



AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

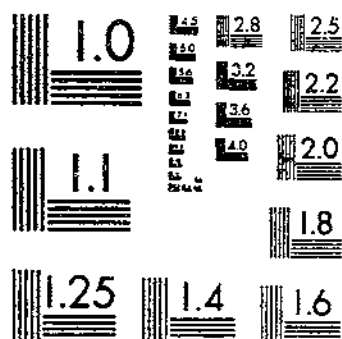
Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

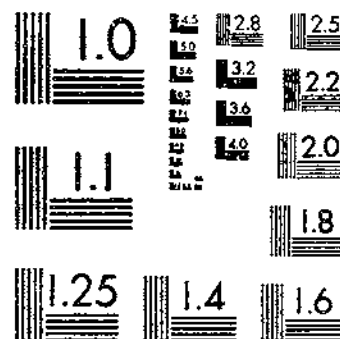
*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

TR 291 (1932) USDA TECHNICAL BULLETINS UPDATA
THE EFFECT OF AIR DRYING ON THE HYDROGEN-ION CONCENTRATION OF THE SOILS
BAILEY, E. H. 1 OF 1

START



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

UNITED STATES DEPARTMENT OF AGRICULTURE
 WASHINGTON, D. C.

 THE EFFECT OF AIR DRYING ON THE
 HYDROGEN-ION CONCENTRATION OF THE SOILS
 OF THE UNITED STATES AND CANADA¹

 By ERNEST H. BAILEY, *Assistant Soil Technologist, Division of Soil Survey, Soil Investigations, Bureau of Chemistry and Soils*

CONTENTS

	Page		Page
Previous work.....	1	Discussion.....	35
Collection and preparation of samples.....	9	Summary.....	40
Description of apparatus and method used.....	10	Literature cited.....	41
Experimental data.....	15		

PREVIOUS WORK

In the last few years several soil investigators have reported that the reaction of soil samples changed more or less on passing from the moist field condition to the air-dry state. Some have gone so far as to declare that no hydrogen-ion determinations are reliable unless made on the fresh moist samples.

Healy and Karraker (19)² made determinations with the hydrogen electrode on six acid Kentucky soils in both the moist field condition and in the air-dry state. Five of those soils on air drying increased in acidity 0.17 to 0.55 pH unit.

Burgess, (11) used the hydrogen electrode on 11 acid to neutral Rhode Island soils ranging in reaction from 4.36 to 7.00 pH units and on three alkaline soils ranging from 7.40 to 7.78 pH units. Three of the 11 acid samples became 0.20 to 0.39 pH unit more acid, and the 3 alkaline samples became 0.21 to 0.23 pH unit less alkaline on drying.

Rost and Fieger (36) also worked with the hydrogen electrode on 36 acid soils and 4 alkaline soils from Minnesota. The acid soils in their fresh, moist condition ranged in reaction from 5.50 to 6.63 pH units and the alkaline soils from 7.34 to 7.54 pH units. The acid soils on becoming air-dry changed in reaction from 1.15 pH units more acid to 0.49 pH unit less acid, only 12 of the 36 changing less than 0.10 pH unit. The alkaline soils on drying changed in reaction from 0.38 pH unit more acid to 0.29 pH unit less acid, 2 of the 4

¹ The writer is deeply indebted to C. F. Marbut, H. G. Byers, M. S. Anderson, E. C. Shoray, Mark Baldwin, and E. F. Snyder, of the Bureau of Chemistry and Soils for their helpful suggestions; to Bessie Hoopshaw, of the same bureau, for making the diagram of the electrode and electrode vessel used in the investigations, to the field men in the soil survey, and to the experiment station workers in this country and Canada who have made the work possible by collecting the moist soil samples.

² Italic numbers in parenthesis refer to Literature Cited, p. 41.

samples changing less than 0.10 pH unit. The general tendency was for the soils to become more acid on air drying. Remoistening the dried soils in most cases made the reaction more acid than in the air-dried samples.

Joseph and Martin (22) used the hydrogen electrode on arid alkaline Egyptian soils and found that drying them at 100° C. made them 0.13 to 0.75 pH unit less alkaline, but that, if the water used in the determinations stood on them for a week, the pH of the moist and of the dried samples were practically the same.

Knickmann (26) worked with acid German soils. He determined the "active" acidity by titrating the water extracts from the soils with sodium hydroxide, using methyl red as an indicator, instead of making hydrogen-ion determinations. He found that in some cases the acidity was twice as great after air drying for a week and four times as great after six months as that of the original moist samples. Heating the soils to above 100° C. made the acidity forty times as great. Knickmann concluded from his experiments that the increase in acidity was proportional to the humus content as it was the organic matter that caused the change in acidity on drying.

Baver (6) used the quinhydrone electrode in the study of cultivated Ohio soils. He found that the upper 7 inches from 12 unlimed plots, ranging in reaction from 4.41 to 5.02 pH units, changed less than 0.10 pH unit either way, on drying out. But the upper 7 inches from 12 limed plots, ranging in reaction from 7.71 to 8.14 pH units, in every case became less alkaline on air drying, ranging from 0.12 to 0.32 pH unit less alkaline. On 4 limed plots where the samples were taken at a depth ranging from 0 to 7 inches, 7 to 14 inches, 14 to 21 inches, and 21 to 28 inches, respectively, he found that on drying the acidity increased with depth in every plot. The differences in reaction between the moist and the air-dry samples varied as much as 0.63 pH unit in the deepest layer of one of the limed plots. Baver's conclusions are that fresh moist samples should be used for refined reaction studies.

Büllmann and Tovborg-Jensen (7) worked with the quinhydrone electrode on 19 Danish soils and found that 7 of them changed in reaction more than 0.10 pH unit on drying. These changes ranged from 0.11 to 0.20 pH unit more acid.

Achromeiko (2) worked with Russian podsoils, podsolie soils, and chernozems, using the quinhydrone electrode. The results he obtained with the thoroughly crumbed-up and mixed soils are given in Tables 1 and 2.

TABLE 1.—Effect on the upper 8 inches of a Russian podsolie soil of drying in the sun and at 100° C.¹

Treatment of soil sample	pH	Stored with capillary moisture		
		After 3 days	After 7 days	After 21 days
Crumbed soil:		pH	pH	pH
Fresh moist.....	6.20	6.22	6.26	6.23
Dried in sun.....	5.94	6.08	6.31	6.24
Dried in oven at 100° C. for 36 hours.....	4.52	5.50	6.31	6.38

¹ Data from Achromeiko (2) on Russian soils.

TABLE 2.—Effect of drying soil samples at 100° C. and restorative treatment¹

Soil	Location	Depth	Fresh moist sample	Dried 36 hours at 100° C.	4 days after remoistening
			pH	pH	pH
Chernozem	Schatilow	Surface	5.90	4.67	6.06
Do.	Anutschino	do.	5.65	4.43	5.48
Do.	Artscheda	do.	6.24	5.35	6.34
Podsol	Agricultural Academy, Moscow	Podsol layer	6.20	6.20	6.21
Loam	do.	39 inches	5.41	5.41	


¹ Data from Achromeiko (2) on Russian soils.

As shown in Table 1 the crumbed-up 3-inch surface layer of a podsol soil from the experimental farm at the academy became 0.26 pH unit more acid on drying in the sun and 1.68 pH units more acid when dried in the oven at 100° C. for 36 hours. This showed that drying at high temperatures had a far more drastic effect on changing the reaction than drying the sample in the sun. Moistening the dried samples appeared to restore their pH values to approximately that of the fresh moist sample, as both the sun-dried sample and the one dried at 100° were brought back to the original pH value of the fresh moist sample by being moistened from 3 to 7 days before making the determinations.

In Table 2, the three chernozem surface soils became 0.89 to 1.23 pH units more acid after drying for 36 hours in the oven at 100° C. Unfortunately the effect of air drying on these soils was not shown. Four days after remoistening, these dried samples were restored to the approximate pH value of the fresh, moist samples, the first surface layer being 0.16 pH unit less acid, the second 0.17 pH unit more acid, and the third 0.10 pH unit less acid than the original moist sample. The podsol layer of a podsol soil and the loam subsoil, which were both very low in organic matter, did not change on being dried at 100°. From these results Achromeiko came to the same conclusion as did Knickmann (26)—that the increase in acidity of a soil sample on drying was dependent on the amount of organic matter present. This point will be discussed later.

But the most spectacular results have been obtained by Aarnio (1). He worked with the quinhydrone electrode on Finnish soils and his results are directly quoted in Tables 3 and 4.

TABLE 3.—The influence of drying on soil reaction.¹

Item	Days at 25° C.	Crumbly clay from south Finland (Dreg-sby)			Heavy clay from southwest Finland (Paatinen)			Heavy clay from southwest Finland (Paatinen)		
		Surface soil	Surface soil	Surface soil	Surface soil, 0-8 inches	Flow sole, 8-18 inches	Subsoil, 25-39 inches	Surface soil, 0-10 inches	Flow sole, 10-12 inches	Subsoil, 25-39 inches
	0	pH 5.01	pH 5.31	pH 5.90	pH 6.32	pH 7.17	pH 6.87	pH 5.77	pH 6.41	pH 6.80
	3	4.85	5.16	5.67	6.07	7.04				
	6				5.82	6.88	6.69			
	9	4.73	5.03	5.51						
	12				5.53					
	15									
	18									
	21				4.83	6.04	5.21	5.44	5.72	
	24							5.28	5.28	5.45
	27			5.36						
	30					5.28	4.78	4.67	4.83	4.91
	33	4.25	4.50	5.14						
	36				4.44	6.77	5.33	4.83	4.37	4.07
	39				3.66	3.97	3.74	3.82	4.09	4.07
	42	3.81	3.75	4.48						
	45	3.62	3.56	4.05						
	48	-1.42	-1.75	-1.85	-2.66	-3.20	-3.13	-1.95	-2.32	-2.73
	51									
	54									
	57									
	60									
Organic matter		Per cent 11.06	Per cent 6.73	Per cent 10.01	Per cent 1.71	Per cent .54	Per cent .83	Per cent 3.63	Per cent 1.17	Per cent .66

¹ Data from Aarnio (7) on Finnish soils.TABLE 4.—The reaction changes of soils at 25° C.¹

Item	Days at 25° C.	Heavy clay from southwest Finland (Pöytä)		Heavy clay from southwest Finland		
		Surface soil, peat covered and mixed with clay, 0-10 inches	Subsoil, 31-39 inches	Clay from Lohma, surface humus, 0-10 inches	Clay from Lohma, surface soil, 0-8 inches	Pöytä, surface peat mixed with clay, 0-10 inches
Moist sample	0	pH 4.63	pH 5.60	pH 5.01	pH 4.84	pH 4.94
	3			5.14	5.16	
	4	4.85				4.89
	5		6.12	5.23	5.21	
	6	4.80				
	7		6.24	5.23	5.34	5.02
	8					
	9		6.12	5.09	5.17	
	11	4.95				
		4.90	6.02	5.06	5.14	4.80
		+ .27	+ .42	+ .05	+ .30	- .14
Change in reaction ²						
Dry sample	26	4.23	4.20			
	28			3.96	4.19	
	35	4.06	3.50	3.80	4.11	4.10
	42		3.48	3.79	3.79	3.97
	70	3.73				
Change in reaction		- .90	-2.12	-1.22	-1.05	- .97
Organic matter		Per cent 29.41	Per cent 0.41	Per cent 8.96	Per cent 6.35	Per cent 20.49

¹ Data from Aarnio (7) on Finnish soils.² This change in reaction is introduced by the author of this bulletin.

The soils (Tables 3 and 4) show a great increase in acidity on drying and storing. In Table 3, the minimum change is 1.42 pH units and the maximum, 3.20 pH units more acid. Table 4 shows a minimum change in reaction at the end of 11 days, when the samples were air-dry, of only 0.05 pH unit less acid, and a maximum change of 0.42 pH unit less acid. However, at the end of a period ranging from 42 to 70 days all the samples had become very much more acid, ranging from 0.90 to 2.12 pH units more acid. These samples changed in reaction in storage far more after they were air-dry than they did while drying. Table 3 shows that the increase in acidity was, with a single exception, continuous as the days passed, whereas Table 4 shows that the soils became less acid during the first week of storage but rapidly increased in acidity after that. In general, the subsoils increased in acidity more than did the surface soils, and the surface soils high in organic matter showed less change than did those low in organic matter. From these results Aarnio naturally concluded that hydrogen-ion determinations should be made only on fresh, moist samples.

In the light of the investigations recorded in this bulletin, these results of Aarnio are inexplicable unless the samples were dried in an atmosphere containing acid fumes. Although the laboratory in which the tests discussed in this bulletin were made is comparatively free from fumes of any kind, air-dry samples of soil if allowed to remain uncovered in it become from 0.20 to 0.30 pH unit more acid in a few weeks' time.

Coles and Morison (14) used the quinhydrone electrode on English and Irish soils. They dried these soils from 14 to 28 days in a desiccator over sulphuric acid at room temperature and also dried them in an oven at 98° C. The results are given in Tables 5 and 6.

TABLE 5.—Effect of drying various soils over sulphuric acid and dripping all the water off in an oven at 98° C.¹

Soil	Description	Soil No.	Fresh, moist sample	After drying 14 days over H ₂ SO ₄	Change ²	After all water was driven off in oven at 98° C.	Change ³
			pH	pH	pH	pH	pH
Calcareous grit.....	Sandy humus from forest.....	3	4.38	3.98	-0.40	3.63	-0.75
Coral rag.....	Arable clay soil.....	4	8.01	7.11	-0.90	6.25	-1.76
Kimeridge soils.....	Heavy silt loam pasture soil.....	6	5.74	5.46	-0.29	4.30	-1.44
Do.....	Light clay pasture soil.....	7	6.22	5.92	-0.30	4.97	-1.25
Do.....	Heavy clay pasture soil.....	8	7.40	6.79	-0.61	5.97	-1.43
Do.....	Forest subsoil of clay soil.....	9	4.57	4.43	-0.14	3.48	-1.09
Peat.....	West of Ireland.....	10	4.12	4.12	-0.00	3.06	-1.07
Northampton sand.....	Arable soil.....	11	7.53	6.87	-0.71	5.71	-1.87

¹ Data from Coles and Morison (14).

² Dried over H₂SO₄, 28 days.

³ Calculated by the author.

TABLE 6.—*Recovery of soils that had been completely dehydrated in an oven at 98° C.*¹

Soil No.	Reaction after water used in determinations had stood on samples for—										Fresh, moist sample
	0 day	1 day	3 days	6 days	10 days	15 days	21 days	28 days	42 days	56 days	
	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>
3-----	3.63	3.67	3.60	3.67	3.66	3.73	3.77	3.83	-----	3.90	4.38
4-----	6.25	6.02	7.05	7.33	7.55	7.73	7.84	7.85	-----	7.89	8.01
6-----	4.30	4.49	4.52	4.55	4.71	4.73	4.79	4.80	5.10	5.06	5.74
7-----	4.97	5.03	5.18	5.33	5.33	5.31	6.08	5.95	6.07	6.13	6.22
8-----	5.97	5.98	6.06	6.37	6.74	6.89	7.10	6.95	-----	7.26	7.40
9-----	3.48	3.67	3.77	3.78	3.80	3.92	3.98	4.00	4.09	4.35	4.57
10-----	3.05	3.08	3.06	3.04	3.05	3.04	3.07	3.05	-----	3.04	4.12
11-----	5.71	5.98	5.88	5.97	6.07	6.27	6.26	6.33	-----	6.32	7.58

¹ Data from Coles and Morison (14).

