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Appendices

Appendix A

METALS BY ATOMIC ABSORPTION SPECTROMETRY* (Method 3110)

Because requirements for determining metals by atomic absorption spectrometry vary with metal and/or concentration to be determined, the method is presented as follows:

Section 3111, metals by Flame atomic Absorption Spectrometry, encompasses:

- Determination of antimony, bismuth, cadmium, calcium, cesium, chromium, cobalt, copper, gold, iridium, iron, lead, lithium, magnesium, manganese, nickel, palladium, potassium, rhodium, ruthenium, silver, strontium, thallium, tin, and zinc by direct aspiration into an air-acetylene flame (3111B).

- Determination of low concentrations of cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, silver, and zinc by chelation with ammonium pyrrolidine dithiocarbamate (APDC), extraction into methyl isobutyl ketone (MIBK), and aspiration into an air-acetylene flame (3111C)

- determination of aluminum, barium, beryllium, molybdenum, osmium, rhenium, silicon, thorium, titanium, and vanadium by direct aspiration into a nitrous oxide-acetylene flame (3111D) and

- Determination of low concentrations of aluminum and beryllium by chelation with 8-hydroxyquinoline, extraction into MIBK, and aspiration into a nitrous oxide-acetylene flame (3111E).

Section 3112 covers determination of mercury by the cold vapor technique.

Section 3113 concerns determination of micro quantities of aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum. Nickel, selenium, silver, and tin by electrothermal atomic absorption spectrometry.

Section 3114 covers determination of arsenic and selenium by conversion to their hydrides and aspiration into an argon-hydrogen or nitrogen-hydrogen flame.

* Approval by Standard Methods Committee, 1988.

METALS BY FLAME ATOMIC ABSORPTION SPECTROMETRY*

(Method 3111)

Introduction

1. Principle

Atomic absorption spectrometry resembles emission flame photometry in that a sample is aspirated into a flame and atomized. The major difference is that in flame photometry the amount of light emitted is measured, whereas in atomic absorption spectrometry a light beam is directed through the flame, into a monochromator, and onto a detector that measures the amount of light absorbed by the atomized element in the flame. For some metal, atomic absorption exhibits superior sensitivity over flame emission. Because each metal has its own characteristic absorption wavelength, a source lamp composed of that element is used; this makes the method relatively free from spectral or radiation interferences. The amount of energy at the characteristic wavelength absorbed in the flame is proportional to concentration of the element in the sample over a limited concentration range. Most atomic absorption instruments also are equipped for operation in an emission mode.

2. Section of Method

See Section 3110

3. Interferences

a. Chemical interference: Many metals can be determined by direct aspiration of sample into an air-acetylene flame. The most troublesome type of interference is termed “chemical” and results from the lack of absorption by atoms bound in molecular combination in the flame. This can occur when the flame is not hot enough to dissociate the molecules or when the dissociated atom is oxidized immediately to a compound that will not dissociate further at the flame temperature. Such interferences may be reduced or eliminated by adding specific elements or compounds to the sample solution. For example, the interference of phosphate in the magnesium determination can be overcome by adding lanthanum. Similarly,

introduction of calcium eliminates silica interference in the determination of manganese. However, silicon and metals such as aluminum, barium, beryllium, and vanadium require the higher-temperature, nitrous oxide-acetylene flame to dissociate their molecules. The nitrous oxide-acetylene flame also can be useful in minimizing certain types of chemical interferences encountered in the air-acetylene flame. For example, the interference caused by high concentrations of phosphate in the determination of calcium in the air-acetylene flame does not occur in the nitrous oxide-acetylene flame.

Brines and seawater can be analyzed by direct aspiration but sample dilution is recommended. Aspiration of solutions containing high concentrations of dissolved solids often results in solids buildup on the burner head. This requires frequent shut-down of the flame and cleaning of the burner head. Preferably use background correction when analyzing waters that contain in excess of 1% solids, especially when the primary resonance line of the element of interest is below 240 nm. Make more frequent recovery checks when analyzing brines and seawaters to insure accurate results in these concentrated and complex matrices.

b. Background correction: Molecular absorption and light scattering caused by solid particles in the flame can cause erroneously high absorption values resulting in positive errors. When such phenomena occur, use background correction to obtain accurate values. Use any one of three types of background correction: continuum-source, Zeeman, or Smith-Hieftje correction.

1) Continuum-source background correction—A continuum source background corrector utilizes either a hydrogen-filled hollow cathode lamp with a metal cathode or a deuterium arc lamp. When both the line source hollow-cathode lamp and the continuum source are placed in the same optical path and are timeshared, the broadband background from the elemental signal is subtracted electronically, and the resultant signal will be background-compensated.

