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APPENDIX A

BAN MI SERIES (Bm)

Distribution : Moderate to small extent along the borders of the Central Plain.

Setting : Ban Mi soils are formed from montmorillonitic clays. They occur on semi-recent terraces and along the boundary between these terraces and the recent alluvial plain. Relief is nearly flat with slopes of less than 1%. Elevation ranges from 4 m. to 20 m. above sea level. The climate is Tropical Savanna (Koppen 'Aw'). Annual precipitation ranges from 1,000 mm. to 1,400 mm.

Drainage and Permeability : Poorly to somewhat poorly drained. Runoff is slow and permeability is estimated as slow. These soils are flooded by impounded rainwater to depths of 30 cm. to 40 cm. for several months during the wet season. However, these soils also dry out deeply with groundwater level falling below 2 m. during the peak of the dry season when deep wide cracks may be observel.

Vegetation and Land Use : Mainly used for transplanted rice cultivation.

Characteristic Profile Features : The Ban Mi series is a member of the very fine clayey, montmorillonitic family of Grumusols (National), Entic Pelluderts (USDA). They are deep, slightly acid to neutral soils characterized by a thick, dark coloured A horizon overlying a slightly paler subsoil (B ?) containing predominantly dark yellowish brown mottles. The occurrence of slickensides is characteristic. Cracks are at least 1 cm. wide at 50 cm. depth.

Typifying Pedon : Ban Mi clay - Rice field

from Amphoe Ban Mo, Saraburi Province - Code C4/11 (Type Location)

(moist colours unless otherwise stated)

Ap -- 0-10 cm. Dark grey (10YR4/1), many, fine yellowish red mottles as coatings along root channnels and on ped faces; clay; strong fine angular blocky, granular in upper 2 cm; hard dry; many very fine tubular pores; common very fine roots; clear, wavy boundary; pH 5.5.

A12 -- 10-26 cm. Dark grey (10YR4/1), many, fine and medium, distinct yellowish red mottles as coatings along root channels and on ped faces; clay; moderate coarse angular blocky, breaking into small blocks; firm moist; common pressure faces; common very fine tubular and very fine and fine interstitial pores; common very fine roots; clear, smooth boundary; pH 6.5.

B21 -- 26-70 cm. Dark grey (10YR4/1), many, medium and coarse, distinct dark yellowish brown mottles; clay; weak to moderate coarse angular blocky; many pressure faces and common intersecting slickensides; many very fine interstitial, few very fine tubular pores; common fine manganese nodules; common fine and very fine roots; gradual, smooth boundary; pH 7.0.

B22 -- 70-160 cm. Dark grey (5Y 4/1), many fine and medium, distinct brown mottles; clay; weak to moderate medium angular blocky; firm moist; many intersecting slickensides; common very fine

interstitial pores; common fine manganese nodules and secondary lime concretions in the deeper part; pH 8.0.

C1 -- 160-250 cm. Brown (10YR4/3), common, medium, faint dark brown mottles; clay; common fine manganese nodules and fine calcite crystals; pH 8.0.

Range of Profile Features : The A horizon is from 20 cm. to 40 cm. thick, has dark grey (10YR4/1) matrix colours and has a strong fine blocky structure becoming granular in the uppermost layer. Field pH ranges from 5.5 to 6.5.

The subsoil, provisionally termed B horizon, has a lower boundary deeper than 150 cm. from the soil surface. Matrix colours are dark grey becoming grey in the deeper layers. Hues range from 10YR to 5Y. Field pH values range from 6.5 to 7.0 in the upper B horizon; but below approximately 1 m. pH values may in crease to 8.0. Limestone concretions, when found, are restricted to the deeper layers below approximately 1 m. from the soil surface.

Similar Soil Series :

Wathana - similar profile but dries out for longer periods (Usterts) and is derived from basalt, limestone and andesite.

Chong Kae - has lower pH values and characteristic fine red mottles.

Principal Associated Soils : These include Lop Buri series soils which occupy higher positions and are better drained, and Chong Kae series soils which occupy similar positions on the lower parts of the sem-recent terraces transitional to the flood plains.

KAMPHAENG SAEN SERIES (Ks)

Distribution : Occupies large extent in the southwestern part of the Central Plain.

Setting : Kamphaeng Saen soils are formed from semi-recent alluvium and occur on old levees and breach deposits of the semi-recent terrace. Relief is flat to nearly flat, wity a slightly undulating micro-relief. Slopes are 1% or less. Elevation ranges from 6 to 20 m. above sea level. The climate is Tropical Savanna (Koppen 'Aw'). Mean annual precipitation ranges from 800 to 1,600 mm. Mean annual temperature is 27 °C.

Drainage and Permeability : Well drained. Permeability is moderate and runoff is slow. Groundwater level is below 1.5 m. from the soil surface throughout the year.

Vegetation and Land Use : Mainly used for settlement sites, gardens and orchards; or are put to upland crops such as maize, cotton and sugar cane.

Characteristic Profile Features : Kamphaeng Saen series is a mamber of the fine loamy, mixed family of Nan Calcic Brown Soils (National), Udic Haplustalfs (USDA). They are deep, friable, slightly acid over neutral to mildly alkaline soils. They are characterized by a brown or dark brown loam or clay loam A horizon, overlying a brown or strong brown clay loam, weakly developed, argillic B horizon. Fine mica flakes occur in all horizona; but not enough for the micaceous family.

Typifying Pedon : Kamphaeng Saen clay loam -- Orchard form Amphoe Muang, Nakhon Pathom province - Code SW 53/6 (Type

Location) (moist colours unless otherwise stated)

Ap -- 0-30 cm. Brown to dark brown (10YR4/3); clay loam; weak coarse subangular blocky; nonsticky and nonplastic, friable moist, hard dry; many very fine interstitial and tubular pores; common very fine roots; diffuse, smooth boundary; pH 6.5.