As is shown in Table 5, all the soils tested by Coles and Morison became considerably more acid on drying in the desiccator over sulphuric acid, with the exception of the peat which underwent no change. Complete dehydration of the samples in the oven at 98° C. made all of them still more acid (from nearly twice to nearly eight times as acid as from drying over sulphuric acid). The alkaline soils showed greater changes on drying than did the more acid soils.

In Table 6 is shown the restorative effect of allowing the water used in the determinations to stand on the soils in test tubes for varying lengths of time up to two months. Coles and Morison made only one measurement with each tube so as to avoid any effects that quinhydrone might produce by prolonged contact with the soils. In the peat soil (No. 10) there was no recovery, and in the sandy humous soil (No. 3) the recovery was very slight. In the other soils, which contained considerably more clay than Nos. 3 and 11, there was a very significant recovery, and in the four heaviest soils (Nos. 4, 7, 8, and 9) the pH after two months very nearly equaled that of the original moist soils. From these results Coles and Morison came to the conclusion that it was the mineral colloidal matter and not the organic colloidal matter which caused recovery from the heating effects. They suggested that any explanation involving the biological production of ammonia in the water-logged soils was unlikely, as in that case the organic soils should have recovered as much as, or more than the mineral soils.

By further experiments Coles and Morison found that the changes produced by heating the soils from which the exchangeable bases had all been removed by dilute hydrochloric acid were insignificant and that after treating these base-free soils with various metallic cation solutions in order to supply them with exchangeable bases, all showed a considerable decrease in pH after being dried at 98° C. They also found that after being dried the soils contained a smaller quantity of exchangeable bases than the original moist soils and that they showed increases in water-soluble calcium, potash, and phosphate. Coles and Morison therefore concluded that the exchangeable bases must in some way be responsible for the increase in acidity caused by drying.

Teräsuvuori (40) also worked with the quinhydrone electrode on a wide variety of Finnish soils. As can be seen by comparing Tables 7 and 8 with Tables 3 and 4 he obtained very different results from those of Aarnio.

TABLE 7.—Influence of drying the soil samples¹ to air dryness on the pH of the soil suspensions²

Sample No.	Soil	Description of place where sample was taken	Depth in inches	Fresh, moist sample	Air-dry sample	Change
B238	Low-moor peat	Peat improved by mixing in of loam.	Surface soil.	pH 5.01	pH 5.14	pH +0.13
B453	Muck		0-12	5.89	6.02	+ .13
B454	Heavy loam	Under B453	14-18	5.25	5.33	+ .08
B455	do	Under B454	24-30	5.29	5.31	+ .02
B456	Muck		0-5	6.00	5.97	-.03
B457	Sphagnum peat		28-39	4.10	4.10	0.00
B458	Low-moor peat	Under B456	8-14	5.17	5.16	-.01
B459	Muck		0-9	4.60	4.88	+ .16
B460	Heavy loam	Under B459	12-20	4.44	4.35	-.09
B461	Muck		0-18	4.55	4.28	-.03
B462	Heavy loam	Under B461	16-24	3.80	3.85	+ .05
B463	Humous clay		0-12	4.58	4.66	+ .10
B464	Heavy loam	Under B463	12-20	4.49	4.31	-.18
B465	Humous clay		0-9	5.57	5.63	+ .04
B466	Heavy loam	Under B465	9-20	5.62	5.41	-.21
B467	Humous clay		0-12	6.01	5.98	-.03
B468	Heavy loam	Under B467	12-20	5.48	5.37	-.09
T1a	Humous sand	Cultivated ridge	2-4	5.51	5.87	+ .36
T1b	do	do	2-4	5.70	5.59	-.11
T2a	Humous clay	Beet land	2-4	6.06	5.94	-.15
T2b	do	Beet land, freshly plowed	0-2	6.28	6.09	-.19
T3a	Fine sand	Fallow land	2-4	5.78	5.97	+ .19
T3b	do	do	2-4	5.80	5.92	+ .03
T4a	Low-moor peat	With growth of mixed forest	2-4	4.80	4.84	+ .04
T4b	do	do	2-4	5.32	5.22	-.10
T5a	Humous clay	Alfalfa land in 1925. 2.2 tons CaCO ₃ per acre had been received.	2-4	6.06	6.20	+ .12
T5b	do	do	2-4	6.61	6.53	-.08
T6a	do	Same. In addition 15.8 tons CaCO ₃ per acre had been received on Aug. 5, 1926.	2-4	6.49	6.38	-.11
T6b	do	do	2-4	7.18	7.29	+ .02
T7a		Coniferous forest	1-2	4.12	3.98	-.14
T7b		do	1-2	4.17	4.11	-.06
T8	Clay	River bottom, about 4 inches under water.		6.02	6.00	-.02
T9	Transitional low-moor and high-moor peat	Pea land, poor stand	1-3	5.26	5.19	-.07
T10	Humous clay	Pea land, good stand	1-3	5.39	5.02	-.28
T11	Low-moor peat	Plant improvement station	0-2	6.97	6.91	-.06

¹ Samples were collected in the fall of 1927.² Data from Teräsvuori (40) on Finnish soils.

TABLE 8.—*Influence of the storage of soil samples¹ at different moisture contents on the acidity of the soil²*

Sample No.	Soil	Depth	Days in storage	Moisture, per cent of saturation	Moist sample	Air-dry sample	Change
C539.....	Humous loam.....	Surface soil.....	0	*42.0	pH 5.60	pH 5.27	pH -0.33
			33	33.3	5.61		
			33	66.7	5.48		
			33	100.0	5.65		
			68	33.3	5.49		
			68	66.7	5.46		
			68	100.0	5.62		
			124	33.3	5.36		
			124	66.7	5.21		
			124	100.0	5.55		
C540.....	Humous sand.....	Surface soil.....	0	*50.0	5.18	5.24	+ .06
			33	33.3	5.17		
			33	66.7	5.07		
			33	100.0	5.44		
			68	33.3	5.15		
			68	66.7	5.07		
			68	100.0	5.31		
			124	33.3	5.05		
			124	66.7	4.93		
			124	100.0	5.45		
C541.....	Heavy clay.....	At 47 inches.....	0	*88.7	6.04	5.80	- .24
			33	66.7	5.78		
			33	100.0	6.56		
			68	33.3	5.32		
			68	66.7	5.80		
			68	100.0	7.23		
			124	33.3	5.00		
			124	66.7	5.35		
			124	100.0	5.95		
C542.....	Low-moor peat.....	Surface soil.....	0	*78.2	4.52	4.63	+ .11
			30	33.3	4.54		
			30	66.7	4.51		
			30	100.0	4.65		
			65	33.3	4.52		
			65	66.7	4.37		
			65	100.0	4.49		
			121	33.3	4.46		
			121	66.7	4.20		
			121	100.0	4.81		
C543.....	Muck.....	Surface soil.....	0	*64.1	4.93	4.97	+ .04
			30	33.3	4.75		
			30	66.7	4.64		
			30	100.0	5.06		
			65	33.3	4.66		
			65	66.7	4.61		
			65	100.0	5.20		
			121	33.3	4.56		
			121	66.7	4.50		
			121	100.0	5.33		

¹ Samples were collected in the summer of 1929.² Data from Teräsvuori (40) on Finnish soils.³ Initial moisture content in terms of per cent saturation.

As can be seen in Tables 7 and 8, 17 of the 40 soil samples, on which Teräsvuori made determinations in both the moist and in the air-dry condition, changed more than 0.10 pH unit on air drying. Seven of these samples became less acid and 10 became more acid. Five samples changed more than 0.20 pH unit, and a heavy clay subsoil at a depth of 47 inches changed 0.84 pH unit—the greatest change of any sample on drying out. The subsoils low in organic matter changed as much as did any of the surface soils high in organic matter.

Table 8 shows the effect Teräsvuori obtained on the soil samples by storing them at different moisture contents for several months, as well as the effect of air drying. The samples which were one-third and two-thirds saturated with water became increasingly more

acid with storage. The samples that were two-thirds saturated did not increase in acidity as much as did the corresponding ones that were one-third saturated. In general, there was a tendency for the water-saturated samples to become less acid as time passed. One soil, C539, became very slightly more acid when stored in a water-saturated condition, the change being less than 0.10 pH unit. Sample C541, a heavy clay subsoil, was most erratic in its behavior. It changed more than any other of Teräsuvuori's soils on passing from the moist to the air-dry condition, somewhat resembling Aarnio's (1) clays in its behavior, as shown in Tables 3 and 4.

In view of the wide variance of the recorded data and the fact that the air-dried condition is the usual form in which the soil samples are most readily brought to the laboratory and kept for examination, it seemed very important to determine definitely to what extent alterations of pH by air drying actually occur and, if such changes occur, to ascertain what restorative measures may be used to obviate the inconvenience of collecting fresh moist samples and to avoid any uncertainties arising from seasonal variations in field moisture conditions (10, 12, 15, 16, 24, 27, 29, 31).

COLLECTION AND PREPARATION OF SAMPLES

It seemed desirable that the investigations should cover a wide range of soil types developed and existing under varying climatic conditions and that the samples should receive uniform treatment throughout. Therefore about three years ago the cooperation of the field men in the soil survey and of some of the experiment station workers of this country and of Canada was asked in collecting moist horizon samples from representative profiles in their localities. Tin cans holding about a pint of soil, with covers which fitted tightly enough to prevent rapid air drying of the sample but were not sufficiently air-tight to induce anaerobic conditions, were furnished for collecting the samples. In each case moist samples were collected from representative portions of each horizon of the virgin profile, including the humous or the leaf-mold layer. Each can was labeled as to location, soil type, and depth at which the sample was taken, and it was sent to the laboratory. On reaching the laboratory each sample was immediately carefully mixed so as to have it as homogeneous as possible, and from 4 to 18 determinations were made while it was still moist. Then each sample was air-dried in a room separated from the laboratory so as to be free from fumes of any kind, again thoroughly mixed and run through a 2-mm. mesh sieve, and from 4 to 18 determinations were made in the air-dry state.

The virgin profiles, from which the horizon samples were collected, were selected with a view of covering a wide range of geographical and climatic regions within the United States, Porto Rico, and Canada. They also covered a wide range of soil groups. They included 6 representatives from the humid prairies, 3 from the brownish-red profiles bordering on pedocals, 6 from the chernozem group, 1 from the reddish-brown pedocals, 3 from the desert soils, 10 from the lateritic group, 3 from the imperfectly drained profiles of lateritic regions, 4 from the immature soils, 12 from the podsoles, 2 from the degraded chernozems, and 15 from the podsol profiles. All the soils from this

country and Porto Rico are identified as soil types in terms of the soil survey classification. The groups are in accordance with Marbut's (30) and Glinka's (18) classifications.

DESCRIPTION OF APPARATUS AND METHOD USED

In the investigations the hydrogen-ion concentration was measured by means of a method developed by the author for routine examination of soil samples for the soil survey as a result of his study of other

published methods (4, 7, 8, 13, 17, 21, 33, 38). The apparatus is of the bubbling hydrogen type and is similar to that of Bray (9) although developed independently before the publication of the Bray method. In both methods the hydrogen enters at the bottom of a thick-walled pyrex vessel, the lower part of which is funnel shaped, and the soil is kept in suspension by the stream of hydrogen bubbles. The apparatus differs from that of Bray in that it has no Gooch crucible inserted in the lower part of the electrode vessel to break the stream of hydrogen into a fine spray. Experience has shown that purification of the tank hydrogen is not necessary. The details of the apparatus are shown in Figures 1 and 2.

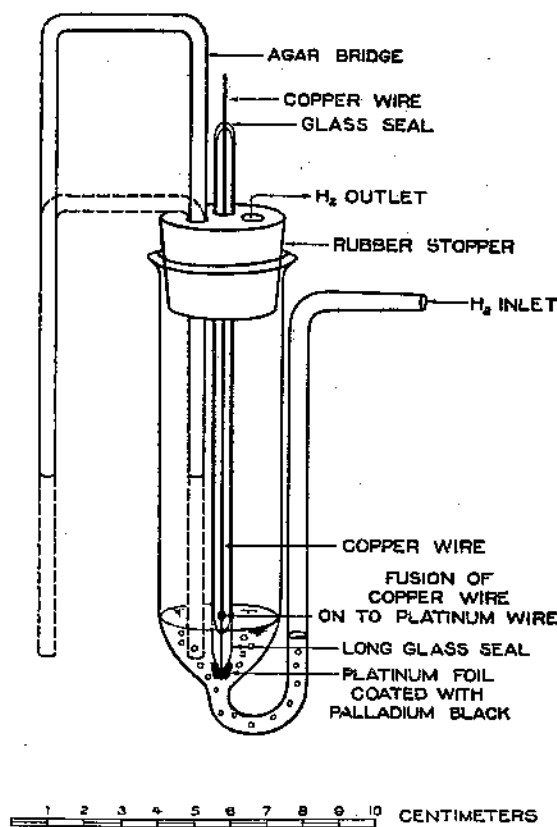


FIGURE 1.—Hydrogen electrode and electrode vessel for soil suspensions.

The agar bridge employed in this method consists of a U-shaped glass tube filled with 5 per cent agar made up with a 3.5 molar potassium chloride solution (7). Any strength potassium chloride from N/10 to a saturated solution gives equally good results. The end of the U tube which is to be dipped into the soil suspension must be kept immersed in distilled water while the apparatus is in use and not actually employed in taking readings. Otherwise potassium chloride is dissolved by the soil suspension, and the acidity may be increased through base exchange. The bridge is made (7) by sucking the melted agar solution into the dry tube, care being taken to have it completely filled. Several agar bridges are made up at a time. When not in

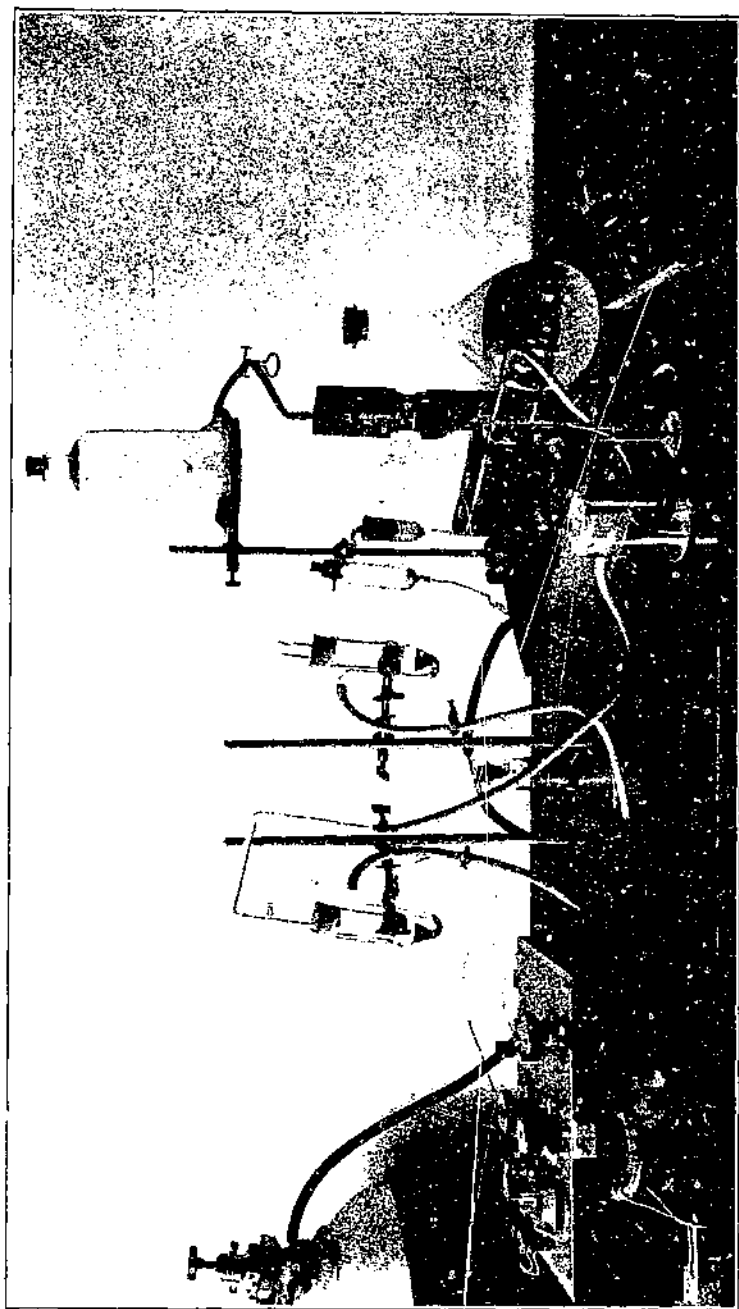


FIGURE 2.—Apparatus for the electrometric measurement of the hydrogen-ion concentration of soils with the hydrogen electrode

use, they are kept from drying out by being placed in a damp chamber. In this way one bridge may last for several months.

