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Exchangeable Cations  
Cation Exchange Capacity

Analyse des Sols, Des Eaux et des Plantes

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LE CENTRE ARABE  
POUR LES ETUDES DES ZONES ARIDES ET DES TERRES SECHES  
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No. 3400

Exchangeable Cations  
Cation Exchange Capacity

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Damascus - October 1980



Author : ABRUKOVA (L.P)  
 Title : Determination of exchangeable bases in calcareous soils.  
 Public : Soviet Soil Science 1964.  
 Pages/ref: 977 - 980 / 17 ref.

Summary:

Three methods are compared for determining exchangeable cations in soil containing 3 to 35% of calcium carbonates, with special mention to exchangeable calcium and magnesium. The morphology of calcium carbonate appears to be an important factor leading to different solubilities in various extractants. Methods based on assumption of constant solubility of carbonates in successive extractions are suspected.

Methods:

Method a) EC are displaced by 1N NaCl solution (up to 500ml) correction for dissolved carbonates is made by titrating carbonates passed into solution.

b) Exchangeable calcium is bound by oxalate ions and calculated from the difference in oxalate concentration before and after saturation. The reagent involved in a mixture of ammonium salts kept at 10°C.

c) Soil is saturated by two times the same volume of 1N NaCl. The first is supposed to contain exchangeable and soluble (Ca, Mg), the second only soluble (Ca, Mg).

All methods gave similar results when calcium carbonate (3%) was in latent, invisible form CEC values differed widely when calcium carbonate was either mycelium or visible crystalline form (5%), method a giving the more reliable results.

Figures :- Determination of exchangeable calcium by three methods.  
 - Determination of ECa and EMg in calcareous chernozems by three methods.

Chemicals: Method 1: Sodium chloride . Hydrochloric acid.  
 Method 2: Amonium oxalate . Amonium acetate . Amonium carbonate . (Plus chemicals for titration of oxalate).  
 Method 3: Sodium chloride.

Key Words: EC - CEC / CALCIUM CARBONATE /

ABRU

Authors : ADAMS (J.M) & EVANS (S)  
 Title : Determination of the cation exchange capacity (layer charge) of small quantities of clay minerals by nephelometry.  
 Public : Clay & Clay Mineral 2-27-1978.  
 Pages/ref: 137-139 / 7 ref.

Summary:

Irreversible cation fixation on clay prevents the Ca determination of CEC of clay when less than 30 mg of sample is available and only layer charge may be measured directly.

Method: 30 mgr of Ca or Ba-saturated clay is fused with 0.7g NaOH to red heat 10 min. and dissolved in HCL (final conc.: 4%).

Barium: To 5ml of the clay solution, 5ml of glycerol/ethanol mixture and 2.5ml of (1.5M) H<sub>2</sub>SO<sub>4</sub> are added, volume is made up to 25ml. Turbidity is measured after 10 minutes.

Calcium: To 5ml of the clay solution add 4.0ml of the glycerol/ethanol mixture, 1.5ml 3M NH<sub>4</sub>OH and 4.0ml oxalic acid solution (20 g/l) turbidity is measured after 25 min. Authors suggest that barium may be fixed on surface of clay particles and propose to use Ca saturated samples even if the quantity of available clay is only 5 to 30 mgr.

Tables : Comparison of nephelometric and others determination of CEC (on Ba and Ca-saturated clays) for bentonite, montmorillonite and beidellite samples.

Precision: For 30 mgr samples having a CEC 70-100 meq/100 gr. duplicate measurements agreed within 10% and comparison with other methods was better than 5%.

Chemicals: NaOH . NaCl . HCL . Glycol . Ethanol . ~~Ammonia~~ . Oxalic acid.

Key Words: CEC / MINE / Ba / Ca /

Auteur : xxx / ARIANA.  
Titre : Mesure de la capacite d'echange et des cations échangeables d'un sol.  
Public : Roneo, D.R.E.S, Tunis.  
Pages/ref: 11 pages / -

Resumé:

La methode decrite, utilise la saturation par l'acetate d'amonium PH 8.2, le rincage a l'ethanol, et le remplacement par le chlorure de sodium. La methode est applicable aux sols neutres.

La technique utilisee, est la percolation a niveau constant (vase de Mariotte) .

Les cations échangeables sont mesures par absorption atomique ou photometrie de flamme et la capacite d'echange determinee par la concentration en amonium dans le percolat NaCl mesure par colorimetrie a l'indophenol.

Une correction est faite pour tenir compte des cations solubles lorsque la somme des cations échangeables depasse la capacite d'echange. Cette correction est ponderee pour le calcium et le magnesium.

Application: Cations échangeables et capacite d'echange.

Materiel : Colorimetre . Photometre a flamme ou spectrophotometre d'absorption atomique .

Produits : Acetate d'amonium . Acide acetique . Chlorure de sodium . HCL . Reactif de Nessler . Ethanol .

Mots Cles : EC - CEC /

ARIA

Author : BECKETT (P.H.T)  
Title : The cation-exchange equilibria of calcium and magnesium.  
Public : Soil Science 100 (2) : 1965.  
Pages/ref: 118-123 / 24 ref.

Summary:

Ion exchange affinities for exchange sites of soils and ion exchange Ca/Mg constant was studied on a natural acid soil (clay 7.5% , organic matter 3.1% , pH 5.2 ,  $\text{NH}_4\text{Cl}$  extractable cations Ca = 6.8 , Mg = 0.7 , K = 0.5 , Na = 0.11 meq/100 gr , clay was montmorillonite with moderate illite. In the presented study, the soil was equilibrated with solutions having a Mg / (Mg + Ca) concentration ratio ranging from 0.07 to 0.94 in 23 different experiments.

Results: It was shown that except at specific sites Ca and Mg are held with similar attraction by exchange sites, the number of sites available for Ca being however greater than for Mg. The difference between Ca and Mg fixation is therefore pronounced only at low level of activities.

Tables : 1 : Ion exchange equilibrium between Ca and Mg for  
(Ca + Mg) = 4.2 meq/l .  
2-3: Quantity - Intensity relation for labile and  
exchangeable Mg and Ca.

Key Words: EC - CEC / Ca - LABIL / Mg - LABIL /

BECK





Authors : BOWER (C.A) , REITEMEIER (R.F) & FIREMAN (M)  
 Title : Exchangeable cation analysis of saline and alkali soils.  
 Public : Soil Science 73 - 4 - 1952.  
 Page/ref: 251 - 261 / 16 ref.

