3.54	Kemper	UCP
Freest	Aquic Paleudalfs	Ap	0-5	7.4	5.6	5.2	82.3	4.42	Marion	LCP
Freest	Aquic Paleudalfs	B21t	9-18	0.3	5.0	23.4	12.8	9.73	Marion	LCP
Freest	Aquic Paleudalfs	Ap	0-6	2.4	4.7	7.1	8.6	2.49	Simpson	LCP
Freest	Aquic Paleudalfs	Bt2	21-30	0.2	5.0	35.7	13.5	8.10	Simpson	LCP
Gillsburg	Aeric Fluvaquents	Ap	0-5	1.2	5.7	8.8	7.9	7.30	Madison	L
Gillsburg	Aeric Fluvaquents	C	15-30	0.3	4.3	14.7	9.4	5.24	Madison	L
Gillsburg	Aeric Fluvaquents	Ap	0-5	1.6	6.4	14.5	10.7	10.47	Lafayette	L
Gillsburg	Aeric Fluvaquents	C	12-20	0.9	5.1	15.2	8.8	5.29	Lafayette	L
Grenada	Glossic Fraguidalfs	Ap	0-5	2.3	6.7	7.6	12.8	7.32	Holmes	L
Grenada	Glossic Fraguidalfs	Bw	5-18	0.4	6.3	26.2	15.7	15.41	Holmes	L
Griffith	Vertic Haplaquolls	Ap	0-6	4.1	7.6	48.9	58.7	15.18	Noxubee	BP
Griffith	Vertic Haplaquolls	Ai2	18-28	1.3	7.7	55.5	57.5	17.36	Noxubee	BP
Guyton	Typic Glossaqualfs	A1	0-5	3.5	5.1	8.8	8.6	2.10	Neshoba	UCP
Guyton	Typic Glossaqualfs	Bt1g	17-30	2.2	4.8	32.3	22.8	2.95	Neshoba	UCP
Guyton	Typic Glossaqualfs	Ap1	0-5	2.6	5.4	16.9	14.2	7.42	Prentiss	UCP
Guyton	Typic Glossaqualfs	B/E1	26-33	0.4	5.0	46.2	23.9	10.02	Prentiss	UCP
Harleston	Aquic Paleudults	A	0-5	5.0	4.8	5.3	13.7	1.67	Stone	LCP
Harleston	Aquic Paleudults	Bt2	25-35	0.1	4.4	13.4	5.8	1.22	Stone	LCP
Heidel	Typic Paleudults	A	0-6	2.3	4.8	4.2	7.9	1.51	Perry	LCP
Heidel	Typic Paleudults	Bt1	13-33	0.1	5.2	24.5	6.3	10.14	Perry	LCP
Houlka	Vertic Haplaquepts	Ap	0-6	5.5	5.5	49.3	48.2	7.37	Scott	BP
Houlka	Vertic Haplaquepts	B2g	12-24	0.7	4.6	64.6	48.3	8.10	Scott	BP
Ichusa	Aquic Dystruderts	A	0-4	7.1	5.0	36.6	42.8	9.48	Smith	BP
Ichusa	Aquic Dystruderts	Bt	11-31	0.5	5.1	56.1	38.0	12.71	Smith	BP

[1] Measured in milligrams of arsenic per kilogram of soil parent materials, which is expressed in this publication as parts per million (ppm).

[2] Region: BP = Blackland Prairie; CF = Coastal Flatwoods; D = Delta; IF = Interior Flatwoods; L = Loess; LCP = Lower Coastal Plain; and UCP = Upper Coastal Plain.

Appendix Table (continued). Organic matter contents, pH, clay contents, CEC, and arsenic concentrations of 260 soil samples.