Both the hydrogen-filled hollow-cathode lamp and deuterium arc lamp have lower intensities than either the line source hollow cathode lamp or electrodeless discharge lamps. To obtain a valid correction, match the intensities of the continuum source with the line source hollow-cathode or electrodeless discharge lamp. The matching may result in lowering the intensity of the line source or increasing the slit width; these measures have the disadvantage of raising the detection limit and possibly causing nonlinearity of the calibration curve. Background correction using a

continuum source corrector is susceptible to interference from other absorption lines in the spectral bandwidth. Miscorrection occurs from significant atomic absorption of the continuum source radiation by elements other than that being determined. When a line source hollow-cathode lamp is used without background correction, the presence of an absorbing line from another element in the spectral bandwidth will not cause an interference unless it overlaps the line of interest.

Continuum-source background correction will not remove direct absorption spectral overlap, where an element other than that being determined is capable of absorbing the line radiation of the element under study.

2) Zeeman background correction—This correction is based on the principle that a magnetic field splits the spectral line into two linearly polarized light beams parallel and perpendicular to the magnetic field. One is called the pi (π) component and the other the sigma (σ) component. These two light beams have exactly the same wavelength and differ only in the plane of polarization. The π line will be absorbed by both the atoms of the element of interest and by the background caused by broadband absorption and light scattering of the sample matrix. The σ line will be absorbed only by the background.

Zeeman background correction provides accurate background correction at much higher absorption levels than is possible with continuum source background correction systems. It also virtually eliminates the possibility of error from structured background. Because no additional light sources are required, the alignment and intensity limitations encountered using continuum sources are eliminated.

Disadvantages of the Zeeman method include reduced sensitivity for some elements, reduced linear range, and a “rollover” effect whereby the absorbance of some elements begins to decrease at high concentrations, resulting in a two-sided calibration curve.

3) Smith-Hieftje background correction—This correction is based on the principle that absorbance measured for a specific element is reduced as the current to the hollow cathode lamp is increased while absorption of nonspecific absorbing substances remains identical at all current levels. When this method is applied, the absorbance at a high-current mode is subtracted from the absorbance at a low-current mode. Under these conditions, any absorbance due to nonspecific background is subtracted out and corrected for.

Smith-Hieftje background correction provides a number of advantages over continuum-source correction. Accurate correction at higher absorbance levels is possible and error from structured background is virtually eliminated. In some cases, spectral interferences also can be eliminated. The usefulness of Smith-Hieftje background correction with electrodeless discharge lamps has not yet been established.

FLAME ATOMIC ABSORPTION SPECTROMETRY (3111)/Introduction

4. Sensitivity, Detection Limits, and Optimum Concentration Ranges

The sensitivity of flame atomic absorption spectrometry is defined as the metal concentration that produces an absorption of 1% (an absorbance of approximately 0.0044). The instrument detection limit is defined here as the concentration that produces absorption equivalent to twice the magnitude of the background fluctuation. Sensitivity and detection limits vary with the instrument, the element determined, the complexity of the matrix, and the technique selected. The optimum concentration range usually starts from the concentration of several times the sensitivity and extends to the concentration at which the calibration curve starts to flatten. To achieve best results, use concentrations of samples and standards within the optimum concentration range of the spectrometer. See Table 3111:1 for indication of concentration ranges measurable with conventional atomization. In many instances the concentration range shown in Table 3111:1 may be extended downward either by scale expansion or by integrating the absorption signal over a long time. The range may be extended upward by dilution, using a less sensitive wavelength, rotating the burner head, or utilizing a microprocessor to linearize the calibration curve at high concentrations.

5. Preparation of Standards

Prepare standard solution of known concentrations in water with a matrix similar to the sample. Use standards that bracket expected sample concentration and are within the method's working range. Very dilute standards should be prepared daily from stock solutions in concentrations greater than 500 mg/L. Stock standard solution can be obtained from several commercial sources. They also can be prepared from National Institute of Standards and Technology (NIST, formerly National

Bureau of Standards) reference materials or by procedures outlined in the following sections.

For samples containing high and variable concentrations of matrix materials, make the major ions in the sample and the dilute standard similar. If the sample matrix is complex and components cannot be matched accurately with standards, use the method of standard additions, to correct for matrix effects. If digestion is used, carry standard through the same digestion procedure used for samples.

6. Apparatus

a. Atomic absorption spectrometer, consisting of a light source emitting the line spectrum of an element (hollow-cathode lamp or electrodeless discharge lamp), a device for vaporizing the sample (usually a flame), a means of isolating an absorption line (monochromator or filter and adjustable slit), and a photoelectric detector with its associated electronic amplifying and measuring equipment.

b. Burner: The most common type of burner is a premix, which introduces the spray into a condensing chamber for removal of large droplets. The burner may be fitted with a conventional head containing a single slot: a three-slot Belling head, which may be preferred for direct aspiration with an air-acetylene flame; or a special head for use with nitrous oxide and acetylene.