B2t -- 30-65 cm. Dark yellowish brown (10YR4/4); clay loam to clay; weak to moderate medium subangular blocky; slightly sticky and slightly plastic, friable moist, hard dry; thin, broken, brown to dark brown clay coatings in pores and on ped faces; many fine and very fine tubular and interstitial pores; few mica flakes; many fine and medium and common very fine roots; gradual, smooth boundary; pH 7.5.

B3 -- 65-90 cm. Brown to dark brown (7.5YR4/4); clay loam; moderate medium and fine subangular blocky; slightly sticky and slightly plastic, friable moist; thin patchy clay coatings; many fine and very fine interstitial and tubular pores; many white lime pseudo-mycelia, strongly calcareous, common mica flakes; common fine and very fine roots; gradual, smooth boundary; pH 8.0.

C -- 90-130 cm. Strong brown (7.5YR5/6); loam; moderate medium subangular blocky; nonsticky and nonplastic, friable moist; many very fine interstitial mycelia, many mica flakes; few very fine roots; pH 8.0.

Range of Profile Features : The A horizon is from 20 to 40 cm. thick, has 10YR or 7.5YR hues, values of 3 through 5 and chromas of 2 and 4 in 7.5YR hue, and 2 or 3 in 10YR hue. Texture may be sandy clay loam and structure is weak coarse blocky. Field pH values range from 6.0 to 6.5.

The B horizon has 10YR or 7.5YR hues, values of 4 and 5 and chromas of 4 through 8. Reddish brown (5YR5/4 or 4/4) colours may also occur in the deeper subsoil. Textures may be silty clay loam and structure is weak to moderate, medium blocky. Field pH values range from 7.0 to 8.0. The lower B and C horizons commonly contain white, soft, powdery lime; but its presence is not diagnostic for the series.

Similar Soil Series :

Pran Buri -- does not contain micas or soft, powdery lime and has somewhat lower pH values.

Ruso -- has a similar profile but lower pH values throughout, no soft, powdery lime and has an udic moisture regime.

Principal Associated Soils : These include Nakhon Pathom and Nakhon Phanom series on the semi-recent terrace, and Saraburi series on the transition between the semi-recent terrace and flood plain.

PAK CHONG SERIES (Pc)

Distribution : Occupies moderate extent in Central Highlands and small extent in North Thailand.

Setting : Pak Chong soils are formed from residuum and local colluvium from shale in association with limestone and occur on the dissected erosion surface or partial peneplain. Relief is undulating to rolling which slopes range from 2 to 8 percent. Elevation is variable above sea level, but mainly not above 400 m. The climate is Tropical Savanna (Koppen 'Aw'). Average annual precipitation varies from 1,100 mm. to 1,400 mm. Mean annual air temperature is from 26 °C to 28 °C.

Drainage, Permeability and Runoff : is well drained soils. Permeability is moderate to slow. Runoff is rapid to medium.

Vegetation and Land Use : Originally mixed diciduous forest, but mainly cleared for upland crop cultivation such as corn, cotton, beans, sorghum, castor bean and some fruit crops.

Characteristic Profile Features : The Pak Chong series is a member of the very fine clayey, Kaolinitic, acid family of Peddish Brown Lateritic soils (National), oxic Paleustults? (USDA). They are deep soils and are characterized by a dark reddish brown clay or silty clay A horizon overlying a dark reddish brown or reddish brown clay upper argillic B horizon which in turn overlies red or dark red clay lower argillic B horizon. Reaction is slightly acid to neutral over medium to very strongly acid.

Typifying Pedon : A profile taken from 200 m. northwest of Kasetsart University Training Farm, Ban Pang Sok, Amphoe Pak Chong, Nakhon Ratchasima Province : Province; Profile Code NE-S

20/30. (moist colors unless otherwise stated).

Ap -- 0-30 cm. Dark reddish brown (2.5YR3/4) clay; moderate medium subangular blocky structure; friable, slightly sticky, plastic; few fine interstitial pores; common fine roots; slightly acid; gradual smooth boundary to B21t

B21t-- 30-60 cm. Dark reddish brown (2.5YR3/4) clay; moderate medium subangular blocky structure; friable, slightly sticky, plastic; common moderately thisck continuous clay coating on ped faces; many fine roots; very strongly acid; gradual smooth boundary to B22t

B22t-- 60-100 cm. Red (2.5YR4/6) clay; moderate medium subangular blocky structure; friable, sticky, plastic; many moderately thick continuous clay coating on ped faces; few fine roots; very strongly acid.

Type Location : The Pak Chong series was name for Amphoe Pak Chong in which soils of this series were first described by R.L. Dendleton in 1929 and shown on the map as "Pak Chong loam". Then these soils were revised by F.R. Moormann et.al. in 1964 and were called as "Pak Chong series".

Range of Profile Features : The thickness of the A horizon range from 10 to 25 cm. and has 2.5YR or 5YR hues, values of 3 or 4, and chromas of 3 or 4 in 5YR hue and 2 to 6 in 2.5YR hues. Textures of silty clay loam or clay loam may occur. Structure is moderate fine to medium granular at upper most of layer and moderate medium blocky at lower parts of the horizon. Field pH value is from 6.0 to 8.0.

The B horizon has 2.5YR or 10R hues, values of 3 to 5, and chromas of 4 to 8. Few fine hard subrounded and/or rounded iron-manganese nodules may occur. Field pH value is from 4.5 to 5.5.