Summary:

The determination of exchangeable cations (EC), and cation exchange capacity (CEC) is considered with the evaluation of soluble salts (SS) in saturation extract.

EC are determined on 5 gr of soil by three times 33ml of 1N PH7 amonium acetate. Soluble cations in a saturated paste from 200 gr of soil. For CEC, 5 gr of soil is saturated by four 33 ml portions of 1N PH 8.2 sodium acetate, washed with 95% ethanol. Efficiency of washing is controlled by electric conductivity (less than 40 micro S/cm). Replacement step is done by neutral amonium acetate. CEC is proportional to sodium extracted in this last solution.

The paper details experimental conditions as optimum number of acetate extractions to remove (EC + SS) on saline, calcareous and non saline soil samples. Data indicate that three extractions are sufficient to remove all soluble and exchangeable cations. Four treatments with sodium acetate are sufficient to saturate exchangeable sites with sodium.

Hydrolysis of exchangeable sodium upon washing treatment is investigated.

- Tables :- Amounts of various cations removed by successive amonium acetate extractions of soils.  
 - Amounts of Ca plus Mg removed by sodium acetate extraction of soil.  
 - PH value of successive acetate extracts of soils.  
 - Removal of excess salts hydrolysis of exchangeable Na upon washing sodium-treated soil with ethanol.  
 - CEC of soils by Na at various PH values.  
 - Influence of  $\text{CaCO}_3$  upon values obtained for the CEC by saturation with normal sodium acetate solution of PH 8,2.

Material : Flame photometer - PH-meter .

Chemicals: Amonium acetate . Sodium acetate . Ethanol .

Key Words: EC - CEC / SOLUBLE SALTS /

BOWE

Authors : CARPENA (O), LAX (A) & VAHTRAS (K)  
 Title : Determination of exchangeable cations in calcareous soils.  
 Public : Soil Science 3 - 113 - 1972.  
 Pages/ref: 194-199 / 6 ref.

Summary:

A modification of the Mehlich-Piper procedure is proposed to eliminate solubilization of carbonates as a source of errors in exchangeable cation determination. A soil sample is treated twice with same volume and extracting solution. The first fraction is supposed to contain soluble and exchangeable cations. The second only cations from soluble carbonates. The solution used is barium-chloride-triethanolamine 0.2N, pH8.1. The method is applied to dolomitic soils of Spain (pH7.6 to 8.2; 0.M 0.3 to 6%; Clay 5 to 18%). The technique used is percolation on 5 gr sample.

Correction for dissolved carbonates is based on  $\text{HCO}_3^-$  determination, care being taken to prevent  $\text{CO}_2$  contamination from air and correction being made for exchanged  $\text{H}^+$  and TEA reaction with acid. The amounts of carbonates dissolved during the second extraction is smaller than in the first one (the rate of dissolution of carbonate is not constant with respect to time).

Tables :- Analysis scheme. Titration curve for  $\text{HCO}_3^-$   
 - Relationship between ex: (Ca + Mg) calculated and true exch. cations.  
 - Intermediate data used to calculate dissolved carbonates.

Precision: Method is tested for soils containing 5 to 55%  $\text{CaCO}_3$  and 5 to 18% clay.

Material : AA Spectrophotometer.

Chemicals: Barium chloride . HCL . TEA . Amonium sulfate . EDTA . Eriochrome black T.

Key Words: EC - CEC / CARBONATES / CALC. CARBONATE /

Authors : CHHABRA (R), PLEYSIER (J) & CREMERS (A)  
 Title : The measurement of the cation exchange capacity and  
 exchangeable cations in soils: A new method.  
 Public : Proc. of Int. Clay Conf. 1975. Applied Publ. Ltd. Wilmette,  
 Illinois 60091. U.S.A.  
 Pages/ref: 439-449 / 9 ref.

Summary :

One - step method for measuring EC and CEC of soils, based on the high affinity of silver - thiourea complex for exchange sites. Ag, Ca, Mg, Na, K are measured in a single extract. CEC is related to decrease in Ag concentration before and after saturation. The method is compared with  $^{45}\text{Ca}$  isotopic dilution method and  $\text{NH}_4\text{OAC} - \text{NaCl}$  method, and is tested on 30 podzolic, 15 saline alkali, and 6 calcareous soils ( $\text{CaCO}_3$  7 to 65%). Different procedures were tested with or without 1M  $\text{NH}_4\text{OAC}$  pH7 as a buffer. Direct saturation of alkali soils with silver - thiourea being impossible because the unstability of the complex at pH above 8 . All methods are described into detail.

Results :

Silver - thiourea method and ammonium acetate gave correlation coefficient higher than 0.98 and exhibited a similar dependence on organic matter content of samples. For exchangeable cations the best agreement appeared on Ca determination.

Tables :- Comparison of CEC values as obtained by different methods on podzolic, saline alkali and calcareous soils.  
 - Correlation between silver - thiourea method and  $\text{NH}_4\text{OAC}$  percolation method for exchangeable cation (Ca, Mg, K) on podzolic soils and exchangeable + soluble cations on saline alkali soils.

Precision: Reproducibility is better than 5% for 53 duplicate.

Material : AA Spectrophotometer . Centrifuge . End-over-end shaker (optional: scintillation counter).

Chemicals: For Ag - Thiourea method only:  $\text{NH}_4\text{OAC}$  .  $\text{AgNO}_3$  . Thiourea (optional Ag gamma tracer).

Key Words: CEC / AAS - IND. METH. /



Authors : CURTIN (D) & SMILLIE (G.W)  
 Title : Estimation of components of soil cation exchange capacity from measurements of specific surface and organic matter.  
 Public : Soil Science Society of America proceedings 40 - 1976.  
 Pages/ref: 461 - 462 / 13 ref.

Summary:

CEC was correlated with specific surface using the ethylene glycol monoethyl ether retention method. A simple correlation coefficient with CEC,  $r = 0.81$ . The study was made on 51 samples of 10 profiles with a CEC ranging 6 to 63 me / 100 g, clay 0.4 to 55%, organic matter 0.2 to 15% and specific surface (sq. meter / g) 5 to 250.

A multiple regression analysis with two factors gave a value  $r^2(1) = 0.97$  when specific surface was combined with organic matter and  $r(2) = 0.58$  when clay percentage was combined with organic matter.