TABLE 3111:1 ATOMIC ABSORPTION CONCENTRATION RANGES WITH DIRECT ASPIRATION ATOMIC ABSORPTION

Element	Wavelength nm	Flame Gases*	Instrument Detection Limit mg/L	Sensitivity mg/l	Optimum Concentration Range mg/l
Ag	328.1	A-Ac	0.01	0.06	0.1-4
Al	309.3	N-Ac	0.1	1	5-100
Au	242.8	A-Ac	0.01	0.25	0.5-20
Ba	553.6	N-Ac	0.03	0.4	1-20
Be	234.9	N-Ac	0.005	0.03	0.05-2
Bi	223.1	A-Ac	0.06	0.4	1-50
Ca	422.7	A-Ac	0.003	0.08	0.2-20
Cd	228.8	A-Ac	0.002	0.025	0.05-2
Co	240.7	A-Ac	0.03	0.2	0.5-10
Cr	357.9	A-Ac	0.02	0.1	0.2-10
Cs	852.1	A-Ac	0.02	0.3	0.5-15
Cu	324.7	A-Ac	0.01	0.1	0.2-10
Fe	248.3	A-Ac	0.02	0.12	0.3-10
Ir	264.0	A-Ac	0.6	8	-
K	766.5	A-Ac	0.005	0.04	0.1-2
Li	670.8	A-Ac	0.002	0.04	0.1-2
Mg	285.2	A-Ac	0.0005	0.007	0.02-2
Mn	279.5	A-Ac	0.01	0.05	0.1-10
Mo	313.3	N-Ac	0.1	0.5	1-20
Na	589.0	A-Ac	0.002	0.015	0.03-1
Ni	232.0	A-Ac	0.02	0.15	0.3-10
Os	290.9	A-Ac	0.08	1	-
Pb+	283.3	A-Ac	0.05	0.5	1-20
Pt	265.9	A-Ac	0.1	2	5-75
Rh	343.5	A-Ac	0.5	0.3	-
Ru	349.9	A-Ac	0.07	0.5	-
Sb	217.6	A-Ac	0.07	0.5	1.40
Si	251.6	N-Ac	0.3	2	5-150
Sn	224.6	A-Ac	0.8	4	10-200
Sr	460.7	A-Ac	0.03	0.15	0.3-5
Ti	365.3	N-Ac	0.3	2	5-100
V	318.4	N-Ac	0.2	1.5	2-100
Zn	243.9	A-Ac	0.005	0.02	0.05-2

* A-Ac = nitrous oxide-acetylene..

+ The more sensitive 217.0 nm wavelength is recommended for instruments with background correction capabilities.

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c. *Readout*: Most instruments are equipped with either a digital or null meter readout mechanism. Most modern instruments are equipped with microprocessors capable of integrating absorption signals over time and linearizing the calibration curve at high concentrations.

d. *Lamps*: Use either a hollow-cathode lamp or an electrodeless discharge lamp (EDL). Use one lamp for each element being measured. Multi-element hollow-cathode lamps generally provide lower sensitivity than single-element lamps. EDLs take a longer time to warm up and stabilize.

e. *Pressure-reducing valves*: Maintain supplies of fuel and oxidant at pressured somewhat higher than the controlled operating pressure of the instrument by using suitable reducing valves. Use a separate reducing valve for each gas.

f. *Vent*: Place a vent about 15 to 30 cm above the burner to remove fumes and vapors from the flame. This precaution protects laboratory personnel from toxic vapors, protects the instrument from corrosive vapors, and prevents flame stability from being affected by room drafts. A damper or variable-speed blower size to provide the air flow recommended by the instrument manufacturer. In laboratory locations with heavy particulate air pollution, use clean laboratory facilities.

7. Quality Assurance/Quality Control

Some data typical of the precision and bias obtainable with the methods discussed are presented in Tables 3111:II and III.

Analyze a blank between sample or standard readings to verify baseline stability. Rezero when necessary.

To one sample out of every ten (or one sample from each group of samples if less than ten are being analyzed) add a known amount of the metal of interest and reanalyze to confirm recovery. The amount of metal added should be approximately equal to the amount found. If little metal is present add an amount close to the middle of the linear range of the test. Recovery of added metal should be between 85 and 115%.