Similar Soil Series :

Chok chai Series (Ci)	- semilar profile, but are derived from basalt and some andesite.
Ao Luk Series (Ak)	- similar profile, but have udic moisture regimes.
Loei Series (Lo)	- semilar profile, but are derived from granite and shale and contain lower clay fraction.

Principal Associated Soils : These include Muak Lek, Lop Buri, and Tha Kli Soils. The Muak Lek and Tha Kli soils occupy on the higher topography while the Lop Buri soils occupy on slightly lower topography.

NARATHIWAT SERIES (Nw)

Classification : Organic soils

Described by : P.Vijarnsorn

Date : September 12, 1974

Location : Plu Thung Ka, Amphoe Yi-ngo, Changwat Narathiwat

Elevation : Approximately 5 m. above sea level

Relief and slope : Flat; 0 - 1 % slope

Physiography : Domed bogs

Natural Vegetation or Land Use : Swamp forest

Climate :

- Climate type : Tropical monsoon climate (Koppen "Am")
- Annual rainfall : 2,644.8 mm.
- Mean temperature : 27.0°C

Parent material : Organic material

Drainage : Very poorly drained

Permeability : Estimated to be slow

Run off : Slow

Ground water depth : Near the surface

Other : -------

Horizon	Depth (cm)	Description
O_{11}	0 - 60	Dark reddish brown (5YR 3/2, 5YR 3/3) peaty muck; peaty part containing very fine and fine roots mostly; structureless; non sticky, non plastic; very strongly acid (pH 5.0).
O_{12}	60 - 120	Dark reddish brown (5YR 3/2) peaty muck; peaty part containing very fine and fine roots mostly; structureless; non sticky non plastic; very strongly acid (pH 5.0).

Remark : Soil pH and texture are determined in laboratory. Color are for fully moist soil except where designated.

Source :

1. Soil Survey Division. 1979. Detailed Reconnaissance Soil Map of Lop Buri Province Ministry of Agriculture and Cooperative, Bangkok.

2. Soil Survey Division. 1979. Detailed Recomaissance Soil Map of Nakhon Pathom Province Ministry of Agriculture and Cooperative, Bangkok.

3. Soil Survey Division. 1979. Detailed Reconnaissance Soil Map of Nakhon Ratchasima Province. Ministry of Agriculture and Cooperative, Bangkok.

4. Soil Survey Division. 1979. Detailed Reconnaissance Soil Map of Narathiwat Province Ministry of Agriculture and Cooperative, Bangkok.

Results of Soil Analysis

Ban Mi Series : Bm

Type Profile Code No. C-4/11	Range in Master Horizons													
Laboratory No.of Topsoil : Pb 494						Horizon A			Horizon B			Horizon C		
Horizon Depth (cm)	Ap 0-10	A_{12} 10-26	B_{21} 26-70	B_{22} 70-160	C_1 160-250	Max.	Min	Ave.	Max	Min	Ave.	Max	Min	Ave.
Particle Size Analysis (%) (USDA Grading)														
Sand	3.0	2.0	1.5	6.0	9.5	11.9	2.38	7.98	9.46	4.52	6.99			4.9
Silt	29.0	29.0	26.0	21.5	25.5	41.75	23.6	31.45	38.92	22.98	30.95			14.6
Clay	68.0	69.0	72.5	72.5	65.0	68.62	48.58	60.57	72.5	51.46	61.98			80.5
pH 1:1 H_2O	5.4	5.35	6.95	8.3	7.9	6.9	5.37	6.36	7.86	6.82	7.34			7.2
11 KCl	3.85	3.6	4.9	6.6	7.2	5.96	3.7	5.12	6.04	5.82	5.93			5.6
$CaCO_3$%	1.79	1.94	1.79	5.51	5.07	3.28	1.4	2.19	4.29	2.5	3.4			2.2
Moisture Air to Over dry %	6.6	6.8	8.0	8.1	7.9	6.72	5.62	6.17	8.07	4.68	6.38			-
Conductivity 1 : 5 EC X 10^6	67.0	48.0	29.0	85.0	1000.0	965.31	55.31	404.21	767.49	66.61	417.05			94.0
C %	1.38	0.77	0.35	0.22	0.13	1.2	0.68	0.96	0.36	0.26	0.31			0.4
Exchange Capacity & Cation (Meq.100 g)														
Ca	27.3	29.8	35.9	45.7	80.6	34.47	25.6	29.64	39.81	31.12	35.47			22.6
Mg	0.5	0.5	0.5	0.7	0.9	16.6	0.5	6.0	0.63	0.43	0.53			23.8
K	0.7	0.4	0.3	0.2	0.2	1.0	0.17	0.56	0.23	0.1	0.17			0.7
Na	0.7	0.9	1.3	3.6	9.5	2.72	0.32	1.58	2.84	2.78	2.81			3.8

Type Profile Code No. C-4/11	Range in Master Horizons													
Laboratory No.of Topsoil : Pb 494 1,336.-						Horizon A			Horizon B			Horizon C		
Horizon Depth (cm)	Ap 0-10	A_{12} 10-26	B_2 26-70	B_{22} 70-160	C_1 160-250	Max	Min	Ave.	Max	Min	Ave.	Max	Min	Ave.
(B)Sum(Ca+Mg+K+Na)	29.2	31.6	38.0	50.2	91.2	44.4	30.68	37.78	46.19	34.42	40.31			50.9
(A)Extr Acidity	17.2	14.2	8.5	4.3	2.9	15.35	4.71	9.45	5.68	4.51	5.1			8.5
(B+A) Sum	46.4	45.8	46.5	54.5	94.1	52.7	42.97	47.23	51.87	38.93	45.4			59.4
(C) CEC Soil	50.0	49.7	51.8	53.3	46.8	49.82	37.79	44.2	52.81	33.45	43.13			49.2
CEC, 100 g. clay	73.5	72.0	71.5	73.5	72.0	93.53	72.58	83.06	72.84	64.79	68.82			60.99
Base Saturation. %														
B X 100														
C	58	64	73	94	195	100.61	61.69	87.1	104.33	87.1	95.72			
B X 100														103
B+A	63	69	82	92	97	88.44	66.69	79.71	88.72	87.83	88.28			86
P (ppm) Bray N.2	7.1	5.5	4.3	9.1	15.8	10.3	2.25	6.22	7.52	1.97	4.75			9.7
K (ppm) Ammon														
Acetate	286	193	131	119	113	228.77	78	159.59	122.94	67.75	95.35			250