The difference between  $r(1)$  and  $r(2)$  is attributed to the ability of specific surface measurement to count for phyllosilicates in silt and sand fractions.

Tables : Summary of laboratory data for the soils and estimates of organic and mineral components of CEC.

- Simple correlation coefficients between CEC and various soil properties.
- Multiple regression equations relating CEC with (i) organic matter (O.M) and clay and (ii) O.M and specific surface.

Precision: CEC was measured at PH 8.2 using barium chloride with triethanolamine without washing step.

Chemicals: (CEC only) barium chloride . Triethanolamine .

Key Words: CEC / CLAY / PHYS - ANALYSIS /

CURT



Authors : DOLCATER (D.L) , LOSTE (E.G) , SYERS (J.K) & JACKSON (M:L)  
 Title : Cation exchange selectivity of some clay rigid minerals and soil materials.  
 Public : Soil Sci. Am. Proc. 32 - 1968.  
 Pages/ref: 795-798 / 20 ref.

Summary:

The cation selectivity on soil exchange material depends not only on pH temperature, ion size, ion valence, ion hydration, ion concentration of equilibrating solution but also on structural and charge properties of micaceous vermiculites. Cation exchange selectivity was measured for montmorillonite, vermiculite, muscovite, biotite. CES was measured by a modified version of Schachtschakel's method:

- A Na saturated clay sample is equilibrated with a solution having a K/Ca<sup>1/2</sup> concentration ratio of 0.10 and sorbed K and Ca were displaced by Mg. Excess saturating solution was determined by weighing. The hypothesis that the high K/Ca selectivity of micas as compared to montmorillonite was due to steric hindrance of hydrated divalent cation such as Ca and Sr was tested.

- Tables :
- 1 : Mineralogical analysis of samples.
  - 2 : Flow sheet for the determination of CEC and EC of fine grained material.
  - 3-4: K/Ca , K/Sr , K/Ba , CES of Na saturated exchange material.
  - 5 : Mg/Ca , Sr/Ca , Ba/Ca , CES of Na saturated exchange material.
  - 6 : CEC of original samples as given by different saturating cations.
  - 7-8: Diagramatic cross-sections of micaceous vermiculite showing K selectivity mainly in the wedge sites and of muscovite showing K selectivity both in wedge sites and on cleavage surface.

Key Words: CLAY MINE. / CEC /

Author : EDWARDS (A.D)  
 Title : An ion-exchange resin method for the determination of cation exchange capacity.  
 Public : Canadian Journal of Soil Science 47 - 140 - 1967 .  
 Pages/ref: 140 - 142 / 5 ref.

Summary:

A method using saturation by ammonium ion from a cation exchange resin (ammonium form) instead of ammonium salt is described. It is convenient for micro soil samples. A home-made sieving arrangement made from a side-arm distillation flask is shown.

Method: 0.2 to 0.5 gr of sample is mixed with  $\text{NH}_4$ -resin in small glass vials (5 ml) and shaken 16 hours. Resin is removed by sieving into a distillation flask with a proper home-made adaptor. Separation of resin and soil is achieved by 25 ml of water if suction is applied to the mixture. Steam distillation is carried out after addition of sodium chloride and magnesium oxide. Titration of distilled ammonia is made by a 5ml microburette and 0.029 N acid.

Tables :- Sieving arrangement for transferring saturated soil to steam distillation flask while removing the cation exchange resin.  
 - CEC values by three methods on five soils and soil properties (Ph, Clay, Organic matter).

Precision: Relative standard deviation of 6 replicates is around 1% from 18 to 62 me/100 gr of CEC and 3% at 3 me/100 gr.

Material : Distillation flask fitted with filter funnel and 80 mesh stainless steel screen (removable).

Chemicals: Sodium chloride . Magnesium oxide . Cation exchange resin (40 mesh minimum size).

Key Words: CEC / RESIN /

EDWA



Authors : FERNANDO (M.J) , BURAU (R.G) & ARULANANDAN (K)  
Title : A new approach to determination of cation exchange capacity.  
Public : Soil Sci. Soc. Am. J. 41 - 818 - 1977.  
Pages/ref: 818-820 / 8 ref.

Summary:

The CEC of artificial clay-sand mixture was related to dielectric dispersion (i.e: the difference between the dielectric constant of a soil sample at 3 and 75 megahertz respectively). Different regression equations were found for kaolinite, illite and montmorillonite-enriched samples: The relationships found were tested on natural soils and linear equation was found though the slope was different, the difference being attributed to organic matter, iron oxides and carbonates which cement colloid particles decreasing the dielectric dispersion.

Tables : 1. Elec. dispersion of different types of silica-flour / clay mixtures.  
2. Effect of clay type on magnitude of dielectric dispersion.  
3. Relationship between dielectric dispersion of CEC.  
4. Composition and properties of studied soil samples.

Material : Radiofrequency bridge.

Chemicals: None

Key Words: ELEC / CEC / SOL /

Authors : GARMAN (M) & HESSE (P.R)  
 Title : Cation Exchange Capacity of Gypsic Soils.  
 Public : Plant & Soil 42 - 1975.  
 Pages/ref: 477-480 / 1 ref.

Summary:

The method relies on saturation of exchange sites by barium at pH 8.1. Barium is exchanged with magnesium using a standard magnesium sulfate solution. The CEC is determined by calculating the loss of magnesium from the added standard solution of magnesium sulfate. The method is appreciable for soil containing up to 70% of gypsum providing some precautions:

1. A great excess of barium ions is used in saturation step.
2. EDTA titration of magnesium is corrected for calcium.

It was demonstrated that 1): even an excess of barium chloride does not dissolve all gypsum when present in quantities superior to 3% (overnight treatment). 2): pH 5.5  $MgSO_4$  treatment removes barium sulfate coating and an appreciable amount of remaining gypsum is dissolved during the second step of the procedure.

Tables :- CEC (me/100 g soil) of gypsic soil using the original and a modified version of the Bascomb's method.  
 - Calcium content of final magnesium sulfate extract of soils during determination of CEC by Bascomb's method.

Chemicals: Barium chloride . Magnesium sulfate . Solochrome dark blue .

Key Words: GYPSUM / CEC /  $CaCO_3$  /

GARM



Author : HESSE (P.R)  
Title : Cation Exchange Capacity and Exchangeable Cations.  
Public.in: Methods of Soil Analysis. Euphrate Pilot Irrigation Project  
1974.  
Pages/ref: 11 - 13 .