Analyze an additional standard solution after every ten samples or with each batch of samples, whichever is less, to confirm that the test is in control. Recommended concentrations of standards to be run, limits of acceptability, and reported single-operator precision data are listed in Table 3111:III

TABLE 3111:III INTERLABORATORY PRECISION AND BLAS DATA FOR
 ATOMIC ABSORPTION METHODS—DIRECT ASPIRATION AND
 EXTRACTED METALS

Metal	Conc. mg/L	SD mg/L	Relative SD %	Relative Error %	No. of Participants
Direct determination:					
Aluminum ¹	4.50	0.19	4.2	8.4	5
Barium ²	1.00	0.089	8.9	2.7	11
Beryllium ¹	0.46	0.0213	4.6	23.0	11
Cadmium ³	0.05	0.0108	21.6	8.2	26
Cadmium ¹	1.60	0.11	6.9	5.1	16
Calcium ¹	5.00	0.21	4.2	0.4	8
Chromium ¹	3.00	0.301	10.0	3.7	9
Cobalt ¹	4.00	0.243	6.1	0.5	14
Copper ³	1.00	0.112	11.2	3.4	53
Copper ¹	4.00	0.331	8.3	2.8	15
Iron ¹	4.40	0.260	5.8	2.3	16
Iron ³	0.30	0.0495	16.5	0.6	43
Lead ¹	6.00	0.8	4.7	0.2	14
Magnesium ³	0.20	0.021	10.5	6.3	42
Magnesium ¹	1.10	0.116	10.5	10.0	8
Manganese ¹	4.05	0.317	7.8	1.3	16
Manganese ³	0.05	0.0068	13.5	6.0	14
Nickel ¹	3.93	0.383	9.8	2.0	14
Silver ³	0.05	0.0088	17.5	10.6	7
Silver ¹	2.00	0.07	3.5	1.0	10
Sodium ¹	2.70	0.122	4.5	4.1	12
Strontium ¹	1.00	0.05	5.0	0.2	12
Zinc ³	0.50	0.041	8.2	0.4	48
Extracted determination:					
Aluminum ²	300	32	10.7	0.7	15
Beryllium ²	5	1.7	34.0	20.0	9
Cadmium ³	50	21.9	43.8	13.3	12
Cobalt ¹	300	28.5	9.5	1.0	6
Copper ¹	100	71.7	71.7	12.0	8
Iron ¹	250	19.0	7.6	3.6	4
Manganese ¹	21.5	2.4	11.2	7.4	8
Molybdenum ¹	9.5	1.1	11.6	1.3	5
Nickel ¹	56.8	15.2	26.8	13.6	14
Lead ³	50	11.8	23.5	19.0	8
Silver ¹	5.2	1.4	26.9	3.0	7

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FLAME ATOMIC ABSORPTION SPECTROMETRY (3111)/ Direct Air-Acetylene
Flame Method

TABLE 3111:III SINGLE-OPERATOR PRECISION AND RECOMMENDED
CONTROL RANGES FOR ABSORPTION METHODS—DIRECT ASPIRATION
AND EXTRACTED METALS

Metal	Con	SD	Relative	No. of	QC	Acceptable Range
	c. mg/ L	mg/L	SD %	Participan ts	Std. mg/ L	
Direct						
determination:						
Aluminum ¹	4.50	0.23	5.1	15	5.00	4.3-5.7
Beryllium ¹	0.46	0.012	2.6	10	0.50	0.46-0.54
Calcium ¹	5.00	0.05	1.0	8	5.00	4.8-5.2
Chromium ¹	7.00	0.69	9.9	9	5.00	3.3-6.7
Cobalt ¹	4.00	0.21	5.3	14	4.00	3.4-4.6
Copper ¹	4.0	0.115	2.9	15	4.00	3.7-4.3
Iron ¹	5.00	0.19	3.8	16	5.00	4.4-5.6
Magnesium ¹	1.00	0.009	0.9	8	1.00	0.97-1.03
Nickel ⁴	5.00	0.04	0.8	-	5.00	4.9-5.1
Siler ¹	2.00	0.25	12.5	10	2.00	1.2-2.8
Sodium ⁴	8.2	0.1	1.2	-	5.00	4.8-5.2
Strontium ⁴	1.00	0.04	4.0	12	1.00	0.87-1.13
Potassium ⁴	1.6	0.2	12.5	-	1.6	1.0-2.2
Molybdenum ⁴	7.5	0.07	0.9	-	10.0	9.7-10.3
Tin ⁴	20.0	0.5	2.5	-	20.0	18.5-21.5
Titanium ⁴	50.0	0.4	0.8	-	50.0	48.8-51.2
Vanadium	50.0	0.2	0.4	-	50.0	49.4-50.6
Extracted						
determination:						
Aluminum ¹	300	12	4.0	15	300	264-336
Cobalt ¹	300	20	6.7	6	300	220-380
Copper ¹	100	21	21	8	100	22-178
Iron ¹	250	12	4.8	4	250	180-320
Manganese ¹	21.5	202	10.2	8	25	17.23
Molybdenum ¹	9.5	1.0	10.5	8	10	5.5-14.5
Nickel ¹	56.8	9.2	16.2	14	50	22-78
Silver ¹	5.2	1.2	23.1	7	5.0	0.5-9.5

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Direct Air-Acetylene Flame Method (Method 3111B)

1. General Discussion

This method is applicable to the determination of antimony, bismuth, cadmium, calcium, cesium, chromium, cobalt, copper, gold, iridium, iron, lead, lithium, magnesium, manganese, nickel, palladium, platinum, potassium, rhodium, ruthenium, silver, sodium, strontium, thallium, tin, and zinc.