Series	Classification	Horizon	Depth	Organic matter	pH	Clay	CEC	Arsenic [1]	County	Region [2]
			inches	*%*		*%*	*cmol kg^{-1}*	*ppm*		
Kipling	Vertic Hapludalfs	Ap	0-5	3.3	4.5	14.1	15.8	3.85	Rankin	BP
Kipling	Vertic Hapludalfs	Bt1	12-26	0.4	4.5	51.5	35.3	9.10	Rankin	BP
Kipling	Vertic Hapludalfs	Ap	0-7	4.1	4.7	55.8	48.3	8.47	Scott	BP
Kipling	Vertic Hapludalfs	Bt2	24-33	0.3	4.8	59.8	42.2	7.89	Scott	BP
Kirkville	Fluvaquentic Dystrochrepts	Ap	0-5	1.5	4.9	6.8	6.6	2.75	Simpson	LCP
Kirkville	Fluvaquentic Dystrochrepts	Bt	15-24	0.1	5.0	6.8	6.0	2.59	Simpson	LCP
Kolin	Haplic Glossudalfs	A	0-2	3.9	4.4	5.1	11.8	1.95	Franklin	L
Kolin	Haplic Glossudalfs	Ap	0-7	3.1	5.2	15.7	13.6	9.45	Copiah	LCP
Kolin	Haplic Glossudalfs	B22t	14-26	0.1	5.3	25.4	32.4	14.97	Copiah	LCP
Lakeland	Typic Quartzipsamments	A1	0-2	2.1	4.7	2.8	5.2	0.78	Lauderdale	UCP
Lakeland	Typic Quartzipsamments	C1	6-16	0.6	4.8	0.5	2.8	0.33	Lauderdale	UCP
Lakeland	Typic Quartzipsamments	A1	0-6	1.5	5.4	4.2	3.5	0.51	Pearl River	LCP
Lakeland	Typic Quartzipsamments	A3	18-52	0.1	5.1	0.0	1.3	0.26	Pearl River	LCP
Leeper	Vertic Epiaquepts	Ap	0-4	2.7	7.2	33.4	35.0	8.36	Kemper	BP
Leeper	Vertic Epiaquepts	Bg2	13-29	0.5	7.5	30.8	26.5	5.40	Kemper	BP
Leon	Aeric Haplaquods	A	0-5	13.2	3.7	2.6	32.2	0.86	Jackson	CF
Leon	Aeric Haplaquods	Bh2	15-22	2.0	4.1	2.5	9.6	0.38	Jackson	CF
Leon	Aeric Haplaquods	A	0-5	4.8	3.6	2.0	14.0	0.88	Jackson	CF
Leon	Aeric Haplaquods	Bh2	21-27	1.0	4.4	8.1	8.0	4.33	Jackson	CF
Lexington	Typic Paleudalfs	A	0-2	5.0	5.1	8.4	14.6	6.31	Marshall	L
Lexington	Typic Paleudalfs	Bt2	12-38	0.3	5.1	29.8	14.8	17.91	Marshall	L
Loring	Oxyaquic Fragiudalfs	Ap	0-5	1.2	4.8	10.6	8.5	4.85	Holmes	L
Loring	Oxyaquic Fragiudalfs	Bt2	10-26	0.2	4.6	24.3	14.6	13.25	Holmes	L
Loring	Oxyaquic Fragiudalfs	A	0-5	2.3	5.4	11.4	12.2	8.53	Hinds	L
Loring	Oxyaquic Fragiudalfs	Bt1	10-15	0.4	5.8	23.1	12.9	15.93	Hinds	L
Loring	Oxyaquic Fragiudalfs	Ap	0-6	3.0	5.7	15.1	14.6	16.37	Wilkinson	L
Loring	Oxyaquic Fragiudalfs	Bt	6-12	0.8	5.6	30.8	17.0	19.35	Wilkinson	L