Summary:

Methods using (1) sodium as saturating ion (with washing by 95% ethanol and replacing by ammonium acetate), and (2) barium as saturating ion are presented. The sodium method is the conventional batch-centrifuge one. The barium method is the following:

Method:

To 1g soil add 20 ml 1N barium chloride (buffered to PH 8.1 by the same vol. of TEA. Shake, centrifuge. Wash quickly with 40 ml water, centrifuge. Add 20.0 ml magnesium sulfate (6.2 gr/l) shake two hours, centrifuge. Titrate Ca in the supernatant by EDTA with eriochrome black T as indicator and (Ca + Mg) on another aliquot. Calculate CEC from loss of Mg during saturation.

Chemicals: (Barium method only)

Triethanolamine . Barium chloride . Magnesium sulfate hexahydrate . EDTA (disodium). Eriochrome black T . Solochrome dark blue . Sodium hydroxide . Polyvinyl alcohol.

Key Words: EC - CEC /

HESSE



Authors : JUO (A.S.R) , AYANLAJA (S.A) & OGUNWALE (J.A)  
 Title : An evaluation of cation exchange capacity measurements  
 for soils in the tropics.  
 Public : Commun. Soil Sci. & Plant Analysis ( 7(8) 1976.  
 Pages/ref: 751-761 / 13 ref.

Summary:

Three methods are tested on 16 B horizons-samples of Ultisols and Alfisols from west Africa (pH 1/1: 4.5 to 6, clay%: 32 to 74,  $\text{NH}_4\text{OAc}$  - CEC: 4 to 30). The three methods gave different values of CEC: KCl - CEC,  $\text{BaCl}_2$  - CEC,  $\text{NH}_4\text{OAc}$  - CEC (in increasing order).

The surface-charge properties of these highly weathered soils containing Fe and Al oxides and hydroxides, depends on pH and concentration of displacing solution. Authors suggest to use the value of effective CEC i.e: Sum of exchangeable cation (N  $\text{NH}_4\text{OAc}$ ) and exchangeable acidity (N KCl). This value is more significant and reproducible. The differences between the methods of CEC is due to different pH of extracting solution to washing technique and to acetate anion on oxide surface.

Tables :- CEC of B horizon of 16 soils as determined by three methods./  
 - Effect on anion on CEC / Exchange acidity determined by three different methods / Observed and predicted values of base saturation of soils.

Precision:  $\text{NaOAc}$  -  $\text{NH}_4\text{OAc}$  method gave a CEC : 4 to 20 meq/100 gr.  
 Effective CEC as proposed gave CEC range : 2 to 13 meq/100 gr.  
 ( $\text{BaCl}_2$ -TEA acidity +  $\text{NH}_4\text{OAc}$  exch.cations gave: 4 to 31 meq/100 gr.)

Chemicals: Method 1:  $\text{NaOAc}$  - ETOH -  $\text{NH}_4\text{OAc}$  /  
 Method 2:  $\text{NH}_4\text{OAc}$  -  $\text{BaCl}_2$  - Triethanolamine .  
 Method 3: KCl -  $\text{NH}_4\text{OAc}$  - Chemicals for Al titration .

Key Words: CEC

Auteurs : MARCCEN (J.M) & LACROIX (J.P)  
Titre : Mesure de la capacity d'echange cationique de la fraction argileuse des sols par 85 Sr .  
Public : Annales de Gembloux 83 - 277 - 1977 .  
Pages/ref: 277 - 281 / 6 ref.

Resume:

La CEC des argiles est mesuree par scintillation liquide et par spectrometrie gamma de radio strontium. La methode par analyse d'amplitude permet de mesurer la radioactivite du strontium directement sur le sol.

Mode operatoire:

- 15 a 75 mg d'argiles sont saturees par 7 ml de chlorure de strontium, 0.1N (deux fois quatre heures d'agitation) dopee a 85 Sr, on centrifrige.
- on lave avec 3 ml de methanol.

On mesure la radioactivite soit sur les surnageants de centrifrigation successifs et sur les lavages (par scintillateur liquide) soit a l'aide d'un analyseur d'amplitude multicanaux equipe d'une sonde NaI de 8 x 8 cms.

Figures : Activite du radiostrontium au cours des differentes phases d'equilibre avec la solution saturante.

Precision:- La technique s'applique a des echantillons de 15 mg a 8 g.  
- La CEC d'une montmorillonite est mesuree a 10% pres a 85 me / 100 g.

Materiel : Analyseur d'amplitude NaI

Produits : Chlorure de strontium . Chlorure de strontium radioactif.

Mots Cles: CEC / MINERALOGIE / RADIO /

MARC

Authors : MAC LEOD (S) & ZARCINAS (B)  
 Title : The determination of amonium and chloride by an autoanalyser for the measurement of cation exchange capacity of soils.  
 Public : Communication in Soil Science and Plant Analysis 7-8-1976.  
 Pages/ref: 743 - 750 / 8 ref.

Summary:

A continuous flow colorimetric method is developed for the simultaneous determination of amonium and chloride from amonium chloride used to saturate the exchangeable complex of soils.

Method: - Salts are removed by a glycol-ethanol wash.  
 - Soil is saturated with 1N amonium chloride PH 8,5 in 60% ethanol. Amonium adsorbed is replaced by a mixture of calcium nitrate / potassium nitrate (0.25 M / 1.5 M) .

Colorimetry: Amonium is determined by Berthelot's sodium phenate - hypochlorite reaction and chloride by mercury (II) thiocyanate, ferric ions being provided by a ferric nitrate solution.

Diagrams (shown here separately) are:

1. Sample (1.6) / air (3.4) / water (1.6) / single mixing coil / iron (III) nitrate 20 gr/l in nitric acid (1.6) / single mixing coil / (II) thiocyanate 0.8 gr/l (1.6) / single mixing coil / colorimeter 480 nm / repump to waste 2.9 / .
2. Sample (1.2) / air (3.9) / EDTA (disodium) M/60 (3.9) / sodium phenate (2.0) / single mixing coil / sodium hypochlorite (3% free chlorine) (2.0) / single mixing coil / bath 95°C (20 feet) / cooling coil / colorimeter 620 nm / repump to waste (2.9) / .