The other end of the agar bridge is pushed into a rubber tube filled with a saturated solution of potassium chloride. The rubber tube is joined to a glass tube provided with a glass stopcock. The glass tube widens into a small cylindrical vessel. Both the glass tube and the vessel are filled with a saturated solution of potassium chloride. Between the glass stopcock and the rubber tube, another glass tube, also provided with a glass stopcock, joins the first glass tube at right angles. This tube leads to an elevated reservoir likewise containing a saturated potassium chloride solution. (Fig. 2.) By carefully operating the two stopcocks, air bubbles can be eliminated when the agar bridge is connected with the rubber tube. The cylindrical potassium chloride vessel connects with a saturated potassium chloride calomel electrode (17, 38).

The electrodes are made by welding a small piece of platinum foil one-fourth inch square (13) or smaller (a point of platinum wire gives as good results) to a piece of platinum wire one-half millimeter in diameter and about three-fourths inch long. The other end of the platinum wire is welded to a piece of copper wire (21) of the same diameter and about 7 inches long. With the exception of about an inch and a half of the free end of the copper wire, the rest of it and the platinum wire are encased in a thick-walled glass tube of which the outside diameter is one-fourth inch. The long glass seal on the platinum wire (from one-fourth to three-fourths inch in length) extends a little way onto the foil in order to give strength. A short glass seal is fastened to the copper wire at the other, or upper, end to hold it firmly. (Fig. 1.)

The electrodes are thoroughly cleaned in chromic sulphuric acid cleaning solution, carefully rinsed in distilled water, and are given a medium-gray coat of palladium black from a 3 per cent palladium chloride solution containing 1½ per cent hydrochloric acid (4, 38). Direct current of 115 volts is used in series with a 15-watt lamp. To coat an electrode, the copper wire at its upper end is connected by means of a screw clamp soldered to an insulated copper wire leading from the negative pole of the lighting system and another electrode is connected in like manner with the positive pole. Both are then dipped into the palladium chloride solution. In a few seconds the negative electrode has attained a medium-gray coat. After coating, the electrodes are carefully washed in tap water and then rinsed with distilled water. They must then be allowed to stand in distilled water for about 12 hours before being used if certainty of constant readings is to be assured (8). In the opinion of the writer this is necessary in order to remove all the acid palladium chloride solution held by occlusion in the palladium coat. Electrodes will stand from six weeks to two months constant use before they must be recoated and will last almost indefinitely if not used after being coated, provided they are kept covered with distilled water.

For renewal of the electrode, the old coat is first removed by connecting the electrode with the positive pole of the coating apparatus described and the uncoated electrode with the negative pole, then both electrodes are dipped into a 1:1 aqueous hydrochloric acid solution (38). This dissolves the coat in a few seconds. The electrode is then cleaned and recoated as already described.

A high-grade portable potentiometer is used, which gives accurate enough readings for soil work. It is shown on the left in Figure 2. Its positive pole is connected by means of an insulated copper wire to the calomel electrode.

When possible, 1 part of soil by volume to 2 parts of distilled water are used. (This volume relation approximates a weight relation of 1:3 for the humus layers and 1:1½ for the mineral soil horizons.) In the case of clays twice that amount of water is necessary, otherwise the soil suspension would be a thick paste. It has been found most convenient to use a small spoon holding 1½ cubic centimeters of soil, when level full, as a measure and to add to this quantity of soil 3 cubic centimeters of boiled distilled water. The mixture is shaken up in duplicate in short thick-walled pyrex tubes, about 2 inches in length, with No. 4 rubber stoppers tightly pushed into their mouths. (Fig. 2.) Usually enough samples of soil are measured and mixed with water at a time for half a day's work. It appears to make no difference whether the water stands on the soil for 5 minutes or for 6 or 7 hours.

The stream of hydrogen is divided by means of a Y tube into two streams. Each stream is conducted by a rubber hose to an electrode vessel held in an upright position by a clamp attached to the electrode stand. (Fig. 2.) On each inlet hose is a screw clamp to regulate the flow of hydrogen so that there will be an equal flow into each vessel at the same time. While the hydrogen is running into the duplicate electrode vessels the contents of each of the two duplicate tubes of soil suspension are poured simultaneously into each, care being taken that all the soil from each tube is shaken into each vessel. On transferring the soil suspensions from the shaking tubes to the electrode vessels, a 3-hole stopper with a coated electrode inserted through one of its holes is thrust into each so that the blackened portion of the platinum is completely submerged in the suspension. The hydrogen is run in fast enough to keep the soil in each vessel in complete suspension. It appears to make no difference how fast the hydrogen bubbles pass through, so long as the soil particles are equally distributed throughout the suspension. With acid soils equilibrium is attained in from one-half minute to 5 minutes, whereas alkaline soils require from 5 to 10 minutes. When a reading of one of the duplicates is taken, the potentiometer is first balanced with the standard cell, then the copper wire from its negative pole is connected, by means of a screw clamp soldered to its other end, with the corresponding hydrogen electrode, and the free end of the agar bridge is removed from the glass of distilled water and pushed through one of the two remaining holes in the stopper until it comes in contact with the suspension. The hydrogen escapes through the third hole. The reading is then taken, together with the temperature from a thermometer immersed in water. At the same time that the agar bridge is shoved through one of the holes of the stopper into the suspension of one of the duplicates, a solid glass rod of the same diameter is stuck into one of the stopper holes of the other so as to give equality of pressure. The other duplicate is then similarly treated. The stream of hydrogen is provided with a mercury trap which serves as a safety valve in case the duplicates become clogged. The hydrogen then escapes through the mercury. The readings are always taken while the hydrogen is being bubbled through the suspension. While one pair of duplicates is coming to equilibrium, another pair of dirty electrodes with the

dirty stoppers, electrode vessels, and shaking tubes are being washed with tap water and rinsed with distilled water, the readings in millivolts are being converted by means of conversion tables into pH values, and the results tabulated. At the beginning of each day the apparatus and the hydrogen electrodes are checked by making determinations of samples of soil, the pH value of which is known and its constancy well established. By following the procedure outlined above, one person without assistance is able to do from 60 to 70 single determinations or from 30 to 35 duplicate determinations in a 7½-hour day.

The results of this method on a number of soil samples were compared with the unpublished results obtained on them by five other investigators of wide experience in making hydrogen-ion determinations. These investigators used different electrometric methods. Table 9 shows the comparison of the results obtained.

TABLE 9.—Comparison of method with data obtained by five other investigators with the hydrogen electrode and the quinhydrone electrode

Sample No.	A		B	C		D	E	Bailey	
	H. E. ¹	Q. E. ¹	Q. E.	H. E.	Q. E.	Q. E.	Q. E.	H. E.	Q. E.
	pH	pH	pH	pH	pH	pH	pH	pH	pH
2567	4.59	4.44	4.70					4.62	4.56
2568	4.79	4.62	4.70					4.84	4.78
2569	4.68		4.69					4.80	4.51
2601	4.53	4.48						4.47	
2602	5.04	5.00						5.05	
2603			5.41					5.49	5.43
2604			4.79					4.85	4.90
I.	7.38							7.38	
II.	9.16							9.11	9.13
III.	7.94							8.02	
A.				8.50	8.55			8.46	8.44
B.				5.08	5.14			4.97	5.03
C.				5.80	5.56			5.50	5.45
34177						4.55		4.61	4.43
34178						4.65		4.64	4.47
34191						6.41		5.96	5.92
34194						4.90		4.90	4.87
34196						5.46		5.10	5.28
C ₁						4.70		4.50	4.36
C ₂						5.25		4.75	5.01
34188						4.28		4.25	4.29
34139						4.33		4.59	4.54
34141						4.25		4.74	4.63
34161						4.72		4.55	4.49
34165						4.51			
62c							7.35	6.33	
62b							5.30	5.17	
62a							6.95	5.95	
62b							7.18	5.94	
65b							5.08	5.00	
65c							6.19	5.29	
87c							4.58	4.40	

¹ H. E.=hydrogen electrode; Q. E.=quinhydrone electrode.

Table 9 shows excellent agreement between the writer's results and those of A, and good agreement with those of C, with the hydrogen electrode, good agreement with those obtained by A, B, and C with the quinhydrone electrode on Maryland soils, fair agreement with those of D with the quinhydrone electrode on Ohio soils, and very poor agreement with those of E with the quinhydrone electrode on Mississippi River bottom soils from Mississippi. The splendid agreement between the author's hydrogen electrode results and those

of A, even with the three alkaline soils, are especially interesting. The committee on soil reaction measurements of the International Society of Soil Science (37) recommends a hydrogen electrode vessel of the Clark type for alkaline soils in preference to one of the bubbling type, as the removal of carbon dioxide by the current of hydrogen introduces an error. Investigator A used a Clark type of electrode vessel. The close agreement between his hydrogen electrode results and those of the author on the alkaline soils strongly indicates that the author's bubbling type of electrode vessel did not introduce any serious error.

One of D's quinhydrone results (sample No. C₃) was 1.5 pH units less acid than the corresponding hydrogen electrode value obtained by the writer and 0.34 pH unit less acid than the writer's quinhydrone electrode value. Only three of E's seven quinhydrone results came within 0.20 pH unit of those obtained by this hydrogen electrode method. The other four samples showed E's quinhydrone results to be 0.87 to 1.24 pH units less acid than those obtained by the writer with the hydrogen electrode method. These seven samples were tested for their manganese dioxide content by W. O. Robinson of the division of soil chemistry and physics, Bureau of Chemistry and Soils, as soils from lateritic regions are likely to be high in that substance. The three samples, which showed differences of less than 0.20 pH unit between the two methods, all had a very low manganese dioxide content. Two samples (62b and 65c), showing differences between the two methods of 1.24 and 0.87 pH units, respectively, both contained small quantities of manganese dioxide. One sample (52c), which showed a difference of 1.02 pH units between the two methods, contained considerable manganese dioxide, and one sample (62a), showing a difference between the two methods of 1.0 pH unit, contained no manganese dioxide. This last case indicates that there are other substances besides manganese (20, 23, 32) and factors other than alkalinity (5, 7, 28) that disturb the quinhydrone electrode. Because of these results, showing the quinhydrone electrode to be less reliable than the hydrogen electrode, and because of the wide variety of soils used in these investigations, including soils high in manganese as well as alkaline soils, only the hydrogen electrode was used in this work.

EXPERIMENTAL DATA

The data obtained on the hydrogen-ion concentration of fresh, moist profiles, together with that obtained on the same profiles after being air-dried, and the results of restorative treatments are given in Tables 10 to 19. It will be noted in these tables that in each case the mean pH values are given, together with the range of individual values. The mean values are not a true mean of the hydrogen-ion concentrations, since the pH value is a logarithmic function. They do, however, represent the mean range of variation of the 4 to 18 determinations made for each condition of each sample.

Twenty profiles, or 31 per cent of the 64 profiles studied, showed a change of more than 0.10 pH unit in some of their horizons on air drying; 42 horizon samples, or 13 per cent of the 327 horizon samples examined, changed more than 0.10 pH unit on passing from the moist to the air-dry condition; and 26 horizon samples, or 8 per cent of the total number examined, changed more than 0.20 pH unit on drying.

Only 2 of the 64 profiles studied contained horizons that changed 0.50 pH unit or more on becoming air-dry. The samples showing the greatest change were the A horizon (1½ to 6 inches) of a degraded chernozem from Alberta, Canada (Table 17), which changed 0.51 pH unit, and one from a podsol profile (8 to 12 inches), from western Oregon, which changed 0.68 pH unit. (Table 18.) In both samples the change was toward greater acidity. These results differ considerably from those of Aarnio (1), as shown in Tables 3 and 4, who had a minimum increase in acidity of 0.90 pH unit and a maximum of 3.20 pH units with his 14 samples on air drying and storing. They agree fairly well with those obtained by the other investigators (2, 6, 7, 11, 14, 19, 26, 36, 40).

Where the change on drying and storing exceeded 0.10 pH unit, with only two exceptions, namely, in the two deepest layers of a podsol profile from Wisconsin (Table 19), it was toward greater acidity. These results in this regard agree in general with those of Aarnio and the other investigators (1, 2, 6, 7, 11, 14, 19, 26, 36, 40).

With few exceptions the greatest change on air drying took place in the upper layers which were high in organic matter. In this respect these results differ sharply from those of Aarnio (1) and from those of Bayer (6) both of whom found the reverse to be true, but they agree with results obtained by Knickmann (26) and Achromeiko (2).

With only one exception (the humus layer of a reddish-brown pedocal, Table 12) no horizon sample which was neutral or alkaline in the fresh, moist condition changed more than 0.10 pH unit on air drying. This disagrees with the findings of some of the other investigators (1, 6, 11, 36) who found that alkaline and neutral soils as well as acid soils change more than 0.10 pH unit on becoming air-dry.

As has been noted, the greater part of the profiles examined did not change in pH value more than 0.10 pH unit in any of their horizons on air drying. Of the samples that changed more than this amount, some from several groups of profiles were more easily restored to their original pH values by submergence in the water used in the determinations from 18 to 24 hours. (Tables 12-15.) Horizon samples from other groups of profiles responded better to the restorative treatment of being moistened but not saturated with distilled water (to simulate field conditions), and allowed to stand in that condition with the covers on the cans to prevent rapid evaporation from 4 to 7 days (Tables 16-18). One group of profiles contained some horizons which were restored more closely by one treatment and others which responded better to the other treatment. These are shown in Table 19.