Number of Profile Sampled : SW 51/3, C 4/11, C 4/33

Date of Compilation : February 1976

Results of Soil Analysis

Kamphaen Saen series : Ks

Type Profile Code No. SW-53/6	Range in Master Horizons												
Laboratory No.of Topsoil : M - 543					Horizon A			Horizon B			Horizon C		
Horizon Depth (cm)	Ap	B_2t	B_3	C	Max	Min	Ave.	Max	Min	Ave.	Max	Min	Ave.
Particle Size Analysis (%) (USDA Grading)													
Sand	42.5	21.5	28.0	60.0	55.88	3.18	37.78	57.46	4.4	18.13	85.0	8.5	51.17
Silt	40.0	50.5	56.0	28.0	62.41	11.01	39.59	58.61	30.46	45.74	67.5	9.5	35.0
Clay	17.5	28.0	16.0	12.0	39.38	9.33	22.64	36.99	12.08	24.64	24.0	5.5	13.83
pH 1:1 H_2O	7.4	6.3	7.5	8.35	7.4	5.65	6.68	8.34	5.19	6.78	8.35	5.4	7.03
1:1 KCl	6.4	5.7	7.0	7.5	6.7	4.85	6.02	6.7	3.86	5.46	7.5	4.0	6.1
$CaCO_3$%	0.90	0.30	6.90	3.00	2.12	0.39	1.04	8.62	0.39	2.14	21.45	0.57	8.34
Moisture Air to Over dry %	1.1	1.8	2.7	1.1	4.01	0.79	1.79	2.42	0.36	1.51	1.2	0.3	0.87
Conductivity 1 : 5 EC X 10^3	10.0	680.0	800.0	700.0	677.81	10.0	194.02	146.66	725.66	398.45	700.0	11.32	337.4
C %	3.22	2.02	1.42	0.82	17.68	0.65	4.94	1.77	0.23	1.0	0.83	0.49	0.71
Exchange Capacity & Cation (Meq. 100 g)													
Ca	10.6	16.6	37.2	19.5	25.54	5.12	10.61	37.86	1.34	14.84	37.5	0.7	19.23
Mg	1.6	2.1	3.1	2.7	3.71	1.18	2.07	4.9	0.51	2.16	2.7	0.3	1.13
K	0.4	0.2	0.2	0.1	0.53	0.82	0.41	0.8	0.2	0.35	0.2	0.1	0.13
Na	0.8	1.7	11.0	6.6	1.2	0.2	0.54	5.58	0.23	1.62	6.6	0.2	2.37

Type Profile Code No. SW-53/6	Range in Master Horizons												
Laboratory No.of Topsoil : M - 543					Horizon A			Horizon B			Horizon C		
(B)Sum(Ca+Mg+K+Na)	13.4	20.6	53.5	28.9	27.36	7.49	13.63	38.04	2.59	18.98	38.2	1.5	22.87
(A)Ext.r Acidity	3.3	3.8	0.5	0.2	6.31	3.0	4.0	5.79	1.24	3.36	2.1	0	0.77
(B+A) Sum	16.7	24.4	54.0	29.1	30.76	12.3	18.39	40.18	8.38	24.34	38.2	3.6	23.63
(C) CEC Soil	15.1	16.1	15.1	11.5	22.88	9.79	15.52	18.6	5.39	13.41	12.1	2.7	0.77
CEC,100 g clay	85.7	57.5	94.4	95.8	121.83	69.13	92.7	101.67	44.9	66.18	95.8	49.1	65.1
Base Saturation %													
B X 100													
C	89	100	100	100	119.0	53.66	88.59	234.12	31.0	110.1	316.0	42.0	152.67
B X 100													
B+A	80	100	100	100	88.24	70.69	78.02	100	47.46	77.74	100	55	85
P (ppm) Bray N.2	47.6	82.4	44.7	20.5	75.29	12.33	40.38	60.00	3.4	18.08	20.5	3.6	10.37
K (ppm) Ammon													
Acetate	175	70	88	47	187.71	79.25	129.03	400.58	47.44	151.31	73	38	52.67

Number of Profile Sampled : N-35/70, N-38/44

NC-42/6, SW-53/6, SW-56/3

Date of Complitation :