Correction for free amonia used to adjust the PH of saturating solution to 8.5 is made by applying a constant correction factor to amonium results when high retention of saturating solution is suspected (swelling clays). Analysis of variance was made on 23 soil samples. The results for manual and automatic determination of chloride was the same. Standard deviation of amonium determination was higher than in manual titrimetric method.

Precision: R.s.d is 2% at 48 me/100 g amonium level and 0.7% at 15 me/100 gr level of chloride.

Chemicals: Glycol . Ethanol . Sodium hypochlorite . Phenol sodium hydroxyde . EDTA (disodium) Mercury (II) . Thiocyanate . Iron (III) nitrate . Amonium chloride . Calcium nitrate . Potassium nitrate .

Key Words: CHLORIDE / AMONIUM / AUTOANALYSE / CEC /

MACL



Authors : MOLODSTOV (V.A) & IGNATOVA (V.P)  
 Title : Determination of the composition of adsorbed bases in Saline Soils.  
 Public : Soviet Soil Science 3-1976.  
 Pages/ref: 364-367 / 3 ref.

Summary:

It is proposed to determine exchangeable cations of saline soils, especially those with sulfate and chloride salinization after dissolving the salts in water (20 to 40% water/soil ratio) and washing them out by 70% ethanol; up to 10% by weight of soluble salts in soil may be eliminated. Data are presented on 15 samples with 0.6 to 3% water soluble salts, 0 to 30% gypsum and 5 to 12% carboantes.

Method: Wet 5gr of soil to field capacity, leave overnight. Add 10-15ml 70% ethanol mix, centrifuge. Repeat until no sulfate is detected in washings. Add 25ml of 0.1N  $\text{NH}_4\text{Cl}$  in 70% alcohol, mix, allow to stand 1 hour, centrifuge. Repeat three times, collect supernatant in a porcelain dish, evaporate, dissolve in water. Determine Ca, Mg, K and Na.

The method is tested on a chloridic-sulfatic solonchak and a sierozem with sulfate salinization. In none of the soil samples soluble calcium was found in the 70% alcohol extracts. Sulfate of sodium and magnesium were not removed by washing out with alcohol alone.

- Tables :
- Composition of adsorbed bases in meq/100g after removal of soluble salts with water alone, with alcohol alone according to the proposed method.
  - Content of ions in 70% alcohol solutions and composition of exchangeable cations as a function of the degree of wetting before analysis (for 20% and 40% water/soil ratio).
  - Sodium content in various extracts and soil solutions.
  - Content of ions in extracts and soil solution (1/5 water extracts: 70% alcohol extract after wetting; soil solution).

Chemicals: Ethanol - Amonium chloride.

Key Words: EC-CEC / SALINITY / SODIUM /

MOLO

Authors : ~~ROSE~~ OKAZAKI , SMITH (H.V) & MOODIE (C.D)  
 Title : Some problems in interpreting cation exchange capacity data.  
 Public : Soil Science 3 - 97 - 1964.  
 Pages/ref: 202 - 208 / 9 ref.

Summary :

The effect of washing step during CEC measurement is discussed. The effect of washing out excess saturating cation is found to be the most important source of error, without regard to change of index cation used in saturating solution.

The value of CEC is not affected by the choice of divalent (Ba in a mixture barium acetate, barium chloride) or monovalent (Na in a mixture of acetate and chloride also) saturating ion.

It is also demonstrated that the number of washings necessary to remove excess saturating solution without loss by hydrolysis varies from sample to sample.

The batch technique, which involve mixing sample with saturating solution and centrifuging is reconsidered as far as washing step, which necessitates complete resuspension of soil material is concerned. Difficulties were encountered with Ba saturated sample. Resuspension problems may lead to results differring from those obtained by leaching.

Control of washing step by use of a tracer anion, as chloride (in non-saline samples) is not free of errors, and control by limiting the number of washings is not applicable to all samples.

Tables :- Identification of four samples (mineralogy) choosed for experiment.  
 - Effect of washing number on apparant CEC of samples.  
 - Effect of centrifuging and leaching techniques on apparent CEC as measured by Ba and Na saturating cations respectively.  
 - Effect of extent of shaking during washing for achieving resuspension of samples (batch technique) used for experiment, mostly kaolinic.

Material : Clay type had a CEC varying from 4 to 15 me/100 g (four soil samples).

Equipment: Centrifuge . Leaching columns .

Products : Sodium and Barium salts as chloride and acetate . Ethanol .

Key Words: CEC

OKAZ

Authors : OSTER (J.D) & SHAINBERG (I)  
 Title : Exchangeable cation hydrolysis and soil weathering as affected by exchangeable sodium.  
 Public : Soil Science Society of America Journal, 43 - (1) - 1979.  
 Pages/ref: 70 - 75 / 14 ref.

Summary :

Exchangeable and crystalline cations are released from soil minerals as a result of hydrolysis and weathering. Rates of hydrolysis and the resultant changes in the cation exchange composition of three lime free arid zones soils as affected by different values of exchangeable Na are studied.

Methods :

Lime was removed by 1N NaCl/HCL at constant pH4 to 5; (Contact time 24 to 72 hours). Then soils were equilibrated with solutions having a S.A.R. of 5, 20 and "infinite" (chloride of Na, Mg, Ca). PH and Electric Conductivity were measured during the equilibration period (7 to 14 days). The initial CEC was measured by Na-NH<sub>4</sub>OAC method and EC by NH<sub>4</sub>OAC pH7.

Results :

The conductance of aqueous suspensions plotted versus the square root of time exhibited two linear segments. Authors conclude that the release of Ca, Mg, K from silicate minerals is more rapid than the hydrolysis of exchangeable Na and Ca for the three soils considered. The removal of CaCO<sub>3</sub> was suspected to produce intermediate products controlling release of Ca, Mg, K. The rate of exchangeable Ca hydrolysis and release from silicate materials was sufficient to saturate the solution with respect to lime for the calcic haploxeralf soil.

Tables :- General properties of soils (CEC. CaCO<sub>3</sub>. Clay. Silt-clay minerals).  
 - EC composition before and after the treatments.  
 - Relation between specific conductance and time for aqueous suspensions of three soils.  
 - Total initial and final EC and changes in exchange ion composition.

Material : AA Spectrophotometer (for Ca, Mg, Na, K) . Chloride titrimeter. ( for Cl ) Potentiometric titrator . (for carbonates and bicarbonates) Centrifuge .