None of the humid prairie profiles, the brownish-red soils bordering on the pedocals, and, with the exception of one surface layer, none of the pedocals, consisting of the chernozems, the reddish-brown, and the desert soils, changed more than 0.10 pH unit in any horizons on drying. (Tables 10-12.) This statement also applies to four-fifths of the lateritic soils (Table 13), to three-fourths of the immature profiles (Table 15), to two-thirds of the imperfectly drained soils of lateritic regions (Table 14), to more than one-half of the podsol soils of the Eastern and Northwestern States (Table 19), and to approximately one-half of the podsoles and the degraded chernozems (Tables 16 and 17).

TABLE 10.—*Hydrogen-ion determinations of humid prairie soils taken in the moist field condition and in the air-dry state*

Soil type	Location	Depth	Moist, field sample	Air-dry sample	Change from moist field condition
Carrington silt loam ¹	Guthrie County, Iowa.....	<i>Inches</i> 0-2 8-12 20-24 46-50 68-72	<i>pH</i> 6.13±.10 5.58±.05 5.94±.08 6.16±.13 6.02±.08	<i>pH</i> 6.06±.05 5.56±.03 5.91±.02 6.09±.02 6.03±.04	<i>pH</i> -0.05 -0.02 -0.03 -0.07 -0.01
Do. ¹	Butler County, Iowa.....	8-1 1-5 11-15 18-22 27-31 40-44	5.16±.01 5.26±.01 5.63±.02 5.63±.02 5.62±.00 6.00±.05	5.16±.01 5.22±.03 5.60±.01 5.61±.01 5.65±.02 6.00±.00	+0.02 -0.04 -0.03 -0.02 -0.03 +0.00
Tama silt loam ¹	Vernon County, Wis.....	0-6 6-15 15-21 21-32 32-44 44-60	5.02±.01 5.44±.03 5.16±.04 5.46±.03 5.35±.03 5.90±.02	5.03±.01 5.48±.01 5.24±.01 5.53±.04 5.34±.04 5.95±.03	+0.01 +0.04 -0.08 +0.07 -0.01 +0.05
Do. ¹	Guthrie County, Iowa.....	0-2 4-8 11-15 17-21 25-29 40-44 48-52 74-78	6.38±.07 6.53±.04 5.28±.02 5.17±.04 5.25±.03 5.57±.05 5.81±.06 6.16±.09	6.32±.05 6.45±.02 5.30±.01 5.17±.04 5.26±.04 5.57±.04 5.78±.01 6.19±.06	+0.00 -0.06 +0.02 -0.00 +0.01 -0.00 -0.03 +0.03
Do. ¹	Butler County, Iowa.....	0-1 4-8 14-18 27-31 40-44 54-58	4.58±.02 4.22±.03 5.65±.02 5.64±.01 5.97±.02 6.21±.01	4.98±.01 6.19±.01 5.67±.00 5.63±.02 5.69±.00 6.21±.01	-0.00 -0.03 -0.02 -0.01 +0.02 -0.00
Dickinson fine sandy loam ²	Butler County, Iowa.....	0-4 14-18 29-33 44-48	5.63±.02 5.43±.00 5.13±.00 5.30±.01	5.59±.00 5.42±.01 5.18±.00 5.28±.01	-0.04 -0.01 -0.00 -0.02

¹ 8 determinations were made of each sample in each condition.² 4 determinations were made of each sample in each condition.

TABLE 11.—Hydrogen-ion determinations of brownish-red soils, bordering on pedocals, taken in the moist, field condition and in the air-dry state and the effects of restorative treatments on the pH of some of the air-dried samples¹

Soil type	Location	Depth	Moist field sample	Air-dry sample	Change from moist field condition	Air-dry soil in contact with water 18-24 hours	Change from moist field condition	Air-dry soil moistened 4-7 days before	Change from moist field condition	Air-dry soil moistened 30 days before	Change from moist field condition
Las Posas stony fine sandy loam	Oceanside area, Calif.	Inches 0-1/2	pH 6.39±0.01	pH 6.32±0.00	pH -0.07	pH 6.41±0.02	pH +0.02	pH 6.01±0.01	pH -0.38	pH 5.54±0.03	pH -0.85
		1/2-4	6.57±.03	6.49±.04	-.08	6.50±.04	-.01	6.54±.03	-.03	6.23±.03	-.34
		8-12	7.00±.07	6.97±.05	-.03						
		22-26	7.07±.05	7.08±.03	+.01						
Fallbrook sandy loam	do.	0-1/4	6.97±.00	6.95±.05	-.02	6.97±.03	0				
		1-5	6.66±.01	6.66±.01	.00						
		12-16	7.13±.06	7.17±.02	+.04						

¹ 8 determinations were made of each sample in each condition.

The horizons appreciably altered by air drying, which responded best to the treatment of submergence from 18 to 24 hours in the distilled water used in the determinations, were from the reddish-brown pedocal profile (Table 12), from the lateritic group (Table 13), from the imperfectly drained soils of lateritic regions (Table 14), and from the immature profiles (Table 15).

TABLE 12.—Hydrogen-ion determinations of pedocal soils taken in the moist field condition and in the air-dry state

CHERNOZEMS

Soil type	Location	Depth	Moist field sample	Air-dry sample	Change from moist field condition
		Inches	pH	pH	pH
Weyburn clay loam ¹	Saskatchewan, Canada	0-2	7.88±0.03	7.91±0.06	+0.03
		2-5	7.08±.08	6.92±.09	-.06
		10-14	8.06±.07	7.07±.05	-.99
Do. ²	do	22-26	8.49±.04	8.47±.05	-.02
		45-50	8.18±.09	8.22±.06	+.04
		58-62	8.48±.05	8.48±.04	-.01
Melfort silt loam ¹	do	0-1 1/4	7.99±.06	7.98±.09	-.01
		3-7	7.67±.08	7.75±.08	+.08
		10-14	6.93±.08	6.89±.06	-.04
Do. ²	do	16-20	7.19±.06	7.15±.02	-.04
		33-37	8.63±.08	8.54±.05	-.09
		74-78	8.60±.13	8.52±.05	-.08
Moody silt loam ¹	Moody County, S. Dak.	0-4	7.35±.03	7.36±.03	+.01
		4-11	7.06±.03	7.03±.03	-.03
		11-20	6.82±.06	6.82±.02	-.04
Do. ²	do	20-34	7.31±.01	7.33±.02	+.02
		34-44	8.70±.01	8.70±.05	-.04
		44-56	8.69±.03	8.66±.03	-.03
		56-78	8.67±.02	8.68±.02	+.01
Barnes loam ¹	Kingsbury County, S. Dak.	0-2	8.05±.03	8.05±.02	-.01
		2-11	7.85±.00	7.82±.01	-.01
		11-23	7.40±.02	7.41±.04	+.01
Do. ²	do	23-44	8.41±.09	8.43±.07	+.02
		44-53	8.61±.08	8.57±.08	-.04
		53-64	8.63±.06	8.65±.04	+.02
		64-73	8.48±.04	8.51±.04	+.03
Summit silt loam ¹	Ellis County, Kans.	0-6	8.43±.03	8.45±.03	+.02
Do. ²	do	28-30	8.35±.05	8.38±.04	+.03
Do. ³	do	50-54	8.36±.09	8.35±.08	-.01
		58-62	8.03±.07	8.03±.05	-.02
		118-122	7.35±.05	7.64±.04	+.29
		142-146	8.68±.02	8.68±.02	-.00
Pullman silty clay loam ^{1, 4}	Potter County, Tex.	0-6	6.68±.13	6.72±.05	+.04
		10-20	7.78±.11	7.72±.05	-.06
Do. ²	do	30-40	8.17±.10	8.21±.04	+.04
Do. ³	do	64-64	7.96±.13	7.98±.05	+.02
		70-76	8.02±.15	8.04±.05	+.02
		90-95	8.31±.11	8.30±.05	-.01

REDDISH-BROWN SOILS

Merriam sandy loam ^{1, 2}	Oceanside area, California	0- 3/4	7.23±0.06	6.94±0.04	-0.29
Do. ¹	do	10-14	6.20±.03	6.18±.02	-.02
Do. ²	do	21-25	7.71±.08	7.72±.02	+.01
		35-40	8.57±.06	8.64±.03	+.07
		60-64	8.53±.06	8.51±.04	-.02

¹ 18 determinations were made of each sample in each condition.

² Lime zone.

³ 4 determinations were made of each sample in each condition.

⁴ Lime concretions.

⁵ Full of lime concretions.

⁶ Southern chernozem; first 2 horizons, dark chocolate brown; third horizon, medium chocolate brown.

⁷ The air-dry sample, after being in contact with water from 18 to 24 hours, showed a pH of 7.21±0.02, the change from the moist field condition being -0.02 pH. On moistening the air-dry sample from 4 to 7 days before, the pH became 6.86±0.04, showing a change from the moist field condition of -0.07 pH. The air-dry sample, after being stored for 30 days in a moistened condition, had a pH of 5.92±0.04, which gave a change of -1.31 pH from the moist field condition.

TABLE 12.—*Hydrogen-ion determinations of pedocal soils taken in the moist field condition and in the air-dry state—Continued*

DESERT SOILS

Soil type	Location	Depth	Moist field sample	Air-dry sample	Change from moist field condition
		Inches	pH	pH	pH
Relston loam ¹	Basin area, Wyoming.....	0- ½	8.60±0.03	8.62±0.02	+0.02
Do. ²	do.....	2-6	8.51±.04	8.61±.06	+0.10
Do. ³	do.....	18-22	9.14±.09	9.12±.02	-.02
Do. ⁴	do.....	33-37	8.21±.09	9.24±.02	+0.03
Relston sandy loam ¹	do.....	0-2	8.25±.00	8.20±.07	-.05
Do. ²	do.....	3-7	8.48±.08	8.48±.04	-.00
Do. ³	do.....	9-14	8.74±.11	8.72±.05	-.02
Do. ⁴	do.....	16-20	9.04±.11	9.07±.04	+0.03
Do. ⁵	do.....	30-34	9.16±.13	9.18±.04	+.00
Chipeta fine sandy loam ¹	do.....	0-1	8.51±.04	8.60±.06	+0.09
Do. ²	do.....	6-10	8.63±.10	8.73±.04	+0.10
Do. ³	do.....	16-20	8.70±.07	8.77±.07	+0.07
Do. ⁴	do.....	23-28	8.89±.07	8.78±.06	-.10

¹ 8 determinations were made of each sample in each condition.² Lime concretions.³ Full of lime concretions.

One profile (five horizon samples) belonging to the reddish-brown pedocal group was examined (Table 12). Its humus layer became 0.29 pH unit more acid on drying. This was the only alkaline sample (pH 7.23) in the fresh, moist condition which showed a change of more than 0.10 pH unit on becoming air-dry.

Ten profiles (49 horizon samples) of the lateritic group were studied (Table 13). Three of the upper layers of two of the profiles became more than 0.10 pH unit more acid on air drying.

TABLE 13.—Hydrogen-ion determinations of lateritic soils taken in the moist field condition and in the air-dry state and the effects of restorative treatments on the pH of some of the air-dried samples

Soil type	Location	Depth	Moist field sample	Air-dry sample	Change from moist field condition	Air-dry soil in contact with water 18-24 hours	Change from moist field condition	Air-dry soil moistened 4-7 days before	Change from moist field condition	Air-dry soil moistened 30 days before	Change from moist field condition
		Inches	pH	pH	pH	pH	pH	pH	pH	pH	pH
Rio Piedras clay ¹ -----	San Juan area, Porto Rico-----	0-2	6.03±0.04	6.03±0.05	0	6.03±0.04	0				
		2-12	5.18±.04	5.17±.04	-.01						
		12-30	5.20±.03	5.18±.01	-.02						
		30-48	4.99±.03	5.02±.03	+.03						
		48-60	4.41±.03	4.42±.02	+.01						
Bayamon clay loam ¹ -----	do-----	0-2	4.81±.02	4.65±.05	-.16	4.80±.02	-.01	5.14±0.01	+0.33	4.82±0.03	+0.01
		2-12	4.81±.02	4.81±.06	.00						
		12-30	4.81±.02	4.85±.02	+.04						
		30-48	4.81±.02	4.83±.04	+.02						
		120-144	4.79±.04	4.76±.03	-.03						
Red Bay fine sandy loam ¹ -----	Mobile County, Ala-----	0-2	5.06±.04	5.62±.00	-.04	5.63±.02	-.03				
		5-9	5.76±.06	5.80±.00	+.04						
		24-28	5.29±.00	5.26±.03	-.03						
		44-48	4.95±.05	4.97±.01	+.02						
		0-1½	5.65±.04	5.63±.00	-.02	5.50±.01	-.03				
Ruston loamy fine sand ² -----	do-----	5-9	5.84±.01	5.85±.04	+.01						
		15-19	5.18±.05	5.21±.08	+.03						
		42-46	5.26±.03	5.29±.03	+.03						
		0-½	5.74±.02	5.71±.01	-.03	5.75±.05	+.01				
		½-3	5.69±.06	5.68±.02	-.01						
Blakely loam ¹ -----	Dougherty County, Ga-----	3-7	5.58±.01	5.58±.04	+.02						
		7-12	5.74±.02	5.80±.00	+.06						
		12-16	6.02±.05	6.04±.01	+.02						
		16-20	6.03±.04	6.06±.03	+.03						
		20-24	6.05±.05	6.05±.02	.00						
		24-28	6.03±.04	6.05±.02	+.02						
		28-32	6.39±.08	6.40±.00	+.01						
		32-36	6.38±.03	6.37±.05	-.01						
		36-40	6.39±.04	6.41±.01	+.02						
		40-44	6.39±.04	6.42±.01	+.03						
		44-48	6.50±.03	6.48±.01	-.02						
		0-4	5.20±.00	5.21±.02	+.01	5.22±.00	+.02				
		18-22	5.34±.02	5.35±.04	+.01						
		40-44	5.10±.00	5.08±.01	-.02						
		74-78	4.93±.00	4.93±.03	.00						
Cecil sandy loam ² -----	Coosa County, Ala-----	0-4	5.20±.00	5.21±.02	+.01	5.22±.00	+.02				
		18-22	5.34±.02	5.35±.04	+.01						
		40-44	5.10±.00	5.08±.01	-.02						
		74-78	4.93±.00	4.93±.03	.00						

¹ 8 determinations were made of each sample in each condition.² 4 determinations were made of each sample in each condition.