Lorman	Vertic Hapludalfs	Ap	0-3	2.9	4.7	5.3	8.4	2.78	Wayne	LCP
Lorman	Vertic Hapludalfs	Bt1	12-18	0.3	4.7	40.3	18.8	15.26	Wayne	LCP
Lorman	Vertic Hapludalfs	Ap	0-8	2.9	4.4	6.8	7.2	1.09	Copiah	LCP
Lorman	Vertic Hapludalfs	Bt1	8-28	0.5	4.4	53.5	31.4	4.35	Copiah	LCP
Lorman	Vertic Hapludalfs	Bt1	5-10	0.9	4.5	52.2	45.5	9.24	Franklin	L
Lucedale	Rhodic Paleudults	Ap1	0-6	2.4	5.6	11.5	8.8	12.86	Greene	LCP
Lucedale	Rhodic Paleudults	Bt1	9-20	0.3	5.4	25.7	5.2	19.81	Greene	LCP
Lucedale	Rhodic Paleudults	Ap	0-8	3.3	4.9	19.1	16.3	16.28	George	LCP
Lucedale	Rhodic Paleudults	Bt2	24-40	0.2	4.3	35.5	8.2	22.00	George	LCP
Luverne	Typic Hapludults	Ap	0-2	5.5	5.2	5.9	17.7	3.27	Prentiss	UCP
Luverne	Typic Hapludults	Bt2	20-32	0.2	4.8	39.7	19.4	16.54	Prentiss	UCP
Maben	Ultic Hapludalfs	Ap	0-2	6.4	4.7	8.9	16.2	3.25	Winston	UCP
Maben	Ultic Hapludalfs	Bt2	19-28	0.4	4.9	51.0	23.8	8.66	Winston	UCP
Maben	Ultic Hapludalfs	Ap	0-5	1.8	4.6	24.4	15.6	10.19	Choctaw	UCP
Maben	Ultic Hapludalfs	B22t	15-30	0.2	4.6	34.2	30.0	11.68	Choctaw	UCP
Malbis	Plinthic Paleudults	Ap	0-6	3.4	6.0	3.2	12.4	1.89	Pearl River	LCP
Malbis	Plinthic Paleudults	B21t	11-25	0.3	4.8	20.7	7.8	7.33	Pearl River	LCP
Malbis	Plinthic Paleudults	Ap	0-8	2.5	4.7	12.3	9.6	3.37	Jackson	LCP
Malbis	Plinthic Paleudults	Bt2	16-27	0.2	4.9	21.7	7.8	7.15	Jackson	LCP
Mantachie	Aeric Endoaquepts	Ap	0-4	1.0	5.3	6.2	6.1	1.62	Prentiss	UCP
Mantachie	Aeric Endoaquepts	Bg1	17-34	0.2	4.3	18.4	12.8	2.07	Prentiss	UCP
Mathiston	Aeric Fluvaquents	A1	0-4	4.1	4.8	23.1	26.7	9.31	Winston	IF
Mathiston	Aeric Fluvaquents	C	19-34	0.4	4.7	29.4	23.0	10.30	Winston	IF
Mayhew	Chromic Dystraquerts	A1	0-3	2.9	4.2	25.1	36.0	5.50	Kemper	IF
Mayhew	Chromic Dystraquerts	Btg1	7-13	0.3	3.9	37.8	38.1	5.48	Kemper	IF
Maytag	Oxyaquic Hapluderts	Ap	0-4	7.2	7.4	63.3	64.0	6.86	Scott	BP
Maytag	Oxyaquic Hapluderts	Bk2	24-39	0.2	7.5	87.4	118.7	8.42	Scott	BP
Maytag	Oxyaquic Hapluderts	Ap	0-6	5.3	7.6	47.0	55.2	12.34	Smith	BP

