

1 **SOIL MINERAL STRUCTURAL WATER LOSS DURING LOI ANALYSES**

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7
8 **ABSTRACT**

9 Water loss from soil minerals has been known to cause errors in the determination of soil
10 organic matter when the loss on ignition (LOI) method is used. Unfortunately, no known
11 published studies reliably quantify the range of structural water in the soil. To do this, 15
12 common reference minerals were analyzed by LOI to obtain their individual water loss. In
13 addition, 14 upland, loamy soil samples and 3 wetland/hydric soil samples with varied mineral
14 contents were analyzed to collect their X-ray powder diffraction spectra. Based upon X-ray
15 spectra peak intensities, the modal abundance of minerals in each soil sample was determined by
16 the RockJock computer program. The resultant modal weight percentages of all identified
17 minerals in each soil sample then were multiplied by the LOI value for each mineral to obtain the
18 mineral structural water loss (SWL) of that soil sample. For the 17 soil samples analyzed, the
19 range of mineral water loss is 0.56% to 2.45%. Depending on the LOI values of the soil samples,
20 the SWL/LOI ratios range from 0.04 to around 1.00. The SWL/LOI ratios are particularly low
21 for top wetland soil when LOI value is higher. The ratios are lower for surface soil samples than
22 for subsurface soil samples because of the high LOI values in surface soil samples.
23 Understanding the soil mineral water loss and their relation to the LOI patterns from various
24 environments is important for the accurate evaluation of soil organic matter when the LOI
25 method is used.

26
27 **Abbreviations:** LOI, loss on ignition; SOM, soil organic matter; SWL, structural water loss;
28 XRD, X-ray powder diffraction.

29 INTRODUCTION

30 A reliable estimation of soil organic matter (SOM) or soil organic carbon is required for
31 studying agricultural soil reactions and environmental soil water pollution, as soil organic carbon
32 often is the main absorption media of ions and compounds in the topsoil (Drever 1997; Smith
33 2003; Brady and Weil 2007). In addition, the accurate estimation of SOM in soils is necessary
34 for evaluating the carbon trapping ability of various soil environments and the feasibility of
35 sequestering carbon dioxide as a method of mitigating future global warming (Frogbrook and
36 Oliver 2001; Lal 2004; Davidson and Janssens 2006; Fang et al. 2005).

37 The loss on ignition (LOI) method has been widely used for estimating soil organic
38 matter, and it typically involves placing a weighed sample in a muffle furnace at 450-550 °C for
39 2.5 to 4 hours and then determining the sample's weight loss immediately upon removal
40 (Frogbrook and Oliver 2001; Smith 2003; Vos et al. 2005; Abella and Zimmer 2007). Relative
41 error ranges for estimation of SOM based on the LOI method have been reported as 2% to 5%
42 and, traditionally, the method's ability to determine soil SOM has been considered reliable (Dean
43 1974; Howard and Howard 1990; Snowball and Sandgren 1996; Abella and Zimmer 2007).
44 While the LOI method may be appropriate for soil samples with large SOM , as often is found in
45 wetland soils, studies (Konen et al. 2002; Smith 2003) have indicated that soil mineral water
46 loss, particularly the clay minerals, can cause significant errors for upland soils where SOM
47 usually is less than 6%. Unfortunately, there are no known published studies that can reliably
48 quantify this error. Therefore, the purpose of this study is to quantify the structural water loss
49 from a soil sample during the LOI process and to facilitate further in-depth discussion on the
50 subject.

51

52 **STRUCTURAL WATER OF MINERALS**

53 While the structurally bound mineral water can be separated into crystal lattice water for
54 OH- ion and water of hydration for bonded H₂O (Tan et al. 1986), the broad term “structural
55 water” has been commonly used to include both types of water by researchers due to the
56 difficulty of their separation in LOI processes (Howard and Howard 1990; Smith 2003;
57 Sutherland 1998; Heiri et al. 2001; Konen et al 2002; De Vos et al. 2005; Schulte 1991).
58 Therefore, following the common practice, the term “structural water” is adopted in this study,
59 which will include all bonded H₂O molecules and OH units in a mineral that can be lost during a
60 heating process. This includes both interlayer water molecules held in place by polar forces
61 between the tetrahedral and octahedral layers and OH units bonded within the brucite- or
62 gibbsite-like octahedral sheets of the clay minerals (Klein and Dutrow 2007). It also includes the
63 water molecules and OH units bonded within the structures of other minerals. The theoretical
64 weight percentages of structural water of 15 reference soil minerals, which were identified in our
65 soil samples in a later section, were calculated based upon their accepted chemical formulae
66 (Klein and Dutrow 2008) and are given in Table I as a reference. These data are consistent with
67 the data given by Tan et al. (1986).