Key Words: CEC / SALINITY / SODIUM / LABIL /

Auteur : PELLOUX (P)  
 Titre : Methodes de determination des cations echangeables, de la capacite d'echange dans les sols courants calcaires ou non, mais ni sales, ni gypseux.  
 Public : Service des Sols, ORSTOM 1963 .  
 Pages/ref: 55 pages / 7 ref.

Resume:

Une methode permettant la determination de la capacite d'echange des sols peu calcaires utilisant le calcium comme ion saturant et le chlore comme ion traceur est decrite. Les risques d'hydrolyse sont evites en eliminant l'etape de lavage.

Methode:

Percoler 10 g de terre par 500 ml de chlorure de calcium tamponne a PH 7 par de la triethanolamine, puis par 150 ml de chlorure de calcium N/10. On deplace le calcium par 500 ml de nitrate de potassium N. On dose dans le percolat Ca et l'anion Cl qui permet d'evaluer l'excès de chlorure de calcium retenu par capillarite. On titre les carbonates et bicarbonates par acidimetrie pour connaitre la quantite de calcium dissoute par le reactif utilise. On peut egalement doser dans l'extrait au chlorure de calcium, le sodium et le potassium echangeable.

Le calcium est dose par colorimetrie en flux continu (BRION) par le montage:

(Echantillon (0.23) / Air (0.32) / ) // (Tampon diethylamine (1.2) / Cresolphtaleine 0.05% dans HCL 0.25N (0.32) / Agitateur magnetique // Bobine melange 10 tours / Colorimetrie 15 mm , 570 nm .

Figures :- Schema de montage des colonnes de percolation.  
 - Systeme de percolation automatique.

Produits : Chlorure de calcium . Triethanolamine . Nitrate de potassium . Helianthine acide chlorhydrique . Diethylamine . Gamme de potassium.

Mots Cles: EC - CEC / CALCIUM / AUTOANALYSE /

PELL

Author : PAPANICOLAOU (E.P)  
 Title : Determination of Cation Exchange Capacity of Calcareous Soils and their percent base saturation.  
 Public : Soil Science 2 - 121 - 1976.  
 Page/ref: 65 - 72 / 19 ref.

Summary:

Soil is saturated by  $\text{CaCl}_2$  solution using mixing-centrifuging technique. Adsorbed Ca is removed, with excess calcium chloride by sodium or potassium nitrate (eight times). Cation exchange capacity is expressed as total (Ca + Mg) minus total (chloride + carbonate + bicarbonate). Hydrolysis of adsorbed calcium is limited by choosing a washing solution 5 meq/l and washing only once.

Chloride of Na, K, Cs used as replacing solution instead of sodium nitrate gives the same results, though the benefit of having chloride as index ion is lost.

The paper investigates also the percent base saturation which is difficult to determine in calcareous soils.

- Exchangeable Ca, Mg are measured in various extractants (chlorides of lithium, sodium, potassium, ammonium) correction is made for dissolved carbonates and bicarbonates. Lithium chloride and ammonium chloride are found unsuitable as replacing solutions, the first because it does not achieve complete replacement, the second because it instable gives carbonates.
- Exchangeable K and Na are determined in 1N PH 7 ammonium acetate.

Tables :- CEC of calcareous soil samples using saturation by calcium chloride and removal by chlorides of Na, K, Cs, and nitrates of K, Na, Mg. Comparison with isotopic dilution  $^{133}\text{Ba}$ , and ammonium acetate saturation is also included in the same table.

- Effect of various extractants and different numbers of leachings in carbonate dissolution.

Chemicals: Calcium chloride . Sodium or potassium nitrate . Sodium and potassium nitrate.

Key Words: CEC / CALC. CARBONATE /

PAPA

Authors : POLEMIO (M) & RHOADES (J.D)  
 Title : Determining Cation Exchange Capacity : A new procedure for calcareous and gypsiferous soils.  
 Public : Soil Science Society of America Journal 41-3-1977.  
 Pages/ref: 523-528 / 23 ref.

Summary:

A two steps method for CEC is presented:

- First step: 4-5 gm of soil is treated by successive equilibrations with 33 ml increments of 0.4N NaOAC - 0.1N NaCl solution (at pH8.2 in 60% ethanol) to obtain saturation of cation exchange sites.
- The second step is the saturation with three 33 ml increments of 1N MgNO<sub>3</sub> (pH7). Chloride is used as index cation so that the soluble sodium may be counted for. Lower CEC values were obtained with the developed method, as compared with amonium acetate method (Bower).

As there is no absolute reference method for CEC, the values were correlated with saturation percentage and air-dry water content. The method is proposed for calcareous and gypsiferous soils, though it necessitates a preliminary washing out of soluble chlorides.

Tables : - Properties of soils and CEC as determined by the Bower & Al (1952) and the newly developed method.  
 - Relation between CEC and air-dry water content of soils.  
 - Comparison of CEC of soils as determined by the new and Bower methods.

Material : AA Spectrophotometer - Centrifuge .

Chemicals: Ethanol . NaOAC . NaCl . MgNO<sub>3</sub> .

Key Words: CEC / CALC. CARBONATE / GYPSUM /

POLE

Authors : PRATT (P.F) & GROVER (B.L)  
 Title : Monovalent - Divalent Cation Exchange Equilibria in Soils  
 in relation to organic matter and type of clay.  
 Public : Soil Science Society of America Proceedings. 26 - 1 - 1964  
 Page/ref : 32 - 35 / 11 ref.

Summary:

The cation exchange equilibria. Na - Ca, Li - Ca, Mg - Ca, ions pairs was studied on 10 slightly acid soils in relation to clay type (mostly montmorillonite and illite with always some kaolinite) but also amorphous material. The purpose was to find agreement between the double-layer equation and experimental data through a correction factor to be applied to surface charge density.

Correction factor are given as well as ratio of Na adsorbed to Ca adsorbed when soils were equilibrated with solutions having a  $(Na) / (Ca)^{1/2}$  ratio equal to 100, (concentration expressed in millimoles). Soil were equilibrated with solutions buffered at pH 7. At this SAR organic matter free soils with montmorillonite and illite as dominant clays had ratio Na / Ca (adsorbed) of 1,66 to 1,94. Equation relating exchangeable sodium percentage and SAR fit better soils poor in organic matter. Two different regression equations may be calculated (i) for montmorillonite-illite and (ii) for kaolinite and / or amorphous clays soils.