Rssults of Soil Analysis

Pak Chong Series : Pc

Type Profile Code No. NE-S-20/30				Range in Master Horizons								
Laboratory No.of Topsoil : Pa - 1273				Horizon A			Horizon B			Horizon C		
Horizon Depth (cm)	Ap 0-30	$B_{21}t$ 30-60	$B_{22}t$ 60-100	Max	Min	Ave.	Max	Min	Ave.	Max	Min	Ave.
Particle Size Analysis (%) (USDA Grading)												
Sand	7.0	4.0	3.0	29.5	5.5	14.09	17.36	3.3	8.29			
Silt	24.0	16.0	11.0	40.5	11.5	30.41	26.55	6.87	19.48			
Clay	69.0	80.0	86.0	83.0	30.5	55.49	89.83	57.68	72.23			
pH 1:1 H_2O	6.1	4.35	4.0	7.1	5.8	6.38	6.35	4.15	5.23			
1:1 KCl	5.3	3.65	3.65	6.2	4.9	5.51	5.61	3.65	4.78			
$CaCO_3$%	1.2	0.6	0.75	2.58	0.71	1.23	1.18	0.69	0.88			
Moisture Air to Over dry %	7.7	6.4	6.3	7.7	3.4	5.46	6.34	3.21	4.6			
Conductivity 1 : 5 EC X 10^6	52.0	64.0	100.0	640.0	18.0	154.16	140.25	16.97	59.89			
C %	1.14	0.27	0.62	3.73	0.76	1.56	2.12	0.27	0.77			
Exchange Capacity & Cation (Meq.100 g)												
Ca	10.1	3.2	0.7	25.0	7.8	13.6	14.77	1.77	6.99			
Mg	1.8	1.0	0.7	5.2	1.6	2.5	2.62	0.83	1.52			
K	0.1	0.1	0.1	1.93	0.1	0.83	0.5	0.1	0.23			
Na	0.2	0.5	0.2	0.2	0.2	0.2	0.33	0.11	0.21			

Type Profile Code No. NE-S-20/30	Range in Master Horizons											
Laboratory No.of Topsoil : Pa - 1273				Horizon A			Horizon B			Horizon C		
Horizon Depth (cm)	Ap 0-30	$B_{21}t$ 30-60	$B_{22}t$ 60-100	Max	Min	Ave.	Max	Min	Ave.	Max	Min	Ave.
(B)Sum(Ca+Mg+K+Na)	12.2	4.5	1.7	31.9	10.0	17.13	16.56	2.9	8.92			
(A)Extr Acidity	8.5	13.3	15.6	8.8	4.1	7.16	14.61	8.32	11.47			
(B+A) Sum	20.7	17.8	17.3	36.0	18.8	24.29	26.94	16.96	20.38			
(C) CEC Soil	20.4	16.5	17.3	25.05	16.88	21.01	27.22	14.67	18.00			
CEC, 100 g clay	29.6	48.5	66.5	81.6	21.4	45.24	58.79	17.54	34.11			
Base Saturation %												
B X 100												
C	60	27	10	129	56	80.17	74.69	17.29	48.27			
B X 100												
B+A	59	25	10	89	53	67.79	58.09	16.43	40.85			
P (ppm) Bray N.2	5.1	2.0	1.8	49.2	3.05	14.07	6.74	1.04	3.29			
K (ppm) Ammon Acetate	48	24	24	933.7	48	300.74	227.44	24.00	96.61			

Number of Profile Sampled : NE-S20/30, NE-N30/61
NE-S20/23, NE-S20/43

Date of Compilation : February 1976

APPENDIX B

Table 1 Adsorption of Cadmium by Natural Soil Series

Soil series	Initial Cd conc.* (μeq/l)	Equilibrium Cd conc.* c, (μeq/l)	Adsorbed Cd* n,(μeq/g soil)
Bm	227.7	51.2	17.9
	533.8	154.7	38.0
	978.6	440.0	54.4
	2063.9	1063.0	95.3
	2295.2	1483.2	82.5
Ks	227.7	179.5	4.8
	533.8	348.7	17.6
	978.6	848.0	12.8
	2063.9	1710.2	34.0
	2295.2	2035.0	26.7
Pc	227.7	53.2	17.9
	533.8	165.0	34.9
	978.6	469.7	48.3
	2063.9	1283.2	77.1
	2295.2	1601.3	70.7
Nw	220.4	155.5	6.1
	449.4	320.0	12.8
	865.8	667.0	19.1
	1674.6	1399.5	25.8
	2307.6	2041.2	25.5

* The mean value from 4 replications

Table 2 Adsorption of Nickel by Natural Soil Series

Soil Series	Initial Ni Conc.* (μeq/l)	Equilibrium Ni Conc.* c, (μeq/l)	Adsorbed Ni* n, (μeq/g soil)
Bm	170.4	34.1	13.5
	354.3	34.1	22.8
	681.4	72.4	61.1
	1635.4	339.8	130.6
	1737.6	414.8	136.4
Ks	170.4	111.6	5.7
	354.3	247.0	10.5
	681.4	448.9	22.5
	1635.4	1376.4	25.8
	1737.6	1466.0	27.0
Pc	170.4	34.1	13.8
	354.3	34.1	22.6
	681.4	71.6	59.1
	1635.4	416.5	121.4
	1737.6	397.8	128.1
Nw	221.5	158.2	5.5
	432.7	320.7	9.1
	885.9	655.4	15.8
	1754.7	1345.0	36.1
	2248.7	1659.9	31.4

* The mean value from 4 replications

Table 3 Adsorption of Zinc by Natural Soils

Soil Series	Initial Zn Conc.* (μeq/l)	Equilibrium Zn Conc* c, (μeq/l)	Adsorbed Zn* n,(μeq/g soil)
Bm	281.4	9.2	27.6
	572.0	27.6	56.2
	1139.5	42.4	108.9
	2890.1	102.4	266.5
	3212.0	310.6	283.7
Ks	281.4	205.0	7.5
	572.0	403.0	17.3
	1139.5	891.0	24.7
	2890.1	2799.0	39.9
	3212.0	2344.0	54.1
Pc	281.4	9.2	26.7
	572.0	16.3	56.0
	1139.5	43.5	105.9
	2890.1	1258.0	189.1
	3212.0	868.0	197.2
Nw	215.7	135.4	8.2
	415.4	282.8	14.1
	821.6	631.2	24.7
	1719.2	1277.0	45.5
	1984.7	1678.0	55.7