TABLE 13.—Hydrogen-ion determinations of lateritic soils taken in the moist field condition and in the air-dry state and the effects of restorative treatments on the pH of some of the air-dried samples—Continued

Soil type	Location	Depth	Moist field sample	Air-dry sample	Change from moist field condition	Air-dry soil in contact with water 18-24 hours	Change from moist field condition	Air-dry soil moistened 4-7 days before	Change from moist field condition	Air-dry soil moistened 30 days before	Change from moist field condition
		<i>Inches</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>		<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>
Decatur silty clay loam ¹ -----	Coosa County, Ala-----	0-4	5.91±.01	5.89±.00	-.02	5.84±.01	-.07				
		30-34	5.19±.01	5.21±.01	+.02						
		44-48	4.95±.02	4.92±.03	-.03						
Madison gravelly loam ² -----	do-----	0-4	4.87±.03	4.91±.02	+.04	4.84±.01	-.03				
		12-16	5.00±.00	5.05±.02	+.05						
		26-30	5.17±.00	5.20±.02	+.03						
		40-44	5.19±.01	5.30±.02	+.01						
Alken clay loam ^{2 1} -----	Columbia County, Oreg-----	0-2	5.60±.01	5.56±.01	-.04	5.56±.03	-.04	5.68±.01	+.08		
		7-11	5.43±.02	5.46±.01	+.03						
		24-28	5.40±.00	5.42±.03	+.02						
		66-70	5.40±.00	5.39±.00	-.01						
Alken clay loam ^{2 2} -----	Placer County, Calif-----	0-4	5.80±.00	5.50±.03	-.30	5.81±.04	+.01	5.45±.09	-.35	5.25±.00	-.55
		4-20	5.90±.00	5.75±.00	-.15	5.90±.00	+.00	5.84±.02	-.06	5.69±.00	-.21
		20-36	5.44±.01	5.45±.02	+.01						

¹ 4 determinations were made of each sample in each condition.² Humid red soil which probably is lateritic.

Three profiles (11 horizon samples) of imperfectly drained soils of lateritic regions were examined (Table 14). Of these, but one horizon, the surface layer of the Appling sandy loam profile, changed more than 0.10 pH unit on drying. It became 0.22 pH unit more acid.

TABLE 14.—*Hydrogen-ion determinations of imperfectly ¹ drained soils of lateritic regions taken in the moist field condition and in the air-dry state and the effects of restorative treatments on the pH of some of the air-dried samples ²*

Soil type	Location	Depth	Moist field sample	Air-dry sample	Change from moist field condition	Air-dry soil in contact with water 18-24 hours	Change from moist field condition	Air-dry soil moistened 4-7 days before	Change from moist field condition	Air-dry soil moistened 30 days before	Change from moist field condition
		<i>Inches</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>	<i>pH</i>
Irvington very fine sandy loam	Mobile County, Ala.	0-1½	5.41±0.08	5.42±0.03	+0.01	5.37±0.05	-0.04				
		4-8	5.29±0.06	5.33±0.00	+0.04						
		12-16	5.23±0.07	5.23±0.09	+0.00						
Norfolk fine sandy loam	do.	26-30	5.18±0.05	5.22±0.01	+0.04						
		0-1½	5.44±0.01	5.43±0.00	-0.01	5.43±0.00	-0.01				
		3-7	5.23±0.00	5.21±0.01	-0.02						
Appling sandy loam	Coosa County, Ala.	15-19	5.02±0.03	5.03±0.02	+0.01						
		29-33	5.11±0.01	5.05±0.00	-0.06						
		0-4	5.50±0.02	5.28±0.04	-0.22	5.47±0.02	-0.03	5.29±0.03	+0.02	4.87±0.00	-0.63
		18-22	5.26±0.01	5.23±0.01	-0.03						
		22-36	4.92±0.01	4.68±0.01	+0.06						

¹ These soils are sufficiently well drained for agricultural purposes.

² 4 determinations were made of each sample in each condition.

Four immature profiles (15 horizon samples) were studied (Table 15). Of these the profile of Mucara clay from Porto Rico altered on drying between 0.10 and 0.20 pH unit in the upper four of its five horizons.

TABLE 15.—Hydrogen-ion determinations of immature soils taken in the moist field condition and in the air-dry state, and the effects of restorative treatments on the pH of some of the air-dried samples ¹

Soil type	Location	Depth	Moist field sample	Air-dry sample	Change from moist field condition	Air-dry soil in contact with water 18-24 hours	Change from moist field condition	Air-dry soil moistened 4-7 days before	Change from moist field condition	Air-dry soil moistened 30 days before	Change from moist field condition
		Inches	pH	pH	pH	pH	pH	pH	pH	pH	pH
Houston clay ¹ -----	Montgomery County, Ala.-----	0-9	8.00±0.03	8.00±0.03	0	8.00±0.03	0				
		9-35	8.13±.02	8.10±.05	-.03						
		35-50	8.17±.02	8.17±.03	.00						
Mucara clay-----	San Juan area, Porto Rico-----	0-1	6.58±.02	6.45±.05	-.13	6.61±.04	+.03	6.33±0.00	-.25	6.16±0.03	-.42
		1-10	6.77±.03	6.61±.04	-.16	6.74±.01	-.03	6.81±.08	+.04	6.82±.00	+.05
		10-24	6.71±.06	6.57±.08	-.14	6.71±.04	.00	6.72±.10	+.01	6.82±.02	+.11
		24-30	6.89±.03	6.69±.04	-.20	6.87±.05	-.02	6.85±.05	-.04	6.76±.02	-.13
		30-48	7.39±.06	7.36±.03	-.03						
Lehew gravelly silt loam-----	Tioga County, Pa.-----	0-2	4.70±.06	4.77±.00	+.01	4.81±.01	+.05	5.11±.01	+.35		
		2-12	5.15±.02	5.13±.00	-.02						
		12-24	5.13±.02	5.11±.01	-.02						
Elkhorn loamy fine sand ¹ -----	Oceanside area, California-----	0-14	7.11±.08	7.10±.09	-.01	7.20±.02	+.09				
		6-10	6.51±.02	6.53±.06	+.02						
		24-28	7.47±.05	7.45±.03	-.02						
		60-64	7.89±.03	7.83±.02	-.06						

¹ 8 determinations were made of each sample in each condition.

² Rendzina.

³ Bordering on reddish-brown pedocals.

Both restorative treatments were employed on the horizons of the three soil groups which had changed more than 0.10 pH unit on air drying. (Tables 12-15.) All these horizon samples were restored to within the above deviation from the original pH values by submergence in water from 18 to 24 hours. On the other hand, moistening the same samples and keeping them moist from 4 to 7 days failed to restore the original pH value of the moist sample in the case of the reddish-brown pedocal humus horizon sample (note 7, Table 12) in 2 of the 3 horizon samples of the lateritic soils and in 1 of the 4 horizons of the immature soils. In the other samples both treatments were effective. This clearly shows that the first treatment is the better one for these soils. In one case (Table 13) the surface horizon became 0.33 pH unit less acid on standing for 7 days in the moist condition, but at the end of 30 days' storage it returned to its original pH value. Two other moistened horizons (Table 15) became slightly less acid on storage and a surface sample (Table 15) which had changed less than 0.10 pH unit on drying became 0.35 pH unit less acid 7 days after being moistened. This behavior is in contrast with the results shown by Teräsuvuori (40) (Table 8) and similar to those of Achromeiko (2) (Tables 1 and 2). In contrast with these samples the remainder of the horizon samples became more acid as a result of storage in the moist condition as found by Teräsuvuori (40) (Table 8) and Rost and Fieger (36). One sample (footnote 7, Table 12) became 1.31 pH unit more acid than the original moist sample following 30 days of storage in the moist condition.

A check on the restorative treatment by submergence from 18 to 24 hours in distilled water was obtained by using it on 16 upper horizon samples from the brownish-red profiles bordering on pedocals (Table 11) from the lateritic soils (Table 13), from the imperfectly drained soils from lateritic regions (Table 14), and from the immature profiles (Table 15), which had not altered more than 0.10 pH unit on drying. In every case the values obtained did not vary from that of the original moist sample by more than this value.

The horizons, appreciably changed by air drying, which responded best to the treatment of being moistened and stored in a moist condition from four to seven days were from the podsol group (Table 16), from the degraded chernozems (Table 17), and from the podsol profiles of the Pacific coast (Table 18).

TABLE 16.—Hydrogen-ion determinations of podsol soils taken in the moist field condition and in the air-dry state and the effects of restorative treatments on the pH of some of the air-dried samples

Soil type	Location	Horizon	Depth	Moist field sample	Air-dry sample	Change from moist field condition	Air-dry soil in contact with water 18-24 hours	Change from moist field condition	Air-dry soil moistened 4-7 days before	Change from moist field condition	Air-dry soil moistened 30 days before	Change from moist field condition
			Inches	pH	pH	pH	pH	pH	pH	pH	pH	pH
Fine sandy loam ¹	Montreal Island, Quebec, Canada.	Gray-brown humus	0-3	5.13±0.02	4.73±0.06	-0.40	4.89±0.04	-0.24	5.13±0.03	0	4.75±0.05	-0.38
		Black humus	3-4	4.34±0.01	4.22±0.07	-0.12	4.28±0.04	-0.08	4.33±0.03	-0.01	4.46±0.03	+0.12
		Dark-gray layer	4-6	4.45±0.02	4.33±0.06	-0.12	4.41±0.04	-0.04	4.45±0.00	0	4.67±0.00	+0.22
		Brown	6-11	5.12±0.02	5.12±0.02	0						
Do. ¹	Compton County, Quebec, Canada.	Reddish brown	11-16	5.69±0.02	5.70±0.00	+0.01						
		Parent material	16-28	6.94±0.01	6.92±0.02	-0.02						
		Raw humus	0-2	5.60±0.03	5.65±0.02	+0.05						
		Gray	2-3	5.16±0.03	5.09±0.01	-0.10	5.06±0.01	-0.10	5.20±0.02	+0.04	5.37±0.01	+0.18
Do. ¹	Brome County, Quebec, Canada.	Brown	3-4	4.70±0.01	4.67±0.00	-0.03						
		Light brown	7-11	4.89±0.00	4.91±0.01	+0.02						
		Parent material	20-24	5.07±0.02	5.07±0.02	0						
		Raw humus	0-1 1/2	4.72±0.02	4.24±0.01	-0.48	4.36±0.01	-0.36	4.75±0.03	+0.03	4.76±0.06	+0.04
Becket loam ¹	Berkshire County, Mass.	Gray	1 1/2-3	4.80±0.01	4.59±0.01	-0.21	4.79±0.00	-0.01	4.79±0.04	-0.01	4.83±0.01	+0.03
		Dark coffee colored	3-4	4.80±0.00	4.31±0.01	-0.49	4.62±0.00	-0.18	4.79±0.01	-0.01	4.84±0.02	+0.04
		Medium coffee colored	4-8	4.80±0.00	4.56±0.01	-0.24	4.77±0.03	-0.03	4.78±0.03	-0.02	4.93±0.02	+0.13
		Parent material	20-24	4.93±0.03	4.93±0.03	0	4.94±0.04	+0.01	4.94±0.03	+0.01	5.00±0.00	+0.07
Berkshire loam ¹	Hampshire County, Mass.	Humus	0-6	4.04±0.03	4.04±0.02	0						
		Gray	6-11	3.88±0.02	3.86±0.01	-0.02						
		Brown	11-24	4.16±0.04	4.22±0.00	+0.06						
		Parent material	24-36	4.64±0.01	4.63±0.03	-0.01						
Becket finesandy loam ²	Windham County, Vt.	Humus	0-2	4.60±0.02	4.11±0.02	-0.49	4.20±0.00	-0.40	4.59±0.02	-0.01	5.02±0.02	+0.42
		Gray	2-3	3.87±0.05	3.79±0.03	-0.08	3.86±0.01	-0.01	3.91±0.02	+0.04	4.14±0.05	+0.27
		Dark coffee colored	3-5	4.10±0.02	4.11±0.01	+0.01	4.01±0.02	-0.09	4.15±0.02	+0.05	4.57±0.05	+0.47
		Medium coffee colored	5-12	4.59±0.04	4.59±0.00	0	4.62±0.00	+0.03	4.60±0.01	+0.01	4.85±0.00	+0.26
Hermon fine sandy loam ³	Rutland County, Vt.	Light coffee colored	12-20	4.66±0.03	4.67±0.00	+0.01	4.66±0.03	0	4.70±0.05	+0.04	4.88±0.05	+0.23
		Parent material	20-36	4.87±0.02	4.90±0.02	+0.03						
		Humus	0-3	4.03±0.00	4.03±0.00	0	4.03±0.00	0	4.08±0.02	+0.05	4.36±0.03	+0.33
		Coffee colored	3-11	4.45±0.02	4.48±0.03	+0.03	4.48±0.01	+0.03	4.47±0.02	+0.02	4.82±0.00	+0.37
		Parent material	49-30	5.05±0.00	5.02±0.01	-0.03	5.05±0.00	0	5.06±0.01	+0.01	5.29±0.00	+0.24
		Humus	0-2	4.07±0.04	4.00±0.01	-0.07	4.02±0.01	-0.05	4.00±0.00	-0.07	4.78±0.03	+0.69
		Gray	2-4	4.07±0.00	3.77±0.00	-0.30	4.03±0.00	-0.04	4.03±0.00	-0.04	4.03±0.00	-0.04
		Dark coffee colored	4-6	4.00±0.00	3.91±0.01	-0.09	4.02±0.00	+0.02	4.03±0.03	+0.03	4.21±0.01	+0.21
		Medium coffee colored	6-11	4.19±0.00	4.25±0.00	+0.06	4.22±0.03	+0.03	4.18±0.02	-0.01	4.73±0.01	+0.54
		Parent material	60-72	5.05±0.00	5.01±0.02	-0.04	5.13±0.00	+0.08	5.05±0.02	0	5.32±0.00	+0.27

Bath gravelly silt loam ¹	Tioga County, Pa.	Humus	0-2	4.85±.05	4.72±.01	-.13	4.71±.01	-.14	4.80±.00	-.05	5.18±.03	+ .33
		Gray	2-5	4.80±.03	4.59±.00	-.21	4.72±.00	-.08	4.80±.03	0.00	4.86±.03	+ .06
		Brown	5-8	4.08±.01	4.10±.00	+ .02	4.08±.02	0	4.12±.00	+ .04	4.37±.02	+ .29
		Parent material	8-36	4.37±.05	4.39±.00	+ .02	4.39±.00	+ .02				
Leetonia stony loam ²	do.	Humus	0-2	4.41±.04	4.37±.02	-.04	4.39±.00	-.02	4.45±.05	+ .04	4.73±.04	+ .32
		Gray	2-5	4.52±.02	4.40±.00	-.03	4.51±.02	-.01	4.48±.01	-.04	4.53±.00	+ .01
		Brown	5-10	4.18±.02	4.10±.00	+ .01	4.23±.02	+ .05	4.21±.01	+ .03	4.61±.04	+ .43
		Parent material	10-30	4.54±.04	4.53±.00	-.01						
Munising sandy loam ¹	Alger County, Mich.	Humus	0-2	4.56±.07	4.30±.03	-.26	4.10±.02	-.40	4.60±.03	+ .04	5.21±.11	+ .65
		Gray	2-8	4.69±.06	4.74±.05	+ .05						
		Brown	8-24	4.45±.06	4.50±.05	+ .05						
		Parent material	24-40	5.09±.09	5.09±.04	0						
Hiawatha loamy sand ¹	do.	do.	40-60	4.78±.05	4.85±.05	+ .07						
		do.	60-64	4.75±.05	4.79±.01	+ .04						
		Humus	0-3	5.19±.06	5.10±.12	-.09						
		Gray	3-12	4.80±.07	4.78±.08	-.02						
Omega sand ¹	Bayfield County, Wis.	Brown	12-30	4.61±.08	4.71±.09	+ .10						
		Parent material	30-48	4.70±.08	4.75±.05	+ .05						
		Humus	0-3	4.69±.04	4.68±.01	-.01						
		Gray	3-8	4.93±.05	4.79±.00	-.14	4.62±.01	-.31	4.97±.01	+ .04	4.95±.05	+ .02
		Brown	12-30	5.45±.02	5.43±.04	-.02						
		Parent material	30-40	5.40±.05	5.45±.02	+ .05						

¹ 8 determinations were made of each sample in each condition.² 4 determinations were made of each sample in each condition.