- Tables :- CEC , dominant minerals in the fine clay, clay content, and parent material for 10 soil samples used in cation exchange equilibria measurements.
- Relation between ratio of mono to divalent cation adsorption in the solid phase and in the liquid phase 3 ion pairs for each of 4 soils.
  - Relation between  $M^+ / M^{++}$  adsorbed and surface charge density for 10 soils for each of 3 ion pairs.
  - Na / Ca adsorbed ratio form solutions having a SAR equal to 100.
  - Relation between Na / Ca (adsorbed) and  $Na / (Ca)^{1/2}$  in solution for soil treated and untreated with sodium peroxide.

Chemicals: Not mentioned.

Key Words: EC - CEC / CLAY MINERALS /

PRATT

Authors : RHOADES (J.D) & KRUEGER (D.B)  
 Title : Extraction of cations from silicate minerals during the  
 determination of exchangeable cations in soils.  
 Public : Soil Science Society of America Proceedings Vol.32, 1968.  
 Pages/ref: 488-492 / 21 ref.

Summary:

The release of Ca, Mg, Na by silicate minerals during the process of EC determination by 1N, neutral, ammonium acetate was investigated on 15 standard minerals commonly found in arid zones. The CEC was determined by three methods namely: 1): NaOAC - ethanol -  $\text{NH}_4\text{OAC}$ . 2): NaOAC - ETOH -  $\text{Mg}(\text{OAC})_2$ . 3): radioactive Na. The samples being contaminated by carbonate, correction for dissolved calcite and/or magnesite is presented. The extent of cation extraction for the mineral type was: ortho-silicate, pyroxene, feldspathoid, amphiboles, plagioclase feldspars, K feldspars and the proportion of extracted cations was Ca, Mg, Na, K (both sequences in decreasing order of importance).

Conclusions: Determination of exchangeable sodium may be subject to errors under special condition (zeolitic, containing soils, pH above 9...). The problem of exchangeable Ca and Mg is more general and the release of these cations from minerals is a constant problem in the analysis of soils of arid zones.

Tables : 1-2 : Contamination of samples with carbonate (type, amount)  
 3-4-5: Cations extracted in neutral  $\text{NH}_4\text{OAC}$  and in neutral NaOAC (with and without correction for dissolved carbonates), and water.  
 6-7 : Apparent exchangeable cations and apparent CEC of the silicate minerals.

Chemicals: Ammonium acetate . Sodium acetate . Magnesium sulfate . Ethanol (excluding chemicals used in artificial sample preparation).

Key Words: ECEC / LABIL / CALC. SOILS / SALINITY /



Authors : ROUTSON (R.C) , WILDUNG (R.E) & SERNE (R.J)  
 Title : A column cation exchange capacity procedure for low  
 exchange capacity sands.  
 Public : Soil Science 115 - 2 - 1972.  
 Pages/ref: 107 - 112 / 11 ref.

Summary:

The procedure consists of saturating 0.5 to 2.5gr of soil with a mixture of strontium chloride and acetate (1M in Sr), then by 0.01N / 0.04N of the same mixture, traced with 5000 cpm/ml of radio strontium. Excess solution is removed by vacuum, the sample is washed by methanol - polyelectrolyte mixture. Concentration of Sr is measured in the final equilibration solution by AAS at 460,7 nm and 85 - strontium activity is determined by a gamma - analyzer fitted with a 8 cm NaI well crystal into which the soil column may be fitted directly.

The procedure is tested on calcareous sandy samples (1 to 26% calcium carbonate ; 1 to 5% clay) with CEC averaging 4 me / 100 gr.

Application: CEC for sandy soils around 4 me / 100 gr.

Tables : - Properties of four soil samples used in experiments (PH - clay - silt - calcium carbonate).  
 - Illustration of column system.  
 - Measured gamma activity in leaching column.  
 - Equilibration of soil with 85 Sr as related to leaching volume for sands, bentonite, kaolin and humic acid (50 micrograms each).  
 - Measured CEC as a function of the volume of wash solution.  
 - Comparison of proposed procedure with non washing procedure.

Material : AA Spectrophotometer . Gamma counting equipment .

Chemicals : Radio strontium chloride . Strontium acetate . Strontium chloride . Non ionic polyelectrolyte (Magnifloc 905) . Ascarite .

Key Words : CEC / CARBONATES / RADIO /





Authors : SHIELDS (L.G) & MEYER (M.W)  
 Title : Carbonate clay: Measurement and relationship to clay distribution and cation exchange capacity.  
 Public : Soil Sci. Soc. Am. Proc. 3, 28-1964.  
 Pages/ref: 416-419 / 6 ref.

Summary:

The clay-sized carbonate of soil is calculated by measuring the loss of  $\text{CO}_2$  from an aliquot of the clay suspension.

Method: To an aliquot of clay suspension 6N HCL is added. The loss of weight is measured. The values obtained may be corrected for any  $\text{Na}_2\text{CO}_3$  present in the dispersing solution. Eighty four samples were studied, six of them only had a clay-sized carbonate exceeding two-third of the total. Five kinds of possible clay percentage calculations for calcareous materials were discussed: 1) total clay calculated percentage. 2) clay-sized carbonate. 3-4) true clay as a percentage of total soil and carbonate free soil. 5) measured true clay as a percentage of soil after removal of carbonates by NaOAC treatment.

CEC of 28 samples ( $\text{CaCO}_3\%$  10 to 25), as measured after removal of carbonates by NaOAc pH5 and CEC calculated on a carbonate-free soil basis were nearly equal showing that clay-sized carbonate has no exchange capacity.

Tables/Figures:

- 1 : Tot. carbonate vs clay-sized carbonate for 84 soil samples.
- 2-3-4: Clay depth distribution curve for total clay and non carbonate clay/ different kinds of clay percentages / CEC and carbonate values of a profiles containing 8 horizons / .

Key Words:  $\text{CaCO}_3$  / CLAY / CEC / PARTICLE SIZE /

Authors : SMART (R. ST. C) , THOMAS (A.D) & DROVER (D.P)  
 Title : Selective ion electrode measurements of chloride concentrations  
 in the determination of cation exchange capacities of soils.  
 Public : Communication in Soil Science and Plant Analysis 5-1-1974.  
 Pages/ref: 1-11 / 5 ref.