* The mean value from 4 replications

Table 4 Adsorption of Cadmium by Calcium - Saturated Soils

Soil series	Initial Cd conc.* (μeq/l)	Equilibrium Cd conc* c, (μeq/l)	Adsorbed Cd* n,(μeq/g soil)
Ca-sat.Bm	187.3	37.0	15.3
	415.4	63.0	35.2
	776.6	260.6	51.5
	1568.9	771.6	79.9
	1916.2	1021.4	89.6
Ca-sat.Ks	187.3	75.6	11.0
	415.4	119.7	28.4
	776.6	458.0	31.2
	1568.9	1050.0	49.4
	1916.2	1380.0	52.2
Ca-sat.Pc	187.3	35.2	15.3
	415.4	59.6	35.2
	776.6	315.0	41.31
	1568.9	830.0	74.37
	1916.2	1167.0	75.01

* The means value from 4 replications

Table 5 Adsorption of Nickel by Calcium - Saturated Soils

Soil series	Initial Ni conc.* (μeq/l)	Equilibrium Ni conc.* c_e (μeq/l)	Adsorbed Ni* n, (μeq/g soil)
Ca-sat.Bm	187.0	30.2	16.0
	400.0	31.8	37.0
	814.6	93.8	71.3
	1686.5	318.2	137.6
	1994.8	370.6	152.1
Ca-sat.Ks	187.0	68.3	11.9
	400.0	194.0	20.1
	814.6	485.8	32.3
	1686.5	1209.0	46.6
	1914.8	1497.0	41.2
Ca-sat.Pc	187.0	14.4	17.3
	400.0	32.4	36.3
	814.6	77.7	73.6
	1686.5	345.7	134.7
	1914.8	449.0	145.4

* The mean value from 4 replications

Table 6 Adsorption of Zinc by Calcium - Saturated Soils

Soil series	Initial Zn conc.* (μeq/l)	Equilibrium Zn conc.* c, (μeq/l)	Adsorbed Zn.* n, (μeq/g soil)
Ca-sat.Bm	163.6	9.6	15.8
	452.7	26.8	42.3
	1079.8	59.4	103.7
	2138.3	222.5	194.9
	2523.7	219.4	234.3
Ca-sat.Ks	163.6	94.5	6.9
	452.7	93.6	36.1
	1079.8	526.9	54.5
	2138.3	1619.2	51.7
	2523.7	1771.2	74.7
Ca-sat.Pc	163.6	6.6	15.8
	452.7	13.6	44.3
	1079.8	57.2	103.0
	2138.3	376.2	179.8
	2523.7	355.6	216.8

* The mean value from 4 replications

APPENDIX C

Table 7 Effect of pH on the Adsorption of Cd by Bm series

	pH of heavy metal solutions			
	4.0	5.0	6.0	
	----heavy metal adsorbed (μeq/g)----			
	86.03	88.70	69.57	
	87.28	88.03	72.84	
	85.41	95.68	75.28	
	84.29	75.75	76.23	
Total (T)	343.91	348.16	293.92	985.99
Mean ($\bar{y}$)	85.98	87.04	73.48	
Variance $(S)^2$	1.93	68.56	8.82	

Example I The test for equality of Variances for Cochran's test (data from Table 7)

1. H_o : $S_1^2 = S_2^2 = S_3^2$
2. H_1 : at least two of the variance are not equal
3. Significant level , $\alpha = 0.01$
4. Critrical value for cachran's test, $G_\alpha = 0.8831$
5. Computations

$$G = \frac{\text{largest } S_i^2}{\sum_{i=1}^{k} S_i^2}$$

$$= \frac{68.56}{1.93+68.56+8.82} = 0.8644$$

$G < G_\alpha$

Then, accept H_o, the variances are equal

Example II The test for equality of the means, analysis of variance for the one-way classification

From the assumption of equal variances for the k populations when the samples, n are selected. It will be assumed that the k populations are independent and normally distributed with mean, μ_1, $\mu_2 \ldots \mu_k$ and variance, S^2 (data from Table 4.12).

1. H_o : $\mu_1 = \mu_2 = \mu_3$
2. H_1 : at least two of the means are not equal
3. α : 0.01
4. Critrical region, $F > 8.02$ with degree of freedom $\nu_1 = 2$, $\nu_2 = 9$
5. Computations :

Total sum of square (SST) $= \sum_{i=1}^{k} \sum_{j=1}^{n} y_{ij}^2 - \frac{T^2}{nk}$

$$SST = (86.93)^2 + 87.28)^2 + \ldots + (76.23)^2 - \frac{(985.99)^2}{(4)(3)}$$

$$= 693.05$$

Treatment sum of squares (SSA) $= \sum_{i=1}^{k} \frac{T_i^2}{n} - \frac{T^2}{nk}$

$$SSA = \frac{(343.91)^2 + (348.16)^2 + (293.92)^2}{4} - \frac{(985.99)^2}{(4)(3)}$$

$$= 454.92$$

error sum of squares (SSE) = SST-SSA

SSE = 693.05-454.92 = 238.93

treatment mean square (MST) $= \frac{SSA}{k-1}$

$$MST = \frac{454.92}{2} = 227.460$$

error mean square (MSE) $= \frac{SSE}{k(n-1)}$

$$MSE = \frac{238.13}{3(4-1)} = 26.459$$

computed F $= \frac{MST}{MSE}$

$F = \frac{227.460}{26.459} = 8.596$

reject H_o, accept H_1, the means are not equal at $p = 0.01$

Analysis of Variance for the Date of Table 7 (p = 0.01)

Source	df	SS	MS	F
Treatment	2	454.92	227.460	8.596*
Error	9	238.13	26.459	
Total	11	693.05		