TABLE 17.—Hydrogen-ion determinations of degraded chernozem¹ soils taken in the moist field condition and in the air-dry state and the effects of restorative treatments on the pH of some of the air-dried samples²

Soil type	Location	Horizon	Depth	Moist field sample	Air-dry sample	Change from moist field condition	Air-dry soil in contact with water 18-24 hours	Change from moist field condition	Air-dry soil moistened 4-7 days before	Change from moist field condition	Air-dry soil moistened 30 days before	Change from moist field condition
Silt loam	Alberta, Canada	Raw humus	Inches 0-1½	pH 7.25±0.02	pH 7.23±0.01	pH -0.02	pH	pH	pH	pH	pH	pH
		Medium gray	1½-6	5.47±.02	4.96±.00	- .51	5.31±0.02	-0.16	5.45±0.00	-0.02	5.46±0.01	- .01
		Light gray	6-10	5.41±.04	4.96±.00	- .45	5.13±.01	- .28	5.42±.03	+ .01	5.40±.00	- .01
		Light brownish gray	18-22	5.03±.00	4.87±.00	- .16	5.06±.01	+ .03	5.04±.02	+ .01	5.02±.08	- .01
		Medium brownish gray	23-27	5.05±.05	5.03±.03	- .02						
		do	36-40	7.93±.04	7.92±.02	- .01						
		Medium brownish gray with lime concretions.	40-50	8.10±.05	8.10±.03	- .00						
		Medium brownish gray with no lime concretions.	70-74	8.09±.06	8.10±.05	+ .01						
Loam	do	Raw humus	0-2½	6.33±.01	6.38±.03	+ .05						
		Dark brown	2½-6	7.30±.03	7.29±.03	- .01						
		Light gray	8-12	7.42±.09	7.41±.06	- .01	7.36±.04	- .06	7.46±.03	+ .04	6.90±.13	- .52
		Light brownish gray	15-19	5.19±.06	5.18±.03	- .01	5.27±.02	+ .08	5.18±.05	- .01	5.17±.00	- .02
		Medium brownish gray	40-44	5.67±.07	5.60±.04	+ .02						
		Dark brownish gray	58-62	7.98±.06	7.99±.03	+ .01						
		Dark brownish gray containing lime concretions.	70-74	8.20±.07	8.18±.07	- .02						

¹ These soils differ from the true podsols in having the brown color very weakly developed in the B horizon.

² 8 determinations were made of each sample in each condition.

TABLE 18.—*Hydrogen-ion determinations of podsollic soils of the Pacific coast taken in the moist, field condition and in the air-dry state and the effects of restorative treatments on the pH of some of the air-dried samples*¹

Soil type	Location	Depth	Moist field sample	Air-dry sample	Change from moist field condition	Air-dry soil in contact with water 18-24 hours	Change from moist field condition	Air-dry soil moistened 4-7 days before	Change from moist field condition	Air-dry soil moistened 30 days before	Change from moist field condition
Cascade silt loam	Columbia County, Oreg.	Inches 0-2½ 8-12 20-24 40-44 60-64	pH 5.16±0.03 5.91±.01 5.88±.01 6.02±.01 5.59±.01	pH 4.78±0.01 5.23±.02 5.55±.00 5.99±.03 5.59±.04	pH -0.38 -.08 -.33 -.03 -.00	pH 4.86±0.03 5.48±.01 5.78±.01	pH -0.30 -.43 -.10	pH 5.16±0.03 5.86±.05 5.90±.01	pH 0 -.05 +.02	pH 4.84±0.04 5.42±.00 5.90±.00	pH -0.22 -.49 +.02
Willamette loam	do	0-2½ 8-10 21-25 57-61 96-100	pH 5.25±.02 5.50±.02 5.48±.01 5.70±.00 6.15±.02	pH 5.19±.01 5.26±.01 5.45±.02 5.52±.05 5.79±.01	pH -.06 -.24 -.03 -.18 -.36	pH 5.20±.00 5.31±.01	pH -.05 -.19	pH 5.20±.03 5.50±.02	pH +.01 0	pH 5.53±.02	pH +.03
						pH 5.69±.01 5.65±.00	pH -.01 -.50	pH 5.67±.05 6.14±.01	pH -.03 -.01	pH 6.16±.03	pH +.01

¹ 4 determinations were made of each sample in each condition.

Twelve podsol profiles (56 horizon samples) were examined (Table 16). Thirteen horizon samples from seven of the profiles became more than 0.10 pH unit more acid on air drying. Nine changed more than 0.20 pH unit. The greatest difference between the moist and the air-dry samples was 0.49 pH unit. With only three exceptions (podsol layers) the greatest change took place in the humus and in the coffee-colored layers. In most cases the humus horizons showed more change than did the coffee-colored layers.

Two degraded chernozem profiles (15 horizon samples) were studied (Table 17). Three horizon samples from one of the profiles showed a change of more than 0.10 pH unit on air drying. Unlike the podsol group, the three layers that changed appreciably in this group were all from the gray layers. One sample from the upper gray horizon changed as much as 0.51 pH unit.

Two podsol profiles of the Pacific coast (10 horizon samples) were studied (Table 18). Six horizon samples (three from each profile) changed more than 0.10 pH unit and five more than 0.20 pH unit on passing from the moist to the air-dry condition. The horizon from 8 to 12 inches, just below the one high in organic matter from the Cascade silt loam profile became 0.68 pH unit more acid. As has already been pointed out, that was the greatest change made by any of the 327 horizon samples on becoming air-dry. One profile, that of the Cascade silt loam, showed the greatest changes in the upper horizons, whereas the other profile, that of the Willamette loam, showed the greatest changes in the lower layers.

Both restorative treatments were likewise used on the horizons of the last three soil groups which had changed more than 0.10 pH unit on drying. (Tables 16-18.) All these horizon samples were restored to within the above variation from the fresh, moist samples by moistening and keeping them moist from four to seven days. But submerging these same samples in water from 18 to 24 hours failed to restore, within 0.10 pH unit, the value of the original moist sample in 7 of the 13 podsol horizon samples, in 2 of the 3 degraded chernozem horizons, and in 4 of the 6 horizon samples of the podsol profiles of the Pacific coast. In the other cases both treatments were effective. This clearly shows that the former restorative treatment is the better one for these soils. Care has to be taken, however, not to moisten the soils much longer than a week before making the determinations or to allow the room temperature to get much above 25° C. after they are moistened. Otherwise the samples are likely to become considerably less acid in the podsol group and more acid in the degraded chernozems and in the podsol soils of the Pacific coast. This change in reaction on storage in a moist condition and at temperatures above 25° C. is doubtless due to biological activity. Robinson (35) reports that soils on storage in a water-logged condition become considerably less acid.

As a check on these two restorative treatments, 20 horizon samples from the humus, podsol, and coffee-colored layers of these groups that had not changed appreciably on air drying were subjected to both treatments. All these check samples remained within 0.10 pH unit of the original moist samples following both treatments.

Some of the horizons of the podsollic soils of the Eastern and Mid-western States that changed more than 0.10 pH unit on drying responded better to one restorative treatment, whereas others were better restored to the pH values of the original moist samples by the other restorative treatment. Thirteen representative profiles (73 horizon samples) of this group were studied (Table 19).

TABLE 19.—Hydrogen-ion determinations of podsollic soils of the Eastern and Midwestern States taken in the moist, field condition and in the air-dry state and the effects of restorative treatments on the pH of some of the air-dried samples

Soil type	Location	Depth	Moist field sample	Air-dry sample	Change from moist field condition	Air-dry soil in contact with water 18-24 hours	Change from moist field condition	Air-dry soil moistened 4-7 days before	Change from moist field condition	Air-dry soil moistened 30 days before	Change from moist field condition
		Inches	pH	pH	pH	pH	pH	pH	pH	pH	pH
Merrimac sandy loam ¹ -----	Hampshire County, Mass.-----	0-1	4.34±0.05	4.09±0.01	-0.25	4.07±0.02	-0.27	4.39±0.00	+0.05	4.89±0.00	+0.55
		1-5	4.54±.01	4.52±.00	-.02						
		5-15	5.43±.06	5.39±.02	-.04						
		15-24	5.57±.02	5.55±.02	-.02						
		24-36	5.86±.03	5.85±.02	-.01						
Gloucester loam ¹ -----	do-----	0-2	4.16±.07	3.85±.02	-.31	3.90±.03	-.26	4.17±.02	+.01	4.71±.02	+.55
		2-6	4.38±.01	4.27±.02	-.11	4.38±.03	.00	4.67±.05	+.29	5.16±.03	+.78
		6-15	5.04±.04	4.79±.00	-.27	4.69±.04	-.07	5.09±.01	+.33	5.31±.01	+.28
		15-24	5.86±.03	5.69±.02	-.17	5.85±.03	-.01	5.88±.03	+.02	6.00±.01	+.12
		24-36	5.99±.00	5.79±.00	-.20	5.97±.01	-.02	5.98±.02	-.01	6.07±.02	+.08
Volusia gravelly silt loam ² -----	Tioga County, Pa.-----	0-6	4.71±.01	4.78±.01	+.07	4.92±.02	+.21	5.07±.02	+.36	5.16±.01	+.45
		6-10	4.73±.03	4.72±.00	-.01						
		10-15	4.77±.02	4.77±.00	0						
		15-30	5.17±.00	5.17±.00	0						
		30-45	7.08±.02	7.02±.02	-.06						
Chester loam ¹ -----	Fairfax County, Va.-----	0-4	7.09±.13	7.11±.08	+.02	7.13±.04	+.04	7.20±.00	+.11		
		4-8	6.50±.07	6.52±.13	+.02						
		8-25	5.55±.05	5.53±.05	-.03						
		25-35	5.36±.12	5.43±.04	+.08						
		35-48	5.44±.13	5.48±.05	+.04						
		48-60	5.35±.05	5.28±.14	-.07						
		60-80	5.37±.07	5.30±.12	-.07						
Chester loam (claypan phase) ¹ -----	do-----	0-4	5.36±.06	5.46±.04	+.10	5.35±.01	-.01	5.78±.05	+.42		
		4-8	4.71±.09	4.70±.11	-.08						
		8-25	4.85±.05	4.83±.07	-.02						
		25-40	4.94±.06	4.85±.07	-.09						
		40-48	4.94±.06	4.84±.09	-.10						
Collington fine sandy loam ¹ -----	Anne Arundel County, Md.-----	0-4	4.14±.04	4.16±.04	+.02	4.08±.03	-0.06	4.52±.00	-.38		
		4-8	4.44±.08	4.45±.05	+.01						
		8-10	4.91±.14	4.94±.04	+.03						
		10-18	4.99±.11	4.98±.02	-.01						
		18-25	4.63±.06	4.63±.03	0						
		25-33	4.76±.07	4.77±.02	+.01						
		33-43	4.72±.12	4.71±.08	-.01						
		43-62	4.61±.11	4.62±.00	+.01						

Sassafras fine sandy loam ¹	do	0-1	5.49±.06	5.08±.05	- .41	5.31±.11	-.18	5.55±.02	+ .06	5.76±.04	+ .27
		1-4	5.34±.02	4.34±.01	0						
		8-12	4.70±.03	4.68±.03	- .02						
		18-22	4.51±.01	4.51±.02	0						
		32-36	4.45±.02	4.45±.03	0						
		40-53	4.39±.04	4.39±.03	0						
		68-72	4.34±.05	4.37±.00	+ .03						
Alexandria silt loam ¹	Licking County, Ohio	0-4	5.20±.05	5.18±.01	- .02	5.17±.00	-.03	5.55±.00	+ .35		
		6-10	4.64±.05	4.66±.04	+ .02						
		17-21	4.99±.05	4.98±.02	- .01						
		38-42	8.34±.09	8.27±.04	- .07						
Bennington silt loam ^{1*}	do	0-1	5.83±.06	5.46±.03	- .37	5.83±.06	0.00	6.06±.03	+ .23	5.76±.03	- .07
		2-5	5.02±.05	4.90±.05	- .12	5.03±.04	+ .01	5.00±.03	+ .04	5.30±.00	+ .28
		7-10	4.72±.07	4.71±.01	- .01						
		13-17	4.75±.05	4.80±.03	+ .05						
		40-44	8.51±.08	4.47±.04	- .04						
Miami silt loam ¹	Rush County, Ind.	0-2	5.72±.07	5.74±.06	+ .02	5.80±.00	+ .06	6.03±.00	+ .31		
		2-12	5.85±.02	5.87±.03	+ .02						
		12-20	5.03±.07	5.62±.05	- .01						
		20-28	5.03±.06	5.04±.03	+ .01						
		28-32	7.23±.10	7.22±.05	- .01						
		32-45+	8.51±.08	8.48±.05	- .03						
Russell silt loam ¹	do	0-2	5.73±.06	5.74±.05	+ .01	5.74±.01	+ .01	5.79±.03	+ .06		
		2-12	4.30±.03	4.28±.05	- .02						
		12-20	4.64±.07	4.66±.04	+ .02						
		20-40	4.71±.09	4.73±.01	+ .02						
		40-52	7.35±.04	7.36±.04	+ .01						
		52-60+	8.15±.12	8.18±.06	+ .03						
Clinton silt loam ¹	Vernon County, Wis.	0-2	5.37±.03	5.47±.02	+ .10						
		2-3	5.65±.03	5.66±.03	+ .01						
		2-13	5.80±.03	5.85±.04	+ .05						
		13-20	5.20±.03	5.17±.02	- .03						
		20-28	5.05±.03	5.07±.02	+ .02						
		28-32	5.00±.01	5.07±.02	+ .07						
		0-4	4.86±.03	4.91±.01	+ .05	4.90±.03	+ .04	5.18±.01	+ .32		
Boone silt loam ²	do	4-14	5.01±.01	5.92±.03	+ .01						
		14-20	5.11±.01	5.34±.04	+ .23	5.11±.02	.00	5.11±.02	.00	5.11±.02	.00
		20-32	5.10±.03	5.39±.00	+ .23	5.13±.03	-.03	5.13±.00	-.03	5.13±.00	-.03

¹ 8 determinations were made of each sample in each condition.² 4 determinations were made of each sample in each condition.³ Imperfectly drained soils.⁴ 18 determinations were made of each sample in each condition.

Eleven horizon samples from 5 of these profiles changed more than 0.10 pH unit on air drying and 8 horizon samples changed 0.20 pH unit and more. The greatest change was in the humus layer of the Sassafras fine sandy loam from Anne Arundel County, Md., which became 0.41 pH unit more acid. With the exception of its organic layer the Gloucester loam profile from Hampshire County, Mass., showed the greatest change on air drying in its deeper horizons, and the Boone silt loam profile from Vernon County, Wis., showed a change of 0.23 pH unit in both of its deepest layers and none in its leaf-mold horizon. With these exceptions practically all the change took place in the upper humus layers. The two lower horizons from the Boone silt loam profile became less acid. Of the total number of horizon samples from all the groups examined, which changed more than 0.10 pH unit on drying, these were the only ones that became less acid.