68 Because only part of the theoretical “structural water” can be lost for most minerals
69 during the LOI analysis at 550 °C, the LOI values for each reference mineral will need to be
70 collected experimentally in order to evaluate the structural water loss (SWL) of collected soil
71 samples at 550 °C.

72

73 **METHODS**

74 **LOI Measurement of Reference Minerals**

75 Fifteen naturally formed reference mineral samples were obtained from a commercial
76 supplier (Wards Natural Science) and used to measure their LOI values at 550 °C. For the non-
77 clay minerals, quartz, feldspar, gypsum, calcite, biotite, muscovite, hematite, goethite, and
78 dolomite samples were selected from relatively well-formed crystals before being crushed for the
79 LOI procedure to limit their impurities to an insignificant level.

80 For the reference clay minerals kaolinite, vermiculite, smectite, illite, and chlorite,
81 because mixtures of other minerals commonly exist in nature, quantitative XRD analyses (see
82 procedures in a later section) were conducted to obtain the modal abundance (weight percentage)
83 of the minerals. The LOI of individual clay mineral was then corrected based on their mineral
84 modal abundance and the sample LOI value.

85 All 15 minerals with dual samples were heated in a muffle furnace at 550 °C for 4 hours
86 after being dried at 105 °C overnight.

87

88 **Characters of Soil Samples and Measurement of Their LOI**

89 Fourteen upland soil samples and three wetland/hydric soil samples from New Jersey,
90 East Coast of United States were collected using soil hand augers. Samples with the prefix DA
91 (Ultisols) and DB (Alfisols) were collected from areas where a slight surficial soil disturbance
92 exists; samples with the prefix MCP (Alfisols) were collected from wooded areas where no soil
93 disturbance exists; samples with the prefix I (Inceptisols) were collected from a site where
94 serious soil disturbance exists; and samples with the prefix MA (Histosols) were collected from a
95 brackish marsh. The sites of upland samples are underlay by non-calcareous clastic sedimentary
96 rocks and the site of wetland samples is underlay by a sand layer. The selection of the soil

97 samples at varied depths of upland and wetland was to reflect the various amounts of SOM and
98 clay minerals under different environmental conditions.

99 For this study, samples collected at a depth less than 20 cm are roughly classified as
100 surface soil sample and samples collected at a depth greater than 20 cm are roughly classified as
101 subsurface soil sample. All upland samples were collected from the A and B soil horizons at a
102 depth of less than 108 centimeters. LOI of soil sample was measured in the same manner as for
103 the 15 references minerals. The air dried soil samples were dried in a vacuum oven for at least 24
104 hours before being placed in a muffle furnace.

105

106 **The Mineral Modal Abundance and SWL of Soil Samples**

107 In order to calculate the SWL of soil samples based upon their mineral modal abundances
108 (i.e., the weigh percentage), these latter values had to be determined utilizing a quantitative X-
109 ray powder diffraction method. The SWL, which is categorized as the weight loss resulting from
110 all non-organic materials in the soil sample during LOI at 550 °C, will be calculated from the
111 summed products of the mode and the LOI at 550 °C for each mineral.

112

113 **Quantitative XRD for determining mineral modes**

114 Quantitative X-ray powder diffraction (XRD) analysis for determining mineral modes in
115 rock and soil samples is a common practice (Maniar and Cooke 1987; Moore and Reynolds
116 1997; Ward et al. 1999). A quantitative EXCEL macro program, RockJock, developed by Eberl
117 (2003) was selected to do this. The program uses the measured peak intensities as input data and
118 calculates the modal abundance (in weight percent) of all identified minerals using zincite as an
119 internal standard. The theory behind the RockJock program was first described by Srodon et al.

120 (2001), with the program being made public by Eberl (2003). The program placed third in the
121 2002 Reynolds Cup competition, sponsored by The Clay Minerals Society, for the most accurate
122 quantitative phase analysis (McCarty 2002); it has been improved significantly since that time
123 (Eberl 2004). Typical program results are within 1 to 2 weight percent of actual mineral
124 abundance values (Eberl 2003 and 2004). The program also has been recommended by Mertens
125 et al. (2006) as “the method of choice” for the quantification of clay minerals in soil samples
126 after it was compared to the Rietveld approach (Topas Academic by Coelho Software). For this
127 study, we utilized the RockJock6 version, dated 6/10/2008.