Table 8 Effect of pH on the Adsorption of Cd by Ks series

	pH of heavy metal solutions			
	4.0	5.0	6.0	
	------heavy metal adsorbed (μeq/g)-----			
	18.90	29.90	24.46	
	11.21	29.70	20.67	
	19.79	28.61	23.53	
	19.81	22.68	16.61	
Total (T)	69.71	110.89	85.27	265.87
Mean ($\bar{y}$)	17.43	27.72	21.32	
Variance $(S)^2$	17.38	11.63	12.46	

Analysis of Variance for the Data of Table 8 (p = 0.01)

Source	df	SS	Ms	F
Treatment	2	216.19	108.095	7.827
Error	9	124.29	13.81	
Total	11	340.48		

Remark : F (2, 9) = 8.02

Table 9 Effect of pH on the Adsorption of Cd by Pc series

	pH of heavy metal solutions			
	4.0	5.0	6.0	
	----heavy metal adsorbed (μeq/g)----			
	61.74	60.72	51.69	
	58.75	65.10	55.49	
	63.33	58.37	56.26	
	68.71	64.11	-	
Total (T)	252.53	248.30	163.44	664.27
Mean ($\bar{y}$)	63.13	62.07	54.48	
Variance $(S)^2$	17.39	9.61	6.00	

Analysis of Variance for the Data of Table 9 (p = 0.01)

Source	df	SS	MS	F
Treatment	2	146.22	73.11	6.28
Error	8	93.12	11.64	
Total	10	239.34		

Remark : F (2, 8) = 8.65

Table 10 Effect of pH on the adsorption of Ni by Bm series

	pH of heavy metal solutions			
	4.0	5.0	6.0	
	---heavy metal adsorbed (μeq/g)---			
	142.08	148.87	127.65	
	154.14	147.35	125.57	
	150.31	146.31	131.31	
	143.43	141.61	126.75	
Total (T)	589.96	584.14	511.28	1685.38
Mean ($\bar{y}$)	147.49	146.03	127.82	
Variance $(S)^2$	32.60	9.80	6.15	

Analysis of Variance for the Data of Table 10 (p = 0.01)

Source	df	SS	MS	F
Treatment	2	961.09	480.545	29.669*
Error	9	145.77	16.197	
Total	11	1106.86		

Remark : F (2, 9) = 8.02

Table 11 Effect of pH on the adsorption of Ni by Ks series

	pH of heavy metal solutions			
	4.0	5.0	6.0	
	---heavy metal adsorbed (μeq/g)---			
	21.57	21.11	25.36	
	22.23	17.03	25.48	
	22.38	22.52	25.12	
	16.87	21.70	23.72	
Total (T)	83.05	82.36	99.68	265.09
Mean ($\bar{y}$)	20.76	20.59	24.92	
Variance $(S)^2$.	6.86	5.95	0.66	

Analysis of Variance for the Data of Table 11 (p = 0.01)

Source	df	SS	MS	F
Treatment	2	48.10	24.05	5.36
Error	9	40.45	4.49	
Total	11	88.55		

Remark : F (2, 9) = 8.02

Table 12 Effect of pH on the adsorption of Ni by Pc series

	pH of heavy metal solutions			
	4.0	5.0	6.0	
	---heavy metal adsorbed (μeq/g)---			
	142.40	122.41	101.05	
	113.28	133.96	94.66	
	122.46	122.29	105.16	
	112.88	-	101.39	
Total (T)	491.02	378.66	402.26	1271.94
Mean ($\bar{y}$)	122.76	126.22	100.56	
Variance $(S)^2$	190.99	44.89	18.92	

Analysis of Variance for the Data of Table 12 (p = 0.01)

Source	df	SS	MS	F
Treatment	2	1447.33	723.665	8.04
Error	8	120.06	90.007	
Total	10	2167.39		

Remark : F (2, 8) = 8.65

Table 13 Effect of pH on the Adsorption of Zn by Bm series

	pH of heavy metal solutions			
	4.0	5.0	6.0	
	---heavy metal adsorbed (μeq/g)---			
	221.69	199.16	215.09	
	244.81	207.45	224.08	
	234.34	211.84	218.95	
	233.93	212.11	206.88	
Total (T)	934.77	830.56	865.00	2630.33
Mean ($\bar{y}$)	233.69	207.64	216.25	
Variance $(S)^2$	89.30	36.48	52.56	

Analysis of Variance for the Data of Table 13 (p = 0.01)

Source	df	SS	MS	F
Treatment	2	1409.48	704.740	11.845*
Error	9	535.44	59.493	
Total	11	1944.92		

Remark : F (2, 9) = 8.02

Table 14 Effect of pH on the adsorption of Zn by Ks series

	pH of heavy metal solutions			
	4.0	5.0	6.0	
	---heavy metal adsorbed (μeq/g)---			
	25.27	30.93	32.12	
	26.79	20.13	26.41	
	24.85	21.09	44.97	
	-	21.73	37.92	
Total (T)	76.91	93.88	141.42	312.21
Mean ($\bar{y}$)	25.64	23.47	35.35	
Variance $(S)^2$	1.04	25.20	63.20	

Analysis of Variance for the Data of Table 14 (p = 0.01)

Source	df	SS	MS	F
Treatment	2	313.61	156.805	4.697
Error	8	267.09	33.386	
Total	10	580.70		

Remark : F (2, 8) = 8.65

Table 15 Effect of pH to the adsorption of Zn by Pc series

	pH of heavy metal solutions			
	4.0	5.0	6.0	
	---heavy metal adsorbed (μeq/g)---			
	178.21	173.35	176.05	
	184.88	170.71	184.16	
	183.85	173.22	194.29	
	188.01	163.91	172.05	
Total (T)	734.86	681.19	726.55	2142.60
Mean ($\bar{y}$)	183.71	170.30	181.64	
Variance$(S)^2$	17.06	19.62	16.43	