Both restorative treatments were also employed on the 11 horizons of the foregoing group which had changed more than 0.10 pH unit on drying. (Table 19.) Six of these were restored by either treatment, 2 responded only to submergence in water from 18 to 24 hours, and 3 responded only to being moistened and stored in a moist condition from 4 to 7 days. These last three samples were the humus layers of the Gloucester loam and the Merrimac sandy loam profiles of Hampshire County, Mass., and the humus horizon of the Sassafras fine sandy loam profile from Anne Arundel County, Md. These three leaf-mold layers all resembled the raw humus horizons of the podsol profiles in their physical appearance. Therefore, the general statement may be made that the horizon samples of the podsol soils from the Eastern and Midwestern States which have changed more than 0.10 pH unit on air drying are best restored to the approximate pH value of the original moist samples by submergence in water from 18 to 24 hours, unless they resemble the raw humus layers of the podsol in physical appearance, in which case moistening and storing them while moist from 4 to 7 days appears to be the better treatment.

Seven of these 11 horizon samples became distinctly less acid after 30 days' storage in a moist condition. This agrees with the results obtained with the podsol (Table 16), but disagrees for the most part with those obtained with the brownish-red soils bordering on the pedocals, the reddish-brown pedocal humus layer, the lateritic soils, the imperfectly drained soils of lateritic regions, the immature soils, the degraded chernozems, and the podsol soils of the Pacific coast (Tables 11-15, 17, and 18.)

As a check on these two treatments 8 surface horizons that had not changed appreciably on air drying were given both of these treatments. Seven of the 8 samples remained within 0.10 pH unit of the fresh moist samples after submergence in water from 18 to 24 hours; only 1 sample remained within that degree of variation from the original moist sample after being moistened and stored in a moist condition from 4 to 7 days. Only 1 of the 8 check surface horizon samples varied more than 0.10 pH unit from the fresh moist sample by being submerged in water from 18 to 24 hours. This one exception was the 6-inch surface layer from the Volusia gravelly silt loam profile from Tioga County, Pa. It became 0.21 pH unit less acid following that treatment and became 0.36 pH unit less acid after being moistened and stored in that condition from four to seven days.

DISCUSSION

The easy restoration of the air-dried samples to approximately their original pH values by using one or the other of the restorative treatments indicates that the changes induced by drying are readily reversible. The soil samples from the podzols, degraded chernozems, and podsollic soils from the Pacific coast, which altered most on air drying, were the ones that required moistening with distilled water from 4 to 7 days before making the determinations, and the soil samples from the other groups which made less change on drying responded better, for the most part, to being submerged in distilled water from 18 to 24 hours.

In order to explain the changes in reaction of the soil samples on air drying and the restorative effects of the treatments it will be necessary to review briefly the causes of soil acidity. Soils in humid climates have a strong tendency to become acid. Several factors operate in producing this condition. One of the most important is the production of soluble organic acids, particularly of carbonic acid which is abundantly formed through the action of various living organisms on plant remains. This acid forms relatively soluble carbonates and bicarbonates with the bases which are in combination with the relatively insoluble organic and mineral acids. The bases are thus leached away, leaving the insoluble material in a more or less unsaturated condition with respect to bases. This is especially true in the podsol soils.

Soil acids appear to consist largely of compounds of very low solubility. The pH values of such compounds where determined by the hydrogen electrode may be considerably influenced by the presence of the suspended solid material in contact with the electrode. It is for this reason that the soil particles must be kept in as complete agitation as possible when making a hydrogen-ion determination in order to bring the greatest number of soil particles in actual contact with the hydrogen electrode and thereby obtain a measurement of the influence of the almost insoluble acid constituents (9, 17, 19, 21, 33, 36, 38).

As has already been brought out, the greatest changes on air drying in these investigations took place in the upper layers of high organic-matter content. As has also been shown, only 1 sample of the entire 327 horizon samples studied, a surface sample high in humus, which changed more than 0.10 pH unit on becoming air-dry (Table 12), was above neutral in reaction. These two facts show that changes in pH values of soil samples on drying occur mostly in samples high in organic matter that is unsaturated with bases as indicated by the pH values. This explains why the podzols showed such a strong tendency to change in their organic matter layers on becoming air-dry. (Table 16.) Knickmann (26) and Achromeiko (2) are both emphatic in attributing the changes in reaction produced by drying soils to the presence of organic matter. Both worked on acid soils. Knickmann states that the increase in acidity of a soil sample on drying is proportional to its organic-matter content. Tables 20 and 21 from Achromeiko's work indicate his conclusions on this subject.

TABLE 20.—Amount of water-soluble organic matter in 1 liter of extract from the surface 3 inches of a podsollic soil from an uncultivated field of the Agricultural Academy, Moscow, Russia, after several different treatments¹(Expressed in milligrams of oxygen²)

Treatment of sample	Before capillary moistening	After capillary moistening for—					
		3 days	7 days	21 days	45 days	90 days	210 days
Crumbled soil, fresh moist.....	43.9	43.0	40.0	33.0	28.1	26.2	24.3
Crumbled soil, dried in sun.....	230.6	161.2	89.3	62.5	53.1	39.2	36.1
Crumbled soil, dried in oven at 100° C. for 36 hours.....	845.0	633.0	402.0	290.0	195.0	140.0

¹ Data from Achromeiko (?) on Russian soils.² Determined by oxidation with potassium permanganate.

The effect on the solubility of organic matter that Achromeiko obtained by drying the same podsollic surface soil, shown in Table 1, in the sun and in the oven at 100° C., together with the effects of various restorative treatments, is shown in Table 20. It is not clear to the author whether Achromeiko meant a true solution of the organic matter or merely a colloidal solution. More than five times as much organic matter went into solution after the sample had been dried in the sun than from the fresh, moist sample, and drying the sample in the oven at 100° increased the solubility of the organic matter more than nineteenfold. The humus of the moist samples when stored at room temperatures became increasingly less soluble until, at the end of 210 days, just a little more than half as much organic matter was taken into solution as in the fresh, moist sample. Likewise the humus in the samples dried in the sun and in the oven at 100°, when moistened became less soluble as the days passed. The solubility of the organic matter in the sun-dried sample was reduced to the same solubility of that in the fresh, moist sample from 45 to 90 days after moistening, and the solubility of the humus in the sample dried at 100° was reduced after 90 days of storage in a moistened condition from nearly nineteen times to a little more than three times that of the original moist sample. Table 1 shows that the pH value of this same soil was restored to the approximate pH value of the fresh moist sample, both when dried in the sun and when dried at 100°, between three and seven days after moistening. In the same period of time the organic matter in the sun-dried sample was still two to more than three times as soluble as that in the original moist sample, and the solubility of the humus in the oven-dried sample was from nine to more than fourteen times greater than the solubility of the organic matter in the fresh, moist sample. This would indicate that there were other factors operating in the change of pH of the soil sample and in its restoration following moistening and storage besides the mere solubility of the organic matter.

TABLE 21.—Amount of dispersed particles¹ in the suspension in grams from 1 kilogram absolutely dry soil of the surface 3 inches of a podsollic soil from an uncultivated field of the Agricultural Academy, Moscow, Russia, after several different treatments²

[Size of particles <0.001 mm.]

Treatment of soil sample	Precipitate after 24 hours—								
	Without capillary moistening			After capillary moistening					
				7 days			21 days		
	Organic matter	Mineral matter	Total	Organic matter	Mineral matter	Total	Organic matter	Mineral matter	Total
Crumbled soil, fresh moist	Grams 0.84	Grams 3.92	Grams 4.76	Grams 0.73	Grams 3.48	Grams 4.21	Grams 0.87	Grams 4.01	Grams 4.88
Crumbled soil, dried in sun	1.28	2.02	3.30	1.00	3.06	4.06	1.03	3.90	4.93
Crumbled soil, dried in oven at 100° C.	3.27	1.88	5.15	2.01	3.00	5.01	1.42	2.86	4.28

¹ Robinson's method.

² Data from Achromeiko (2) on Russian soils.

Achromeiko shows (Table 21) the effect of drying the same soil in the sun and in the oven at 100° C. on the dispersion of its organic and its mineral matter. He also shows the effect of moistening these dried samples and storing them at room temperatures for different lengths of time. The organic matter became more than 50 per cent more easily dispersed and the mineral matter became nearly 50 per cent less easily dispersed on drying the sample in the sun. By drying the sample in the oven at 100° C. the organic matter became nearly four times as easily dispersed and the mineral matter less than half as easily dispersed as in the original moist sample. Moistening and storing the dried samples had a decided tendency toward reversing the effects of drying. But at the end of 7 days of storage in a moist condition the humus was still nearly 20 per cent more dispersed and the mineral matter more than 20 per cent less dispersed in the sun-dried sample than in the fresh, moist soil, and in the oven-dried sample even at the end of 21 days of storage in a moistened condition the organic matter was still nearly 70 per cent more dispersed, but the mineral-matter content had been brought back to almost the same degree of dispersion it had in the original moist soil. Thus the dispersion of the organic matter worked in the same direction as the solubility of the humus on the reaction of the sample following drying and subsequent restorative treatments, whereas the dispersion of the mineral matter appeared to work in the opposite direction. Probably there were other factors operating besides these three.

Achromeiko is not the only investigator who has found that the dispersion of mineral soil particles is decreased by drying. Steenkamp (39) found that in using Robinson's method of mechanical analysis without dispersing agents, there was less than half as much clay from the air-dried sample as from the corresponding moist sample. He also found the silt content to be only 79 per cent as high from the air-dry sample, whereas the fine sand content from the air-dry sample was nearly 2½ times as high as from the moist sample. Puri and Keen (34) also found that air drying greatly decreases the dispersion

of clay particles due to their becoming cemented together on drying. Anderson and Byers (3) found that with electrolyzed colloids of the major soil groups the clear supernatant liquid from every sample was less acid than was the colloidal suspension. In the former case only the readily water-soluble acidity was being measured, but in the latter case the almost insoluble acidity existing in the mineral colloidal particles was being measured as well as the water-soluble acidity. The writer has also noticed a strong tendency for soil suspensions to become less acid or more alkaline if the soil particles are allowed to settle at the bottom instead of being kept in complete suspension. By combining these facts it can readily be seen that anything such as air drying, which would decrease the dispersion of the mineral soil particles, would have a tendency to cause the soil suspension of the sample to measure less acid or more alkaline. This may be the explanation of the behavior of the two subsoil horizons of the podsolic profile from the Middle West (Table 19) which, having practically no organic matter in them, both became 0.23 pH unit less acid on drying. It may likewise be the reason for the few cases reported by other investigators (1, 36, 40) of soils becoming less acid or more alkaline on passing from the moist to the air-dry condition.

Another factor in the changes in pH values brought about by air drying may be changes in the exchangeable bases. Steenkamp (39) from his work on several English soils found that in three cultivated surface soils the quantity of neutral salt-forming bases such as MgO , K_2O , and Na_2O increased from 11 to 14 per cent on air drying, and the degree of saturation with these bases was also increased 10 or 12 per cent, whereas in the uncultivated pasture soil there was a decrease of 12 per cent in the quantity of neutral salt-forming bases and a decrease of 13 per cent in the degree of saturation with these bases on drying. This uncultivated pasture soil almost doubled its amount of acid salt-forming exchangeable bases on becoming air-dry. Of course the increase in the amount of neutral salt-forming exchangeable bases on drying would make the sample less acid or more alkaline, whereas the increase of the acid salt-forming exchangeable bases would cause the sample to become more acid on passing from the moist to the air-dry condition. As stated before, Coles and Morison (14) also studied the effects of air drying on English soils. Most of the samples were taken from uncultivated land either in forest or in pasture. (Table 5.) These writers found that the soils after drying at $98^{\circ} C.$, like Steenkamp's uncultivated soil from pasture land, contained a smaller quantity of exchangeable bases than did the moist samples. They concluded that the exchangeable bases must in some way be responsible for the increase in acidity which they found in soil samples on air drying. As all the soils in the investigations recorded in this paper were virgin, they would naturally be more like the uncultivated soils of Steenkamp and of Coles and Morison as to the behavior of their exchangeable bases. The other investigators worked with cultivated as well as with virgin soils, hence the findings of Steenkamp and of Coles and Morison may account for some of their soil samples becoming less acid or more alkaline on drying (1, 36, 40).

Still another factor which may influence the reactions of soil on air drying and on subsequent restorative treatments is that of solubility. Kelly and McGeorge (25) worked on two lateritic surface soils and on one lateritic subsoil from the Hawaiian Islands. Since in the

hydrogen-ion determinations given in this bulletin the water used in the determination stood on the soils from 10 minutes to several hours and one of the restorative treatments was to allow the distilled water to stand on the soils from 18 to 24 hours before making the determinations, for comparative purposes Kelly and McGeorge's findings on subjecting the moist and the air-dried soils to 1-hour extraction with distilled water and 24-hour water extraction of the air-dried samples were selected. From their data the water extract from the first surface-soil sample after 1-hour contact with the soil was slightly less acid after the sample was air-dried than was the same extract when the sample was moist, and the extract following 24-hour contact with the air-dried soil was still less acid. The water extract after 1-hour contact with the air-dried second surface-soil sample was more than twice as acid as that from the moist soil and the 24-hour extract from the moist sample. With the subsoil sample the water extract after 1-hour contact with the air-dried sample was slightly more acid than was the same extract from the moist sample, and the water extract after 24-hour contact with the dried sample was slightly less acid than the 1-hour extract from the moist sample. From Kelly and McGeorge's work it appears that some soils may show a decrease and others an increase in soluble acidity from air drying and that submerging the air-dried soil for 24 hours in distilled water may with some soils increase the soluble acidity and with others decrease it.

It can be readily understood from the discussion of the several factors involved in the changes of reaction brought about by drying soil samples and by the subsequent restorative treatments that they do not all operate in the same direction. These different factors appear to balance each other so that in most cases there is no appreciable change in reaction on air drying. By far the most important factors appear to be the amount of acid organic matter present, its solubility and its dispersion.

Cultivated soils under field conditions appear to show considerable seasonal variation (6, 10, 12, 15, 16, 24, 27, 29, 31). Most of the investigators found acid soils to be considerably more acid (0.2 to 2.0 pH units) in late summer and fall than in early spring (6, 10, 12, 15, 16, 24, 27, 31). Lipman and his associates (29) appear to be the only investigators who found acid soils becoming less acid in the fall than in the spring. They found several that became 0.2 to 0.7 pH unit less acid. Most of the alkaline soils showed very little seasonal variations but some were most erratic (6, 10, 15, 24). Bayer (6) and Kelley (24) noticed a tendency for acid soils to increase in hydrogen-ion concentration following a rain. Some of the soils tested by them became from 0.15 to 0.25 pH unit more acid. The seasonal variation in the soil reaction from early spring to late summer and fall is doubtless due to the drying of the soil which causes it to approach an air-dry condition in the later part of the growing season. One would think that with acid soils the reaction would tend to become less acid following a rain but probably some of the factors working in the opposite direction operate more strongly under these conditions. Because of these variations in the hydrogen-ion concentration of soils under field conditions, which appear to be greater than the changes induced by air drying the soil samples, it seems better for comparative purposes to make all hydrogen-ion determinations on air-dry samples rather than to use the moist samples fresh

from the field as some investigators advocate (1, 6, 11, 19, 26, 36). As mentioned earlier in this bulletin, air-dry samples are much more convenient to use than are the fresh, moist samples, and it is practically impossible to store samples in a moist condition for any length of time without having their reaction change more or less.