128 Following the sample preparation procedures described by Srodon et al. (2001) and Eberl
129 (2003), 2 g of each sample was mixed with 0.222 g of zincite (ZnO) and placed in a SPEX
130 mixer/ball mill with 5 ml of methanol added. The mixture was shaken for 10-15 minutes before
131 being removed and dried in a vacuum oven. The dried samples hardened into a durable crust;
132 therefore, samples first were disaggregated and mixed with a spatula, then sieved through a 180
133 um mesh (Standard Sieve No. 80), and finally adhered onto glass slides with petroleum jelly. X-
134 ray diffraction data for the samples were collected from 5° to 65° two-theta using Cu K-alpha
135 radiation and a step-size of 0.02°.

136

137 **SWL of soil samples**

138 Once the modes of the major minerals are measured, the structural water loss (SWL) of
139 minerals in a soil sample can be calculated as the summation of the modal abundances of
140 minerals multiplied by the SWL of each individual mineral:

141
$$SWL = \sum_n SWL_{Mineral} \times Weight\ Percent_{Mineral} \quad (1)$$

142 *Weight Percent_{mineral}* is the weight percent of a mineral measured in a soil sample by the
143 RockJock program; *SWL_{mineral}* is the measured LOI of that mineral; and *n* is the total number of
144 minerals measured in a soil sample.

145

146 RESULTS

147 LOI Results of Fifteen Reference Minerals

148 LOI results for the 15 reference minerals utilizing discussed heating procedures are
149 reported in Table II. For the LOI of each clay mineral, a correction was made based upon the
150 modal abundances of minerals (Table III) and the measured LOI for each clay sample by solving
151 the multiple equations aided by MATHEMATICA (Wolfram Software).

152 The LOI values for clay minerals are consistent with the data patterns reported in
153 previous thermal analysis studies of minerals (Barshad 1965; Tan et al. 1986). In particular, there
154 is a relatively large percentage of water loss by kaolinite during the LOI at 550 °C which is
155 associated with its phase transformations upon thermal treatment. This water loss was reported as
156 the dehydration (or endothermic dehydroxylation) of kaolinite that begins at 500-600 °C to
157 produce disordered metakaolinite, $Al_2Si_2O_7$ (Bellotto et al. 1995; Tan et al. 1986). A moderately
158 large amount of water loss at 550 °C by vermiculite is probably due to both the endothermic
159 dehydroxylation (peaked at 500 °C) and loss of absorbed water as reported by Tan et al.(1986).
160 The relative small amounts of LOI at 550 °C for the other three clay minerals (illite, chlorite and
161 montmorillonite) are probably due to the fact that there are only the loss of adsorbed water and
162 no significant dehydration loss of OH under 550 °C for these three minerals (Barshad 1965; Tan
163 et al. 1986). Because varied cation saturation levels can affect the amount of layer water, a
164 deviation of LOI may exist for a natural clay mineral (Barshad 1965; Tan et al. 1986; Moore and

165 Reynolds 1997). For the non-clay minerals, gypsum, goethite, and dolomite are the minerals
166 measured that have relatively high LOI values. Stantisteban et al. (2004) suggested LOI below
167 550 °C for dolomite was due to the breaking off of inorganic carbon from the dolomite
168 crystalline structure as CO₂. In addition, a small amount of weight loss, <0.2%, was recorded
169 during LOI analysis at 550 °C for quartz and feldspar. This small LOI for quartz and feldspar is
170 consistent with the data reported by Tazaki et al. (1992), where LOI for feldspar was <0.4% and
171 <0.1% for quartz. A small LOI weight loss of 0.134% at 550 °C also was recorded for calcite,
172 indicating that there is little, if any, inorganic carbon breaking off the calcite structure. This is
173 similar to the findings of Heiri et al. (2001) and Dean (1974) of “no significant LOI for calcite.”

174

175 **LOI Result of Soil Samples**

176 Utilizing the same heating procedure as for the reference minerals, LOI values for
177 collected soil samples are given in Table V (together with SWL and SWL/LOI ratio). For
178 samples with apparent larger amount of SOM, there is a larger LOI, such as MA0-19 and MA80-
179 100, which is similar to the previous studies (Konen et al. 2002; Jankauskas et al. 2006; Abella
180 and Zimmer 2007). The overall LOI values for surface soil samples are larger than those for
181 subsurface soil samples.