Analysis of Variance for the Date of Table 15 (p = 0.01)

Source	df	SS	MS	F
Treatment	2	417.25	208.625	4.699
Error	9	399.54	44.393	
Total	11	816.79		

Remark : F (2, 9) = 8.02

APPENDIX D

Cation - Exchange Capacity by Ammonium Saturation

1. Ammomium Saturation

Reagents :

- Ammonium acetate (NH_4OAc) 1 N adjusted to pH 7.0 with NH_4OH
- Isopropyl alcohol 99%
- Ammonium chloride 1 N (NH_4Cl) adjust to pH 7.0 with NH_4OH
- Ammonium oxalate $(NH_4)_2\ C_2O_4\ H_2O$ 10%
- Dilute ammonium hydroxide (NH_4OH)
- Silver mitrate $AgNO_3$ 0.10 N

Procedure

1. Place 10 g. of 2 mm., air-dried soil in 500 ml Erlenmeyer flask, add 250 ml of 1 N NH_4OAc.
2. Shake the flask thoroughly, allow it to stand overnight.
3. Filter the soil and leach with neutral NH_4OAc till no test for calcium can be obtained in the effuent solution.
4. Leach the soil four times with neutral, 1N NH_4Cl and once with 0.25 N NH_4Cl.
5. Wash out the electrolyte with 150 to 200 ml of isopropyl alcohol
6. Allow the soil to drain throughly when chloride test in the leachate becomes neglible.
7. Determine the adsorbed ammonium by the acid - NaCl method

2. Displacement by the acid-NaCl.

Reagents :

- Sodium chloride, NaCl (acidified) 10% approximately 0.005 N with respect to acidity
- Sodium hydroxide, NaOH, 1N
- Boric acid, H_3BO_3 2% solution
- Standard Sulfuric acid, H_2SO_4 0.1 N
- Bromocresol green - methyl red mixed indicator

Procedure

1. Leach the ammonium-saturated soil form section 1 with 10% acidified NaCl till 225 ml have passed.
2. Transfer the leachate quantitatively to an 800 ml Kjeldahl flask, add 25 ml of 1N NaOH and distill 60 ml of the soluton into 50 ml of 2% H_3BO_3.
3. Titrate the boric acid solution with standard 0.1 N H_2SO_4, by using 10 drops of bromocresol green-methyl red mixed indicator At the end point, the color change is from Bluish green through bluish purple to pink.
4. Run blanks on the reagents for the titration figure correction and calculate the milliequivalents of ammonium in 100 g of soil.

Free Iron Oxide

(SCS; 1972)

Reagents

- Sodium dithionite powder, $Na_2 S_2 O_4$
- Sodium citrate pentahydrate powder $Na_3 C_6 H_5 O_7 \cdot 5H_2O$
- Superfloc flocculating agent, 0.2% in water

Procedure

1. Weight 1 to 4 g of 80-mesh soil into nursing bottle.
2. Add 2 g of $Na_2 S_2 O_4$ and 20 to 25 g of $Na_3 C_6 H_5 O_7 \cdot 5H_2O$.
3. Add deionized water to the 4-oz. (118 ml) level.
4. Shake overnight, transfer the suspension to a 250 ml volumetric flask, add 5 drops of supperfloc, stopper and shake vigorously for 15 sec. make to volume & allow to settle 1 hr.
5. Run blank as the same procedure for analysis correction.
6. Calculate the Fe content of the sample as follows :

% Free Fe oxide = 250 x (ppm Fe in sample solution-ppm Fe in blank solution)/sample weight (g) x 10,000

Remark : citted from Black et.al. (1965) and ASA - SSSA (1982)

APPENDIX E

Zinc.

The average Zn content of the lithosphere is 80 ppm while the Zn content of soil ranges from 10 to 300 ppm. Zinc is considered a trace element in soils. The solubilization of Zn minerals usually affects the availability to plants. The Zn hydrolysis species in aqueous solution are given by reactions.

$Zn^{2+} + H_2O \rightleftharpoons ZnOH^+ + H^+$ $\quad \log K^\circ = -7.69$ _____ 1.

$Zn^{2+} + 2H_2O \rightleftharpoons Zn(OH)^\circ + 2H^+$ $\quad \log K = -16.80$ _____ 2.

$Zn^{2+} + 3H_2O \rightleftharpoons Zn(OH)_3 + 3H^+$ $\quad \log K = -27.68$ _____ 3.

$Zn^{2+} + 4H_2O \rightleftharpoons Zn(OH)^{2-} + 4H^+$ $\quad \log K = -38.29$ _____ 4.

(Lindsay, 1979)

Zn^{2+} is the predominant species in solution below pH 7.7. Several investigators have reported that montmorillonite was capable of adsorbing Zn in amount greater than other clays. The mechanism of the adsorption is unknown, the specific adsorption could be replaced by nondestructive dilute acid extraction to release the Zn

Cadmium.

The average Cd content of the lithosphere is 0.2 ppm while the Cd content of soils from 0.01 to 0.70 ppm. The principal use of cadmium in industry is for metal plating. Cadmium is hazard pollutant because of its toxicity to nearly all living organism and its lack of useful biological function. The hydrolysis reaction of Cd^{2+} are given by reactions.

$Cd^{2+} + H_2O \rightleftharpoons CdOH^+ + H^+$ $\quad \log K = -10.10$ _____ 5.

$Cd^{2+} + 2H_2O \rightleftharpoons Cd(OH)_2 + 2H^+$ $\quad \log K = -20.30$ _____ 6.

Source : Lindsay (1979)

Biography

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