SUMMARY

Three hundred and twenty-seven moist horizon samples from 64 representative virgin profiles from widely scattered parts of the United States, from Porto Rico, and from Canada, were collected in tin cans by field men in the soil survey and by experiment station workers from this country and from Canada and sent to the laboratory. On reaching the laboratory each sample was carefully mixed and from 4 to 18 hydrogen-ion determinations were run on it while it was still in a moist condition. The samples were then air-dried and from 4 to 18 determinations were again made on each.

A bubbling hydrogen electrode method was used in making the hydrogen-ion determinations.

Twenty soil profiles, or 31 per cent of the profiles studied, showed a change of more than 0.10 pH unit on air drying. Forty-two horizon samples or 13 per cent of the total number examined, changed more than 0.10 pH unit. Only 2 of the 64 profiles studied contained horizons that changed 0.50 pH unit or more.

When the change exceeded 0.10 pH unit, it was in the direction of greater acidity, with only two exceptions. With few exceptions the greatest change on drying took place in the layers high in organic matter. With only one exception the horizon samples that changed more than 0.10 pH unit on becoming air-dry were acid in reaction.

None of the humid-prairie profiles, the brownish-red soils bordering on the pedocals, and, with the exception of one surface layer, none of the pedocals consisting of the chernozems, the reddish-brown soils, and the desert soils changed more than 0.10 pH unit in any of their horizons on drying. This statement also applies to four-fifths of the lateritic soils, to three-fourths of the immature profiles, to two-thirds of the imperfectly drained soils of lateritic regions, to more than one-half of the podsol soils from the Eastern and Midwestern States, and to approximately one-half of the podsol and degraded chernozems.

The horizon samples from the reddish-brown pedocals, from the lateritic group, from the imperfectly drained profiles of lateritic regions, and from the immature profiles which had changed appreciably on air drying were best restored to the pH value of the original moist samples by allowing them to stand in distilled water from 18 to 24 hours. The horizon samples from the podsol profiles, from degraded chernozems, and from podsol profiles of the Pacific coast which had changed more than 0.10 pH unit on drying were best restored to within that limit of variation from the fresh moist samples by being moistened from four days to a week before making the determinations. The horizon samples from the podsol profiles of the Eastern and Midwestern States, which had changed appreciably on becoming air-dry, were intermediate in their responses to the two restorative treatments. The humus horizons which most resembled the raw humus layers of the podsol required the same treatment,

but the others were best restored by having the distilled water stand on them from 18 to 24 hours before making the determinations.

The most important factor affecting the changes in reaction from air drying appears to be the amount of acid organic matter present in the sample.

The general conclusion is that hydrogen-ion determinations should be made on air-dried soils rather than on samples fresh from the field.

LITERATURE CITED

- (1) AARNIO, B.
1928. DIE VERÄNDERUNG DES AZIDITÄTSGRADES DURCH TROCKNEN DER BODENPROBEN. *Bul. Agrogeol. Inst. Finland* 26, 11 p., illus.
- (2) ACHROMEIKO, A.
1928. DER EINFLUSS DES PULVERISIERENS UND TROCKNENS DES BODENS AUF DESSEN FRUCHTBARKEIT. *Ztschr. Pflanzenernähr. u. Düngung (A)* 11: [65]-89, illus.
- (3) ANDERSON, M. S., and BYERS, H. G.
1931. CHARACTER OF THE COLLOIDAL MATERIALS IN THE PROFILES OF CERTAIN MAJOR SOIL GROUPS. *U. S. Dept. Agr. Tech. Bul.* 228, 24 p.
- (4) ANDREWS, J. C.
1924. EXPERIMENTAL STUDIES ON PALLADIUM ELECTRODES. *Jour. Biol. Chem.* 59:479-494.
- (5) BAVER, L. D.
1926. THE USE OF THE QUINHYDRONE ELECTRODE FOR MEASURING THE HYDROGEN-ION CONCENTRATION OF SOILS. *Soil Sci.* 21:167-179, illus.
- (6) ———
1927. FACTORS AFFECTING THE HYDROGEN-ION CONCENTRATION OF SOILS. *Soil Sci.* 23:399-414, illus.
- (7) BILLMANN, E., and TOYBORG-JENSEN, S.
1927. ON THE DETERMINATION OF THE REACTION OF SOILS BY MEANS OF THE QUINHYDRONE ELECTRODE. *Internatl. Soc. Soil Sci., 2nd Comm. Trans. B:* 236-274, illus.
- (8) BLACKADDER, T.
1925. RIPENING OF HYDROGEN ELECTRODES. *Jour. Amer. Leather Chemists Assoc.* 20:17-19.
- (9) BRAY, R. H.
1928. APPARATUS FOR MEASURING THE HYDROGEN-ION CONCENTRATION OF THE SOIL. *Indus. and Engin. Chem.* 20:421-323, illus.
- (10) BURD, J. S., and MARTIN, J. C.
1924. SECULAR AND SEASONAL CHANGES IN THE SOIL SOLUTION. *Soil Sci.* 18:151-167.
- (11) BURGESS, P. S.
1922. THE HYDROGEN-ION CONCENTRATION OF SOILS AS AFFECTED BY DRYING. *Sci. (n. s.)* 55:647-648.
- (12) ———
1924. THE EFFECT ON PRESENT SOIL REACTION OF LONG-CONTINUED APPLICATIONS OF EQUIVALENT AMOUNTS OF HIGH-CALCIUM AND HIGH-MAGNESIUM LIMES. *Soil Sci.* 18:169-172.
- (13) CLARK, W. M.
1928. THE DETERMINATION OF HYDROGEN-IONS; AN ELEMENTARY TREATISE ON ELECTRODE, INDICATOR AND SUPPLEMENTARY METHODS . . . Ed. 3, 717 p., illus. Baltimore.
- (14) COLES, H. G., and MORISON, C. G. T.
1930. DEHYDRATION AND SOIL ACIDITY. *Soil Sci.* 29: 59-70, illus.
- (15) ERDMAN, L. W.
1921. THE EFFECT OF GYPSUM ON THE SOIL REACTION. *Soil Sci.* 12:433-448.
- (16) GARDNER, F. D., and BROWN, B. E.
1911. THE LIME REQUIREMENT OF THE GENERAL FERTILIZER PLATS AS DETERMINED PERIODICALLY. *Penn. Agr. Expt. Sta. Rpt.* 1910-11 (pt. 2):25-60, illus.

- (17) GILLESPIE, L. J.
1916. THE REACTION OF SOIL AND MEASUREMENTS OF HYDROGEN-CONCENTRATION. Jour. Wash. Acad. Sci. 6: 7-16, illus.
- (18) GLINKA, K. [D].
1914. DIE TYPEN DER BODENBILDUNG, IHRE KLASSIFIKATION UND GEOGRAPHISCHE VERBREITUNG. 365 p., illus. Berlin.
- (19) HEALY, D. J., and KARRAKER, P. E.
1922. THE CLARK HYDROGEN-ELECTRODE VESSEL AND SOIL MEASUREMENTS. Soil Sci. 13: 323-328.
- (20) HEINTZE, S. G., and CROWTHER, E. M.
1929. AN ERROR IN SOIL REACTION DETERMINATIONS BY THE QUINHYDRONE METHOD. Second Comm. Internatl. Soc. Soil Sci. Trans. v. A: 102-110.
- (21) HILDEBRAND, J. H.
1913. SOME APPLICATIONS OF THE HYDROGEN ELECTRODE IN ANALYSIS, RESEARCH AND TEACHING. Jour. Amer. Chem. Soc. 35: [847]-871, illus.
- (22) JOSEPH, A. F., and MARTIN, F. J.
1923. THE HYDROGEN-ION CONCENTRATION OF HEAVY ALKALINE SOILS. Jour. Agr. Sci. [England] 13: [321]-332.
- (23) KARRAKER, P. E.
1930. THE INACCURACY OF THE QUINHYDRONE ELECTRODE IN MANY KENTUCKY SOILS. Jour. Amer. Soc. Agron. 22: 171-180.
- (24) KELLEY, A. P.
1923. SOIL ACIDITY, AN ECOLOGICAL FACTOR. Soil Sci. 16: 41-54, illus.
- (25) KELLEY, W. P. and McGEORGE, W.
1913. THE EFFECT OF HEAT ON HAWAIIAN SOILS. Hawaiian Agr. Expt. Sta. Bul. 30, 38 p.
- (26) KNICKMANN, E.
1925. UNTERSUCHUNGEN ZUR FRAGE DER BODENAZIDITÄT. Ztschr. Pflanzenernähr. u. Düngung (A) 5: 1-92, illus.
- (27) KURZ, H.
1923. HYDROGEN ION CONCENTRATION IN RELATION TO ECOLOGICAL FACTORS. Bot. Gaz. 76: 1-29, illus.
- (28) LA MER, V. K., and PARSONS, T. R.
1923. THE APPLICATION OF THE QUINHYDRONE ELECTRODE TO ELECTROMETRIC ACID-BASE TITRATIONS IN THE PRESENCE OF AIR, AND THE FACTORS LIMITING ITS USE IN ALKALINE SOLUTIONS. Jour. Biol. Chem. 57: 613-631, illus.
- (29) LIPMAN, J. G., PRINCE, A. L., and BLAIR, A. W.
1921. THE INFLUENCE OF VARYING AMOUNTS OF SULFUR IN THE SOIL, ON CROP YIELDS, HYDROGEN ION CONCENTRATION, LIME REQUIREMENT, AND NITRATE FORMATION. Soil Sci. 12: 197-207, illus.
- (30) MARBUT, C. F.
1928. A SCHEME FOR SOIL CLASSIFICATION. First Internatl. Cong. Soil Sci. 1927, Proc. and Papers, Comm. 5, v. 4, p. 1-31, illus.
- (31) MATHER, W.
1922. THE EFFECTS OF LIMES CONTAINING MAGNESIUM AND CALCIUM UPON THE CHEMICAL COMPOSITION OF THE SOIL AND UPON PLANT BEHAVIOR. Soil Sci. 13: 337-354.
- (32) McGEORGE, W. T.
1929. THE INFLUENCE OF MANGANIFEROUS SOILS ON THE ACCURACY OF THE QUINHYDRONE ELECTRODE. Soil Sci. 27: 83-88, illus.
- (33) PIERRE, W. H.
1925. THE H-ION CONCENTRATION OF SOILS AS AFFECTED BY CARBONIC ACID AND THE SOIL-WATER RATIO, AND THE NATURE OF SOIL ACIDITY AS REVEALED BY THESE STUDIES. Soil Sci. 20: 285-305.
- (34) PURI, A. N., and KEEN, B. A.
1925. THE DISPERSION OF SOIL IN WATER UNDER VARIOUS CONDITIONS. Jour. Agr. Sci. [England] 15: [147]-161, illus.
- (35) ROBINSON, W. O.
1930. SOME CHEMICAL PHASES OF SUBMERGED SOIL CONDITIONS. Soil Sci. 30: 197-217.
- (36) ROST, C. O., and FIEGER, E. A.
1923. EFFECT OF DRYING AND STORAGE UPON THE HYDROGEN ION CONCENTRATION OF SOIL SAMPLES. Soil Sci. 16: 121-126.

- (37) SIGMOND, A. A. V. von (president).
1929-1930. REPORT OF THE COMMITTEE ON SOIL REACTION MEASUREMENTS. . .
PART II. CONCLUSIONS AND RECOMMENDATIONS. Soil Research
Bd. 2, no. 2, p. [141]-144.
- (38) SNYDER, E. F.
1928. METHODS FOR DETERMINING THE HYDROGEN ION CONCENTRATION
OF SOILS. U. S. Dept. Agr. Circ. 56, 30 p., illus.
- (39) STEENKAMP, J. L.
1928. THE EFFECT OF DEHYDRATION OF SOILS UPON THEIR COLLOID CON-
STITUENTS. Soil Sci. 25: 163-182, 239-251, 327-332, illus.
- (40) TERÄSVUORI, A.
1930. ÜBER DIE BODENAZIDITÄT MIT BESONDERER BERÜCKSICHTIGUNG
DES ELEKTROLYTGEHALTES DER BODEN AUFSCHLÄMMUNGEN.
Valtion Maatalouskoetoiminnan Julkaisuja, no. 29, 214 p.,
illus. Helsinki.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

<i>Secretary of Agriculture</i>	ARTHUR M. HYDE.
<i>Assistant Secretary</i>	R. W. DUNLAP.
<i>Director of Scientific Work</i>	A. F. WOODS.
<i>Director of Regulatory Work</i>	WALTER G. CAMPBELL.
<i>Director of Extension Work</i>	C. W. WARBURTON.
<i>Director of Personnel and Business Administration.</i>	W. W. STOCKBERGER.
<i>Director of Information</i>	M. S. EISENHOWER.
<i>Solicitor</i>	E. L. MARSHALL.
<i>Weather Bureau</i>	CHARLES F. MARVIN, <i>Chief.</i>
<i>Bureau of Animal Industry</i>	JOHN R. MOHLER, <i>Chief.</i>
<i>Bureau of Dairy Industry</i>	O. E. REED, <i>Chief.</i>
<i>Bureau of Plant Industry</i>	WILLIAM A. TAYLOR, <i>Chief.</i>
<i>Forest Service</i>	R. Y. STUART, <i>Chief.</i>
<i>Bureau of Chemistry and Soils</i>	H. L. KNIGHT, <i>Chief.</i>
<i>Bureau of Entomology</i>	C. L. MARLATT, <i>Chief.</i>
<i>Bureau of Biological Survey</i>	PAUL G. REDINGTON, <i>Chief.</i>
<i>Bureau of Public Roads</i>	THOMAS H. MACDONALD, <i>Chief.</i>
<i>Bureau of Agricultural Engineering</i>	S. H. MCCRORY, <i>Chief.</i>
<i>Bureau of Agricultural Economics</i>	NILS A. OLSEN, <i>Chief.</i>
<i>Bureau of Home Economics</i>	LOUISE STANLEY, <i>Chief.</i>
<i>Plant Quarantine and Control Administration.</i>	LEE A. STRONG, <i>Chief.</i>
<i>Grain Futures Administration</i>	J. W. T. DUVEL, <i>Chief.</i>
<i>Food and Drug Administration</i>	WALTER G. CAMPBELL, <i>Director of Regulatory Work, in Charge.</i>
<i>Office of Experiment Stations</i>	JAMES T. JARDINE, <i>Chief.</i>
<i>Office of Cooperative Extension Work</i>	C. B. SMITH, <i>Chief.</i>
<i>Library</i>	CLARIBEL R. BARNETT, <i>Librarian.</i>

This bulletin is a contribution from

<i>Bureau of Chemistry and Soils</i>	H. G. KNIGHT, <i>Chief.</i>
<i>Soil Investigations</i>	A. G. MCCALL, <i>Chief.</i>
<i>Division of Soil Survey</i>	C. F. MARRUT, <i>Principal Soil Scientist, in Charge.</i>

END