182

183 **Results for Soil Mineral Modal Abundances and Their SWL**

184 Overall, the RockJock program’s calculated spectra produced a fairly good match to the
185 measured XRD spectra for all the samples (Figure 1). The modal abundance of soil minerals
186 shows that the most abundant non-clay mineral group in these soil samples is the framework
187 silicate, which includes quartz and feldspar (Table IV). These two species regularly constitute

188 more than 50% of the total mineral content in the 17 soil samples. Other less abundant, non-clay
189 mineral species include iron oxides and hydroxides, carbonates, and salts. Clay minerals
190 constitute approximately 17 to 54% of the total minerals in the 17 soil samples. Identified clay
191 minerals include the tetrahedral-octahedral (T-O) type, kaolinite, and the tetrahedral-octahedral-
192 tetrahedral (T-O-T) types, smectite, illite, chlorite, and mica group. In general, more K-feldspar
193 than Na, Ca-feldspar is found in the soil samples. There also are no statistically significant linear
194 relationships between mineral abundances and sample depth. However, the data indicate clay
195 mineral abundances generally are greater in subsurface soil horizons (depth >20 cm) than in
196 surface soil horizons (depth <20cm).

197 The LOI, SWL, and SWL/LOI ratios for each soil sample at 550 °C are given in Table V.
198 The SWL of the 17 soil samples collected in this study range from 0.56% to 2.45%. The
199 SWL/LOI ratios range from 0.04 to 1.12, depending on the amount of LOI values of the soil
200 samples. For the two top wetland hydric soil samples, which have large number of LOI, the
201 SWL/LOI ratios are less than 0.1. Also, the SWL/LOI ratios for surface soil samples (<20 cm
202 depth) are smaller than those for subsurface soil samples (20 cm to 108 cm depth).

203

204 **DISCUSSION**

205 From the results given in the previous section for mineral LOI (Table II) and calculated
206 SWL (Table V), it is clear that soil SWL represents only a small percentage of the soil mass,
207 varying from 0.56% to 2.45% in all our samples. In addition, soil sample SWL depends only on
208 the types and modal abundances of the minerals each sample contains. Therefore, the calculated
209 SWL/LOI ratios will largely depend on the LOI value for a given soil sample (Table V).

210 Based upon the LOI data from Table II, efforts were made to use the quantitative XRD
211 mineral modal abundance reported by Ruffell and Wiltshire (2004) to calculate the SWL and
212 SWL/LOI values for their soil samples. For the 21 surface soil samples collected from various
213 locations by Ruffell and Wiltshire (2004), their SWL ranged from 0.03% to 5.55 %. This range
214 of SWL value is comparable to the SWL values from samples in this present study. However,
215 Ruffell and Wiltshire's (2004) samples have a higher average LOI value of 9.8% than the
216 average LOI of 6.67% for samples measured in this study, although Ruffell and Wiltshire (2004)
217 used slightly different temperature steps and heating durations.

218 The SWL/LOI versus LOI plot (Figure 2) clearly shows that SWL/LOI ratio is mainly a
219 function of LOI, as indicated by the best-fit power trend line and the R^2 value of the power
220 equation. The larger the LOI value (likely, a larger SOM), and the less need for SWL correction
221 in the estimation of SOM. Overall, the general characteristics of clay minerals, the distribution of
222 SOM with the depth, and SWL/LOI ratios in different soil horizons lead to the conclusion that
223 correcting for SWL when estimating SOM by the LOI method is more important for subsurface
224 soil samples than for the surface soil samples. From Figure 2, one can also deduce that the
225 potential errors of estimating SOM by LOI method can be significantly larger than the 2 to 5%
226 commonly believed error range (Dean 1974; Howard and Howard 1990; Snowball and Sandgren
227 1996; Abella and Zimmer 2007). For example, if the LOI measurement of a soil sample is 2% ,
228 the structural water loss of a soil sample is 2% and one assumes the LOI being purely due to
229 SOM, then the error will be 100%.