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Appendix Table (continued). Organic matter contents, pH, clay contents, CEC, and arsenic concentrations of 260 soil samples.

Series	Classification	Horizon	Depth	Organic matter	pH	Clay	CEC	Arsenic [1]	County	Region [2]
			inches	*%*		*%*	*cmol kg^{-1}*	*ppm*		
Maytag	Oxyaquic Hapluderts	Bk1	11-17	0.2	8.0	62.4	49.5	11.30	Smith	BP
McLaurin	Typic Paleudults	Ap	0-6	0.5	4.6	1.5	2.3	0.52	Lauderdale	UCP
McLaurin	Typic Paleudults	B22t	14-38	0.2	4.8	18.0	8.4	6.29	Lauderdale	UCP
Memphis	Typic Hapludalfs	Ap	0-7	1.4	5.5	4.2	6.5	8.41	Wilkinson	L
Memphis	Typic Hapludalfs	Bt2	23-40	0.2	5.3	25.4	15.4	16.20	Wilkinson	L
Memphis	Typic Hapludalfs	Ap	0-7	0.5	5.9	11.4	8.7	10.04	Holmes	L
Memphis	Typic Hapludalfs	Bt2	19-48	0.3	5.1	25.6	15.8	10.71	Holmes	L
Okeelala	Ultic Hapludalfs	Bt1	18-26	0.1	5.7	19.6	8.9	5.43	Prentiss	UCP
Okolona	Oxyaquic Hapluderts	Ap	0-10	2.3	6.4	48.0	43.7	27.43	Monroe	BP
Okolona	Oxyaquic Hapluderts	Bwss	30-40	0.7	7.8	56.1	45.2	24.27	Monroe	BP
Ora	Typic Fragiudults	A1	0-4	2.2	4.4	6.3	8.6	1.58	Pike	LCP
Ora	Typic Fragiudults	Bt21	10-24	0.2	4.9	29.5	15.2	13.51	Pike	LCP
Paden	Glossic Fragiudults	Ap	0-6	1.3	6.4	8.6	8.8	7.36	Tishomingo	UCP
Paden	Glossic Fragiudults	Bt	6-19	0.3	4.4	22.8	12.2	11.07	Tishomingo	UCP
Pelahatchie	Aquic Hapludalfs	Ap	0-4	2.3	5.0	19.0	18.7	10.73	Rankin	BP
Pelahatchie	Aquic Hapludalfs	Bt2	14-21	1.1	5.0	31.7	24.9	7.85	Rankin	BP
Pelahatchie	Aquic Hapludalfs	Ap	0-8	2.6	4.7	31.1	29.4	6.39	Scott	BP
Pelahatchie	Aquic Hapludalfs	Bt2	18-25	1.1	4.7	49.5	40.9	8.02	Scott	BP
Petal	Typic Paleudalfs	A1	0-4	1.6	4.7	2.5	4.7	1.06	Marion	LCP
Petal	Typic Paleudalfs	B21t	10-16	0.5	4.9	35.0	16.6	8.90	Marion	LCP
Petal	Typic Paleudalfs	A	0-4	1.7	4.4	2.5	7.3	1.63	Forrest	LCP
Petal	Typic Paleudalfs	Bt1	10-17	0.2	4.5	16.7	7.7	5.53	Forrest	LCP
Poarch	Plinthic Paleudults	Ap	0-6	3.1	4.8	7.5	10.2	2.55	Pearl River	LCP
Poarch	Plinthic Paleudults	Bt2	26-36	0.2	4.4	14.3	5.2	3.92	Pearl River	LCP
Prentiss	Glossic Fragiudults	Ap	0-4	2.5	5.2	8.9	11.2	6.54	Forrest	LCP
Prentiss	Glossic Fragiudults	Bt2	10-20	0.2	5.0	23.0	9.1	12.95	Forrest	LCP
Providence	Typic Fragiudalfs	Ap	0-3	6.2	5.9	7.9	19.8	3.57	Simpson	LCP
Providence	Typic Fragiudalfs	Bt	13-22	0.4	5.0	32.2	16.5	18.80	Simpson	LCP