2. Apparatus

Atomic absorption spectrometer and associated equipment: See Section 311A.6. Use burner head recommended by the manufacturer.

3. Reagents

a. *Air*, cleaned dried through a suitable filter to remove oil, water, and other foreign substances. The source may be a compressor or commercially bottled gas.

b. *Acetylene*, standard commercial grade. Acetone, which always is present in acetylene cylinders, can be prevented from entering and damaging the burner head by replacing a cylinder when its pressure has fallen to 689 kPa (100 psi) acetylene.

c. *Metal-free water:* Use metal-free water for preparing all reagents and calibration standard and as dilution water. Prepare metal-free water by deionizing tap water and/or by using one of the following processes, depending on the metal concentration in the sample: single distillation, redistillation, or sub-boiling. Always check deionized or distilled water to determine whether the element of interest is present in trace amounts. (NOTE: *If the source water contains Hg or other volatile metals, single-or redistilled water may not be suitable for trace analysis because these metals distill over with the distilled water. In such cases, use sub-boiling to prepare metal-free water.*)

d. *Calcium solution:* Dissolve 630 mg calcium carbonate, CaCO_3 , in 50 mL of 1 + 5 HCl. If necessary, boil gently to obtain complete solution, Cool and dilute to 1000 mL with water.

e. *Hydrochloric acid*, HCl, 1%, 10%, 20%, 1 + 5, 1 + 1, and cone.

CALCIUM* (Method 3500)

Introduction

1. Occurrence and Significance

The presence of calcium (fifth among the elements in order of abundance) in water supplies results from passage through or over deposits of limestone, dolomite, gypsum, and gypsiferous shale. The calcium content may range from zero to several hundred milligrams per liter, depending on the source and treatment of the water. Small concentrations of calcium carbonate combat corrosion of metal pipes by laying down a protective coating. Appreciable calcium salts, on the other hand, precipitate on heating to form harmful scale in boilers, pipes, and cooking utensils. Calcium carbonate saturation is discussed in Section 2330.

*Approved by Standard Methods Committee, 1991

2. Selection of Method

The atomic absorption method and inductively coupled plasma method are accurate means of determining calcium. The EDTA titration method gives good results for control and routine applications. For samples containing high P levels (>50mg/L) only Methods B and C are recommended because of interferences with the EDTA method using most of the cited indicators.

3. Storage of Samples

The customary precautions are sufficient if care is taken to redissolve any calcium carbonate that may precipitate on standing.

Atomic Absorption Spectrometric Method (Method 3500B)

See flame atomic absorption spectrometric method, Section 3111B.

CHROMIUM* (Method 3500)

Introduction

1. Occurrence

The hexavalent chromium concentration of U.S. drinking waters has been reported to vary between 3 and 40 $\mu\text{g/L}$, with a mean of 3.2 $\mu\text{g/L}$. Chromium salts are used extensively in industrial processes and may enter a water supply through the discharge of wastes. Chromate compounds frequently are added to cooling water for corrosion control. Chromium may exist in water supplies in both the hexavalent and the trivalent state although the trivalent form rarely occurs in potable water.

2. Selection of Method

Use the colorimetric method for the determination of hexavalent chromium in a natural or treated water intended to be potable. Use the electrothermal (graphite furnace) atomic absorption spectrometric method for determination of low levels of total chromium ($<50 \mu\text{g/L}$) in water and wastewater. Use the flame atomic absorption spectrometric method or the inductively coupled plasma method to measure concentration up to milligram-per-liter levels.

3. Sample Handling

If only the dissolved metal content is desired, filter sample through a 0.45 μm membrane filter at the time of collection. After filtration acidify filtrate with conc nitric acid (HNO_3) to $\text{pH} < 2$. If the total chromium content is desired, acidify unfiltered sample at time of collection with conc HNO_3 to $\text{pH} < 2$.

Atomic Absorption Method for Total Chromium (Method 3500B)

See flame atomic absorption spectrometric method, Sections, 3111B.