Summary:

Comparison of two procedures for the determination of chloride ions. The first method was electrometric titration using a quinhydrone silver-silver chloride electrodes and silver nitrate as titrant. The second method used an Cl selective ion electrode connected to an PH-ion meter calibrated against standards of known chloride ion concentration (1, 10 and mM in equimolar sodium chloride, sodium sulfate solution 0.5M solution).

The possibility of applying the method to measurement of CEC in soils using ammonium chloride was investigated.

Method: For CEC determination, soil was leached with 1N ammonium chloride, fixed ammonium was displaced by 0.5M sodium sulfate. CEC is proportional to ammonium ion in sodium sulfate provided excess ammonium is corrected for by measuring chloride as index ion the method is not suitable for saline soils. Soil samples investigated had PH5 to 6.6. Interference of ammonia was shown. Calibration of electrode with ammonium chloride instead of sodium chloride reduced ammonia interference to 5% at ammonium concentration less than 20 millimoles. Application of systematic activity coefficient (0.75) for index chloride ion in extracts gave results within  $\pm 7\%$  in all cases.

Tables : Comparison of Ion Selective Electrode and titration method for 12 CEC leachates.

Material : 1. Titration method: Quinhydrone electrode . Silver-silver chloride electrode . Null point galvanometer (or potentiometric recorder).  
 2. Selective electrode: Chloride selective electrode . PH-ionmeter.

Chemicals: Ethanol . Ammonium chloride . Ammonia . Sodium sulfate . Sodium chloride . Silver nitrate .

Key Words: CHLORIDE / AMONIUM / CEC / SOILS / ELEC /

SMAR

Authors : SMITH (H.W) , MOODIE (C.D) , OKAZAKI (Rose) & ELLSWORTH Norma  
 Title : Hydrolysis and salt retention errors in conventional cation  
 exchange capacity procedures: II.  
 Public : Soil Science 102 - 2 - 1966.

Summary:

Salt removal and index-cation hydrolysis during CEC measurement were studied with emphasis upon the effect of washing liquid. The reference method choosed was the measure of the net charge (extractable index cation minus extrac. anion) which is equal to CEC for the sample studies. Four index cations (Na, Ca,  $\text{NH}_4$  , Ba) were used and gave good agreement as for CEC values. Effect of washing was studied with ETOH, 95% MEOH, isopropanol, and distilled water. For the sample studied, salt retention was the most difficult problem to control, index cation hydrolysis was not serious and loss of sample by dispersion was eliminated by high speed centrifuging. Removal of  $\text{NH}_4\text{OAc}$ , isopropanol was inadequate, methanol and ethanol were less efficient than water. Two of the studied samples contained amorphous material as major clay component, the third once was montmorillonitic. All of them were neutral samples.

Tables : 1-2 : Properties of samples. CEC (net charge) determined with different index cations on three soils (CEC 10, 14, 99 meq/100 gr respectively).  
 3-4-5: Apparent CEC of samples vs extent and technique of washing.  
 6 : CEC determined by several washing procedure vs reference CEC.  
 7-8-9: Effect of isopropanol washing.

Chemicals:  $\text{NaOAc}$  .  $\text{NH}_4\text{OAc}$  .  $\text{NH}_4\text{Cl}$  . Isopropanol . Ethanol . Methanol .

Key Words: CEC

SMIT

Title : Soil Survey Laboratory methods and procedures for collecting soil samples.  
 Public : USDA - Soil Conservation Service, Soil Survey Investigation Dep. No.1, 1972.  
 Pages/ref: 22-35 / 4 ref.

Summary:

Three procedures for cation exchange capacity (CEC) are described: a)  $\text{NH}_4\text{OAc}$  pH7 , washing with 95% ETOH direct distillation of ammonia; this method is suitable for exchangeable cations (EC) and CEC .  
 b)  $\text{NaOAc}$  pH 8.2 , washing with 95% ETOH, replacement by  $\text{NH}_4\text{OAc}$ . CEC is directly calculated from the quantity of Na replaced. c)  $\text{BaCl}_2$  - triethanolamine pH8.2, washing with methanol, replacement by  $\text{Mg}(\text{NO}_3)_2$  solution. This method gives extractable acidity and CEC. Extractable bases are presumed to be equal to the exchangeable bases if the sample does not contain soluble salts. If it does, the amount of soluble salts is calculated from the saturation extract; except in the case of soils containing carbonates.

Chemicals: Method a) Ammonia . Acetic acid . ETOH Neesler's reagent . Boric acid . Methylene blue . Bromocresol green .  $\text{H}_2\text{SO}_4$  .  
 Method b) ETOH . Acetic acid . Sodium hydroxide . Ammonia .  
 Method c) MeOH . Barium chloride . Triethanolamine . Magnesium nitrate .

Key Words: EC - CEC /

Author : TUCKER (B.M)  
Title : Laboratory procedures for cation exchange measurements of soils.  
Public : CSIRO Div. of Soil, Tech. Paper No.23, 1974.  
Pages/ref: 1-46 / 25 ref.

Summary:

The paper gives full details on EC extraction and CEC estimation after removal of soluble salts. The procedure is essentially the following:

- Soluble salts are removed by an ethylene-glycol / ethanol mixture (preably passed though mixed-bed resin to remove ions).
- Basic exchangeable cations are extracted by pH 8.5  $\text{NH}_4\text{Cl}$ /60% ETOH.
- CEC replacement step is made by a 15%  $\text{KNO}_3$ , 6%  $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$  solution.

Equipment is reviewed for leaching procedure and extraction-centrifuge method as well. A so called flaming solution is used in AAS to eliminate interferences in Ca and Mg determination. Removal of soluble ions, alternative reagent for displacing amonium and AAS interferences are reviewed.

Tables :- 14 tables covering results of each analytical parameter involved in the described procedures.  
- Description of extracting machine and leaching device.

Material : AA Spectrophotometer . Leaching equipment . Soil shaker . Extractor .

Chemicals: 1-2 ethanediol . ETOH . Mixed-bed ion exchange resin .  $\text{NH}_4\text{Cl}$  .  $\text{KNO}_3$  .  $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$  . Formaldehyde . Methanol . Acetone .  
Flaming solution:  $\text{LiCl}$  . Tween 80 . Isopropanol . Perchloric acid . Urea .

Key Words: CEC / SALINITY / AAS-PRECISION /

TUCK