Providence	Typic Fragiudalfs	2Btx2	28-38	0.1	5.3	14.4	8.6	5.20	Simpson	LCP
Providence	Typic Fragiudalfs	Ap	0-3	4.8	5.0	5.6	14.3	4.70	Wilkinson	L
Providence	Typic Fragiudalfs	Btx1	19-27	0.1	5.5	24.2	13.3	12.77	Wilkinson	L
Providence	Typic Fragiudalfs	2Btx1	37-52	0.0	5.4	18.0	7.5	4.25	Wilkinson	L
Providence	Typic Fragiudalfs	Ap	0-5	3.2	5.3	4.5	9.4	5.32	Wilkinson	L
Providence	Typic Fragiudalfs	Bt	9-19	0.4	5.3	22.7	11.3	12.95	Wilkinson	L
Providence	Typic Fragiudalfs	2Btx	33-39	0.0	5.7	17.5	8.5	8.40	Wilkinson	L
Quitman	Aquic Paleudults	A	0-4	7.8	4.5	8.8	18.6	1.33	Smith	LCP
Quitman	Aquic Paleudults	Btx1	6-14	0.4	4.8	14.4	9.2	1.92	Smith	LCP
Quitman	Aquic Paleudults	Ap	0-4	1.4	6.5	8.2	7.6	3.23	Tishomingo	UCP
Quitman	Aquic Paleudults	Bt22	10-22	0.4	4.7	21.4	12.6	8.07	Tishomingo	UCP
Rosebloom	Typic Fluvaquents	Ap	0-9	2.4	5.0	24.8	18.3	4.11	Choctaw	UCP
Rosebloom	Typic Fluvaquents	C	15-30	0.6	4.4	48.9	28.3	7.09	Choctaw	UCP
Ruston	Typic Paleudults	Ap	0-6	0.5	6.5	18.7	9.4	8.21	Tishomingo	UCP
Ruston	Typic Paleudults	Bt2	6-26	0.1	5.0	21.2	9.0	7.38	Tishomingo	UCP
Savannah	Typic Fragiudults	Ap	0-4	1.9	4.7	10.8	1.3	2.98	Neshoba	UCP
Savannah	Typic Fragiudults	Bt2	12-23	0.5	4.9	25.2	10.3	8.42	Neshoba	UCP
Savannah	Typic Fragiudults	Ap	0-4	2.5	4.7	6.7	8.7	3.39	Jones	LCP
Savannah	Typic Fragiudults	Bt1	9-24	0.3	4.5	23.7	8.7	6.67	Jones	LCP
Savannah	Typic Fragiudults	Ap	0-6	1.3	6.4	6.6	6.8	3.73	Prentiss	UCP
Savannah	Typic Fragiudults	Bt2	14-22	0.1	4.7	16.5	8.8	5.22	Prentiss	UCP
Sharkey	Aeric Epiaquerts	Ap	0-5	2.4	6.6	70.7	54.7	16.69	Tunica	D
Sharkey	Aeric Epiaquerts	Bg2	17-26	1.3	6.9	71.6	55.8	13.87	Tunica	D
Sharkey	Aeric Epiaquerts	Ap	0-6	1.9	4.6	57.8	42.9	26.63	Yazoo	D
Sharkey	Aeric Epiaquerts	Bg	10-20	0.8	4.7	64.0	47.2	21.31	Yazoo	D
Sharkey	Aeric Epiaquerts	Ap	0-8	2.3	4.7	44.2	31.3	15.29	Wilkinson	D
Sharkey	Aeric Epiaquerts	Ap	0-9	2.3	6.0	56.5	53.6	26.85	Sharkey	D
Sharkey	Aeric Epiaquerts	Bssg1	16-37	1.4	6.7	63.6	50.2	24.59	Sharkey	D
Sharkey	Aeric Epiaquerts	Ap	0-6	2.1	5.8	63.5	47.3	24.20	Washington	D
Sharkey	Aeric Epiaquerts	Bg	20-30	1.1	6.2	70.4	52.1	18.80	Washington	D
Siwell	Typic Hapludalfs	Ap	0-8	1.9	5.5	14.8	13.9	8.68	Madison	L
Siwell	Typic Hapludalfs	Bt2	13-18	0.5	4.6	52.5	38.2	13.89	Madison	L
Smithdale	Typic Hapludults	A	0-3	3.1	5.1	4.5	7.6	1.83	Prentiss	UCP