MAGNESIUM* (Method 3500)

Introduction

1. Occurrence

Magnesium ranks eighth among the elements in order of abundance and is a common constituent of natural water. Important contributors to the hardness of a water, magnesium salts break down when heated, forming scale in boilers. Concentrations greater than 125 mg/L, also can have a cathartic and diuretic effect. Chemical softening, reverse osmosis, electrodialysis, or ion exchange reduces the magnesium and associated hardness to acceptable levels. The magnesium concentration may vary from zero to several hundred milligrams per liter, depending on the source and treatment of the water.

* Approved by Standard Methods Committee, 1990

2. Selection of Method

The four methods presented are applicable to all natural waters. Direct determinations can be made with the atomic absorption spectrometric and inductively coupled plasma methods. Magnesium can be determined by the gravimetric method only after removal of calcium salts (see Section 3500-Ca). These methods can be applied to all concentrations by selection of suitable sample portions. Choice of method is largely a matter of personal preference and analyst experience.

Atomic Absorption Spectrometric Method (Method 3500B)

See flame atomic absorption spectrometric method, Section 3111B.

SODIUM* (Method 3500)

3500-Na A. Introduction

1. Occurrence

Sodium ranks sixth among the elements in order of abundance and is present in most natural waters. The levels may vary from less than 1 mg Na/L to more than 500 mg Na/L. Relatively high concentrations may be found in brines and hard waters softened by the sodium exchange process. The ratio of sodium to total cations is important in agriculture and human pathology. Soil permeability can be harmed by a high sodium ratio. Persons afflicted with certain diseases require water with low sodium concentration. A limiting concentration of 2 to 3 mg/L is recommended in feedwaters destined for high-pressure boilers. When necessary, sodium can be removed by the hydrogen-exchange process or by distillation.

* Approved by Standards committee. 1990.

2. Selection of Method

Method B uses an atomic absorption spectrometer in the flame absorption mode. Method C uses inductively coupled plasma; this method is not as sensitive as the other methods, but usually this is not an important factor. Method D uses either a flame photometer or an atomic absorption spectrometer in the flame emission mode. When all of these instruments are available, the choice will depend on factors including relative quality of the instruments, precision and sensitivity required, number of samples, matrix effects and relative ease of instrument operation. If an atomic absorption spectrometer is used, operation in the emission mode is preferred.

3. Storage of Sample

Store alkaline samples or samples containing low sodium concentrations in polyethylene bottles to eliminate the possibility of sample contamination due to leaching of the glass container.

Appendix B



Figure B.1 Raw hide.



Figure B.2 Pickling Process.



Figure B.3 Trimming and decorating before Chrome tanning.

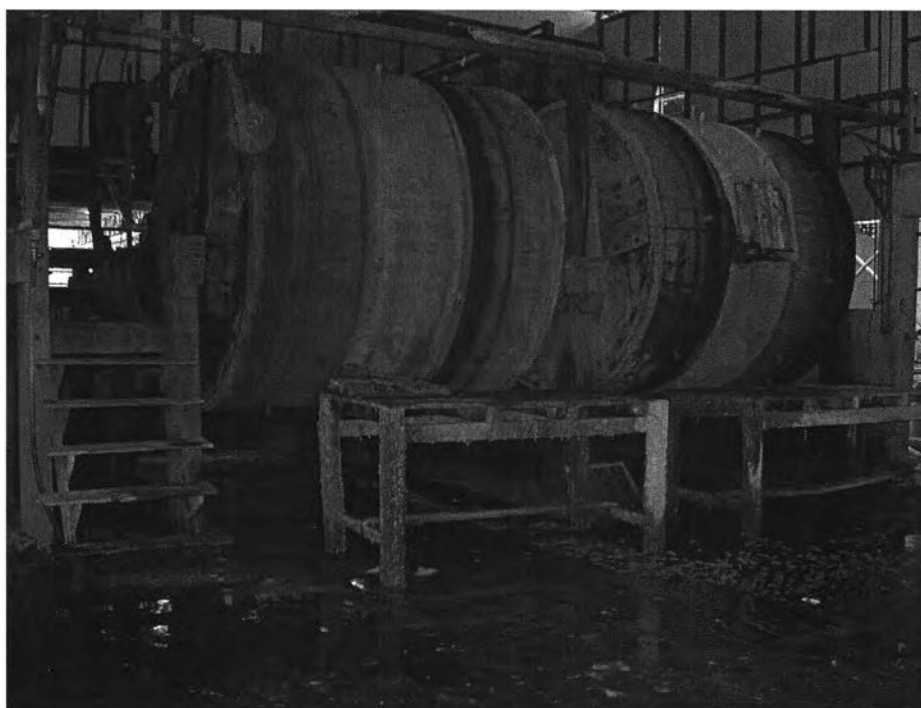


Figure B.4 Chrome tanning drum.



Figure B.5 Saline groundwater from Bandung District, Udon Thani Province before evaporation.