230 The results of this study can also be used to partially explain the differences found in the
231 relationship between LOI and organic carbon or SOM when utilizing LECO and other methods.
232 For example, in the study of Konen et al. (2002), most of the data exhibited good linear

233 relationship between LOI and LECO organic carbon with the coefficients of determination R^2
234 between 0.94 and 0.98 (their Figure 2). In the study of Goldin (1987), R^2 for this relationship of
235 mineral soils is 0.86 (his Figure 1). In the study of Schulte et al. (1991), using Walkley-Black
236 method, the R^2 for the relationship between LOI and SOM is 0.90 from their Figure 1. Generally,
237 a smaller R^2 indicates a larger envelop range along the best fit line and a large potential error for
238 estimating the organic carbon or SOM. From Figure 1 of Goldin 1987, if LOI is given as 90
239 g/kg, the range of LECO carbon can vary from ~22 to 39 g/kg and the difference is $(39 -$
240 $22)/39 = 43.6\%$. From Figure 1 of Schulte et al. 1991, if LOI is given as 6%, the determined
241 organic matter can range from ~4 to 8.7%. The potential error for estimating the SOM can be
242 large.

243 The soil samples for the study of Konen et al. (2002) were from north-central United
244 States. This region is generally dry and there are limited hydrous oxides and relatively abundant
245 mixed and smectite clays (Brady and Weil, 2007). The combination of minerals and high SOM
246 in their soil samples will mean a larger R^2 between the relationship of LOI and organic carbon,
247 and less need for SWL correction during the LOI process. On the other hand, if the soil samples
248 are obtained from a humid climate such as Southern United States and South America or coastal
249 Pacific Canada, as seen in Goldin 1987's study, there may be more goethite (or other hydrous
250 oxides) and/or kaolinite. The relationship between organic carbon and LOI will exhibit a smaller
251 R^2 and the need for SWL correction will be relatively greater.

252 **SUMMARY AND CONCLUSIONS**

253
254 The LOI values for 15 common reference soil minerals were determined at 550 °C. The
255 LOI for clay minerals, due mainly to their abundant structural water, is more significant than that
256 for the non-clay minerals. Seventeen soil samples collected from different environment settings

257 were used to evaluate SWL during LOI analysis. Soil sample mineral modes were obtained from
258 X-ray powder diffraction and the RockJock program. The summed products of the modal
259 abundance for each soil mineral and corresponding LOI value were computed to obtain the total
260 SWL of a soil sample. The calculated SWL ranged from 0.56 to 2.45% for our soil samples. The
261 SWL/LOI ratios largely varied with the LOI values of the samples, ranging from 0.04 to about 1.
262 The ratio was relatively smaller for wetland soil and surface soil, most likely due to the large
263 amount of the SOM in these environments. The result also indicates that SWL correction in the
264 estimation of SOM is needed more in regions where significant amounts of goethite (a hydrous
265 oxide) and kaolinite and vermiculate (clay minerals) are present in soil.

266

267

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278

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358

Figure Captions

359

360 Figure 1. Full pattern fit of calculated spectrum from RockJock vs. measured XRD spectrum of

361 sample DB72-82.

362 Figure 2. SWL/LOI ratio vs LOI plot and the power fitting equations of the two sets of ratio data.

Table I. Weight percent of theoretical “structural water” of reference soil minerals calculated based upon their chemical formulae (Klein and Dutrow, 2008).

Mineral Names	Chemical Formula	% of Theoretical H ₂ O and OH
Chlorite	$(\text{Mg,Fe})_3(\text{Si,Al})_4\text{O}_{10}(\text{OH})_2 \cdot (\text{Mg,Fe})_3(\text{OH})_6$	20.35
Illite	$(\text{K,H}_3\text{O})(\text{Al,Mg,Fe})_2(\text{Si,Al})_4\text{O}_{10}[(\text{OH})_2,(\text{H}_2\text{O})]$	12.03
Kaolinite	$\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$	13.96
Smectite	$(\text{Na,Ca})\text{Al}_4(\text{Si,Al})_8\text{O}_{20}(\text{OH})_4 \cdot 2(\text{H}_2\text{O})$	9.19
Vermiculite	$(\text{Mg,Fe}^{++},\text{Al})_3(\text{Al,Si})_4\text{O}_{10}(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$	17.87
Biotite	$\text{K}(\text{Mg,Fe}^{++})_3\text{AlSi}_3\text{O}_{10}(\text{F,OH})_2$	3.64
Muscovite	$\text{KAl}_2(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH,F})_2$	4.07
Gypsum	$\text{CaSO}_4 \cdot 2(\text{H}_2\text{O})$	20.93
Goethite	$\text{FeO}(\text{OH})$	10.14
Calcite	CaCO_3	0.0
Dolomite	$\text{CaMg}(\text{CO}_3)_2$	0.0
Hematite	Fe_2O_3	0.0
K-Feldspar	KAlSi_3O_8	0.0
Na,Ca-Feldspar	$(\text{Na, Ca})(\text{Si,Al})_4\text{O}_8$	0.0
Quartz	SiO_2	0.0

Table II. Measured weight loss (LOI %) at 550 °C in a muffle furnace after the samples were dried at 105 °C overnight.