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Appendix Table (continued). Organic matter contents, pH, clay contents, CEC, and arsenic concentrations of 260 soil samples.

Series	Classification	Horizon	Depth	Organic matter	pH	Clay	CEC	Arsenic [1]	County	Region [2]
			inches	*%*		*%*	*cmol kg^{-1}*	*ppm*		
Smithdale	Typic Hapludults	Bt1	14-26	0.2	5.2	28.8	10.8	12.13	Prentiss	UCP
Smithdale	Typic Hapludults	A	0-5	2.7	4.0	5.0	9.8	1.39	Smith	LCP
Smithdale	Typic Hapludults	Bt1	11-21	0.3	4.7	44.1	10.8	16.22	Smith	LCP
Stough	Fragiaquic Paleudults	Ap	0-6	1.2	6.3	6.0	5.9	2.13	Neshoba	UCP
Stough	Fragiaquic Paleudults	Bt2	10-20	1.4	4.4	14.9	7.9	5.01	Neshoba	UCP
Stough	Fragiaquic Paleudults	Ap	0-6	1.5	4.7	5.6	7.8	4.55	Marion	LCP
Stough	Fragiaquic Paleudults	Bt2	10-18	0.2	4.7	10.6	5.4	4.52	Marion	LCP
Stough	Fragiaquic Paleudults	Ap	0-7	1.8	5.1	10.5	11.7	4.46	Pike	LCP
Stough	Fragiaquic Paleudults	B2	7-23	0.2	5.1	13.9	7.0	3.58	Pike	LCP
Susquehanna	Vertic Paleudalfs	A	0-4	2.0	4.5	5.1	3.5	2.38	Perry	LCP
Susquehanna	Vertic Paleudalfs	Bt1	7-16	0.9	4.6	64.6	29.4	13.19	Perry	LCP
Susquehanna	Vertic Paleudalfs	A	0-5	2.2	4.8	3.4	9.0	0.88	Jones	LCP
Susquehanna	Vertic Paleudalfs	Bt1	12-19	0.5	5.0	55.9	35.7	17.59	Jones	LCP
Susquehanna	Vertic Paleudalfs	Ap	0-5	3.2	4.4	6.0	9.7	1.00	Jackson	CF
Susquehanna	Vertic Paleudalfs	Btss1	23-34	0.4	4.6	54.2	26.1	14.44	Jackson	CF
Susquehanna	Vertic Paleudalfs	A	0-5	2.8	4.8	7.6	10.1	2.46	Stone	LCP
Susquehanna	Vertic Paleudalfs	Bt1	8-20	0.8	4.7	54.9	29.6	12.20	Stone	LCP
Susquehanna	Vertic Paleudalfs	A1	0-6	2.0	5.0	4.8	5.1	1.03	Hancock	CF
Susquehanna	Vertic Paleudalfs	Bt21	8-14	0.3	4.9	33.0	10.4	5.82	Hancock	CF
Sweatman	Typic Halpudults	A	0-3	4.0	4.7	15.5	17.7	4.25	Smith	LCP
Sweatman	Typic Halpudults	Bt2	20-28	0.4	4.3	69.5	45.1	11.13	Smith	LCP
Talla	Glossic Natrudalfs	Ap	0-6	1.9	6.1	10.6	9.5	1.96	Noxubee	UCP
Talla	Glossic Natrudalfs	Bt21	12-29	0.7	5.0	25.0	17.5	4.21	Noxubee	UCP
Tippah	Aquic Paleudalfs	A	0-6	6.0	4.9	8.2	16.3	7.38	Lafayette	UCP
Tippah	Aquic Paleudalfs	Bt1	15-30	0.3	5.1	31.5	18.4	21.96	Lafayette	UCP
Una	Typic Epiaquepts	Ap	0-4	5.6	5.5	36.1	33.5	9.53	Lee	UCP
Una	Typic Epiaquepts	Bg3	17-25	0.7	4.9	42.9	27.4	10.19	Lee	UCP
Urbo	Vertic Epiaquepts	A1	0-2	3.5	4.8	21.7	23.3	8.60	Winston	UCP
Urbo	Vertic Epiaquepts	Bg2	18-30	0.6	4.4	38.2	24.4	10.05	Winston	UCP
Vaiden	Aquentic Chromuderts	Ap	0-10	2.4	4.8	30.6	29.1	14.56	Monroe	BP
Vaiden	Aquentic Chromuderts	Bg	30-40	0.2	5.0	43.9	38.0	15.31	Monroe	BP
Vancleave	Plinthic Fragiudults	Ap	0-5	2.7	4.6	2.5	6.8	1.47	Jackson	CF
Vancleave	Plinthic Fragiudults	Bt	11-22	0.3	4.7	7.0	2.9	1.56	Jackson	CF
Wadley	Grossarenic Paleudults	A	0-8	2.3	4.4	1.3	5.7	0.80	Perry	LCP
Wadley	Grossarenic Paleudults	Bt1	50-65	0.1	10.8	2.6	4.7	4.70	Perry	LCP
Wilcox	Vertic Hapludalfs	Ap	0-3	7.0	5.3	24.5	36.9	23.58	Winston	IF
Wilcox	Vertic Hapludalfs	Bt2	13-20	0.8	4.8	64.7	44.5	17.90	Winston	IF

[1] Measured in milligrams of arsenic per kilogram of soil parent materials, which is expressed in this publication as parts per million (ppm).

[2] Region: BP = Blackland Prairie; CF = Coastal Flatwoods; D = Delta; IF = Interior Flatwoods; L = Loess; LCP = Lower Coastal Plain; and UCP = Upper Coastal Plain.

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