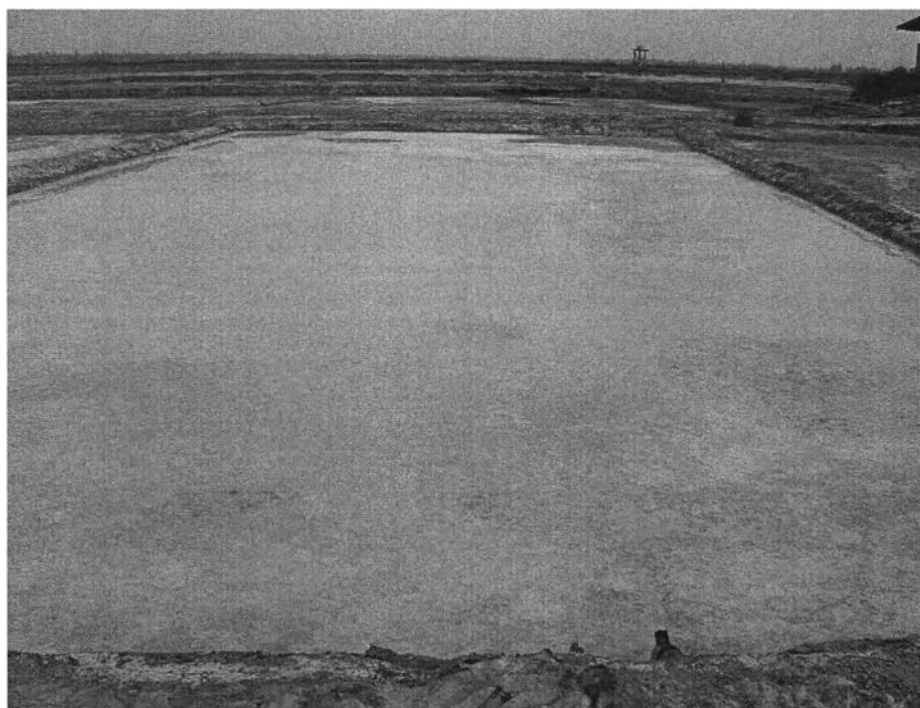


Figure B.6 Saline groundwater from Bandung District, Udon Thani Province after evaporation.

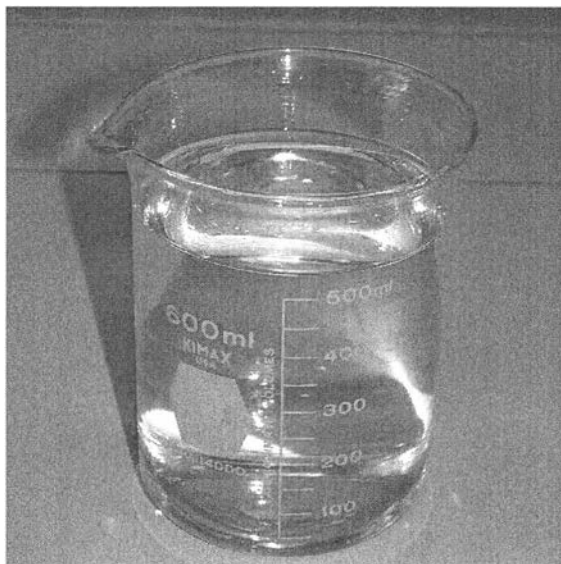


Figure B.7 Saline groundwater before adding NaOH.