Mineral Name	Weight loss at 550 °C (%)	Mineral Name	Weight loss at 550 °C (%)
Chlorite	1.23*	Goethite	2.45
Illite	1.72*	Dolomite	2.02
Kaolinite	18.4*	Calcite	0.13
Smectite	0.95*	Hematite	0.17
Vermiculite	12.6*	K-Feldspar	0.14
Biotite	0.46	Na,Ca-Feldspar	0.08
Muscovite	0.51	Quartz	0.12
Gypsum	15.84		

* Indicates the corrected values of LOI for clay minerals. The initial LOI values of the samples before the correction for impurities are illite 2.08, kaolinite 12.47, smectite 1.69, vermiculite 5.75, chlorite 1.209.

Table III. Mineral modes (%) of clay samples

Chlorite Sample		Illite Sample		Kaolinite Sample	
Non-Clay		Non-Clay		Non-Clay	
		Quartz	17.39	Feldspar	7.00
Total Non-clays	1.50	Total Non-clays	19.70	Total Non-clays	9.68
CLAYS		CLAYS		CLAYS	
Chlorite	97.01	Kaolinite	5.69	Kaolinite	66.61
		Illite	45.97		
		Smectite	23.66	Smectite	22.22
Total Clays	98.55	Total Clays	80.26	Total Clays	90.32
Smectite Sample		Vermiculite Sample			
Non-clay		Non-Clay		Note. Minerals with weight percent less 4% are not listed.	
Quartz	5.56	Feldspar	10.06		
Feldspar	8.17				
Total Non-clays	16.17	Total Non-clays	13.74		
CLAYS		CLAYS			
Kaolinite	5.16	Vermiculite	41.08		
Smectite	77.67	Chlorite	42.67		
Total Clays	83.83	Total Clays	86.26		

Table IV. Mineral modes (%) of soil samples

	Quartz	K- Feldspar	Na,Ca- Feldspar	Calcite	Dolomite	Gypsum	Hematite	Goethite	Kaolinite	Smectite	Illite	Biotite	Chlorite	Muscovite
DA0-19	70.1	4.45	2.94	0.3	0	0.97	0.45	0.7	4.04	5.01	2.68	1.09	3.43	1.02
DA41-47	68.66	7.47	0	0	0	0	0.16	1.56	5.49	7.47	1.97	0.66	2.82	1.5
DA61-67	49.1	5.64	0	0.01	0.64	0	0	1.68	9.86	15.24	6.6	1.58	4.59	3.26
DA91-105	53.1	5.34	4.32	0	0	0.53	0	6.03	2.09	9.02	8.29	2.25	2.98	0.95
DB0-19	63.6	3	4.64	0	0.4	0	0.2	1.51	1.03	6.86	3.93	1.88	4.47	2.38
DB30-45	59.06	3.47	3.02	0	0.14	0	0.56	1.65	2.5	10.82	5.4	2.61	6.63	2.12
DB72-82	62.92	4.23	4.49	0	0	0.8	0	0.85	2.42	12.44	2.89	3.01	3.79	0.6
DB105-108	59.88	5.64	2.93	0	0.15	0.05	0.72	0.71	2.79	10	6.25	3.36	4.2	1.5
I8-19.5	56.45	3.22	0.84	0	0.36	1.31	0.06	1.23	5.67	10.53	3.41	4.65	7.05	3.89
I27-32	59.07	3.74	0	0	0.01	0	0.01	2.27	9.6	13.19	7.42	0.56	1.75	0
I32-36	39.71	5.67	0	0	0.49	0.57	0.4	2.77	9.83	20.46	2.75	2.85	8.83	4.11
MCP0-15	58.87	5.4	11.31	0	0.48	0.35	0.2	0.12	1.74	12.93	0.71	0.74	2.56	1.68
MCP30-45	42.63	3.61	13.25	0	0.13	0	0.6	1.76	3.84	17.62	5.18	1.01	4.52	2.88
MCP40-50	37.52	9.33	10.1	0	0.12	0.38	0	2.92	5.39	18.19	0.06	2.61	3.55	4.79
MA0-19	6.01	13.48	3.46	0	0.17	0.82	0	0.93	3.24	13.72	4.02	3.4	4.75	4.44
MA80-100	10.87	19.36	4.84	0	0	1.59	0.57	1.21	3	21.59	3.43	5.76	7.84	3.8
MA300	12.73	22.63	5.61	0	0	1.9	0.64	1.57	3.23	23.78	2.86	7.57	10.17	6.41

Note: DA: Drexel Woods site A; DB: Drexel Woods site B; I: Near highway I-95 disturbed soil site; MCP; Mercer County Park undisturbed soil site. MA: Marsh soil site in southern NJ. Sample numbers listed after site identification letters give the sample depth interval in centimeters.

Table V. LOI (%) at 550 °C, SWL (%), and SWL/LOI ratios of 17 soil samples

	SWL(%)	LOI(%)	SWL/LOI
DA0-19	1.28	3.61	0.36
DA41-47	1.32	3.26	0.41
DA61-67	2.31	3.53	0.66
DA91-105	1.02	5.95	0.17
DB0-19	0.56	6.49	0.09
DB30-45	0.90	2.44	0.37
DB72-82	0.92	2.41	0.38
DB105-108	0.92	2.38	0.39
I8-19.5	1.66	2.11	0.79
I27-32	2.23	4.08	0.55
I32-36	2.45	3.30	0.74
MCP0-15	0.67	3.57	0.19
MCP30-45	1.18	3.80	0.31
MCP40-50	1.52	6.17	0.25
MA0-19	1.83	42.34	0.04
MA80-100	1.52	16.71	0.09
MA300	1.45	1.30	1.12

Note: LOI, Loss on ignition (%); SWL, structural water loss (%); SWL/LOI, ratio of SWL to LOI. Sample numbers listed after site identification letters are the sample depth interval in centimeters.

Figure 1.

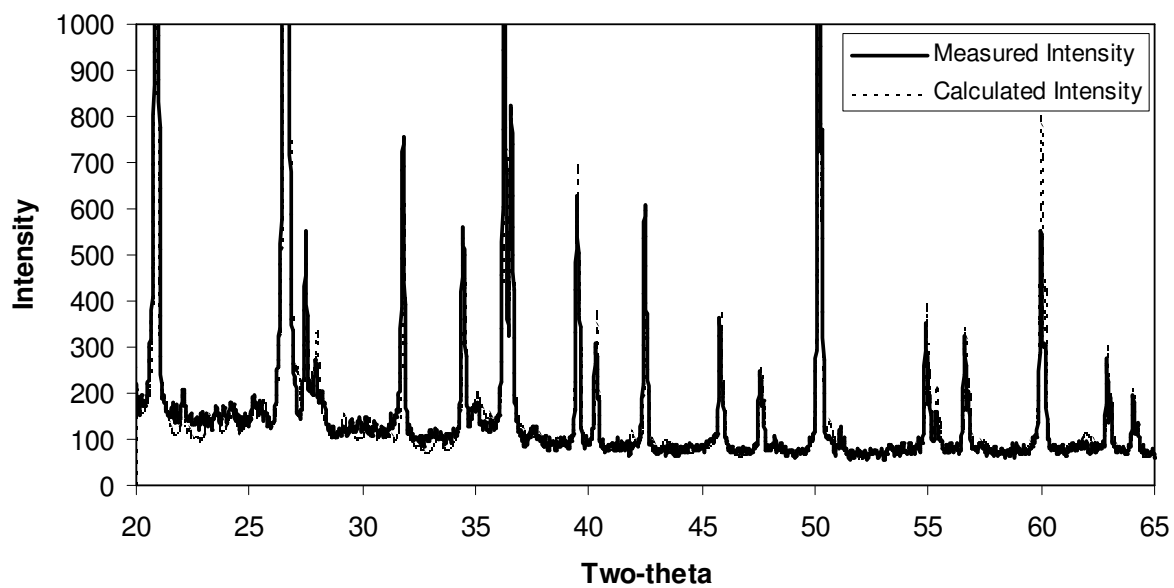


Figure 2.