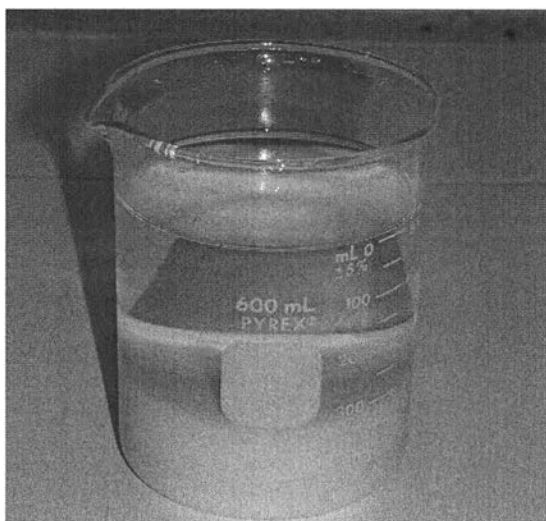
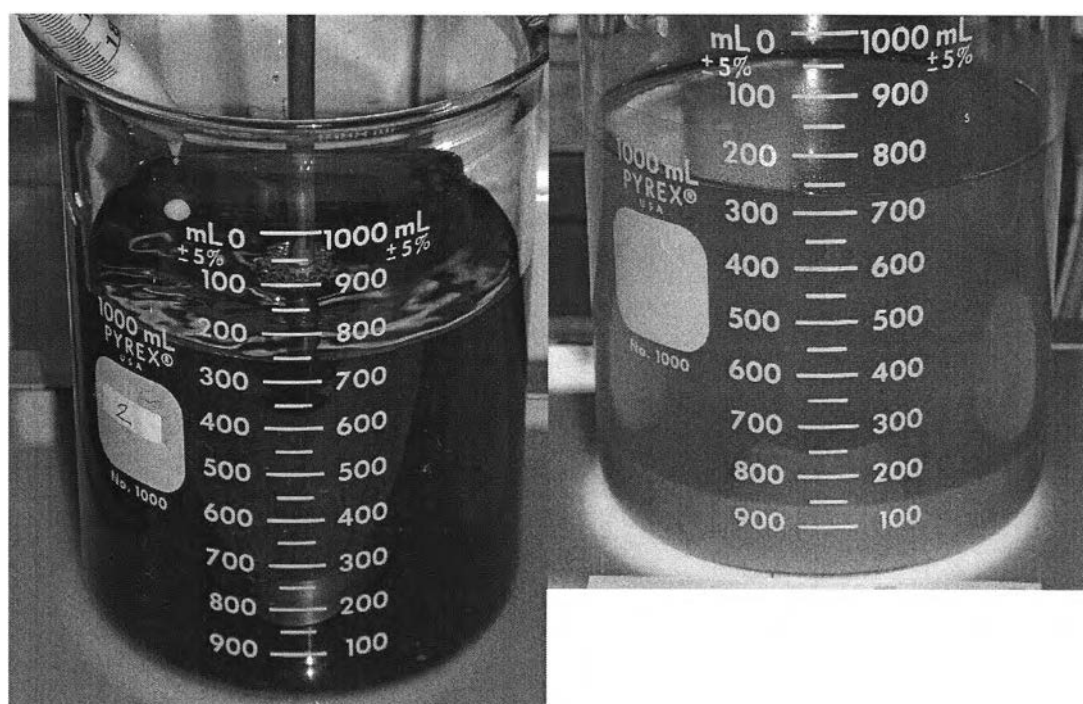


Figure B.8 Saline groundwater after adding NaOH.



Figure B.9 Jar test experiment.



Before adding white slurry.

After adding white slurry.

Figure B.10 Jar test experiment.

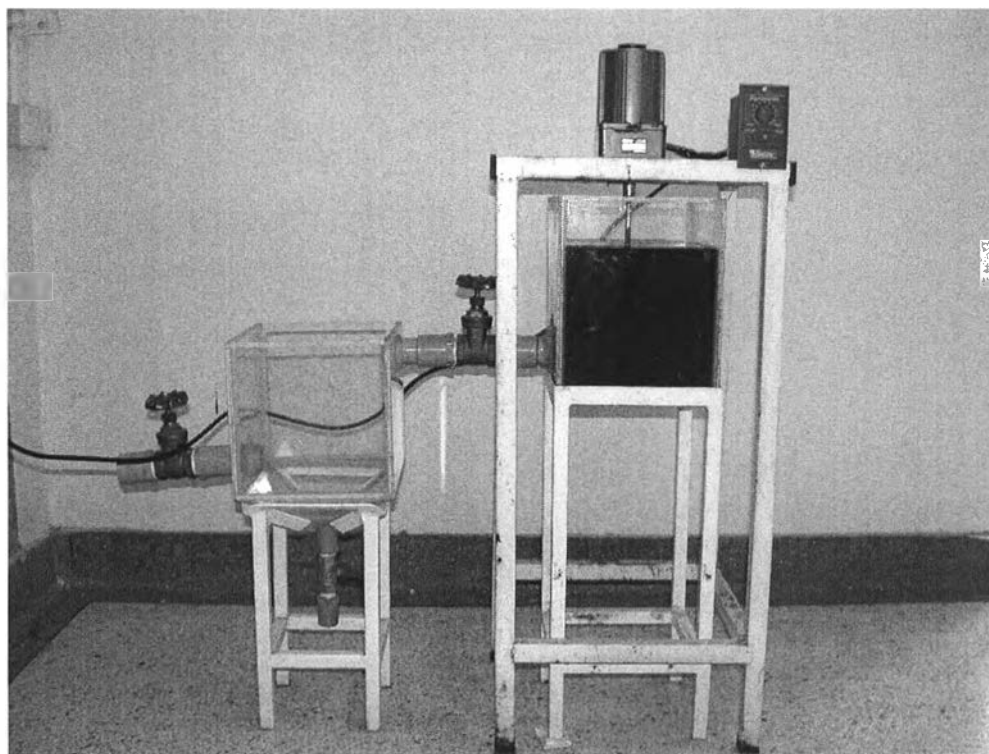


Figure B.11 Model scale reactor.

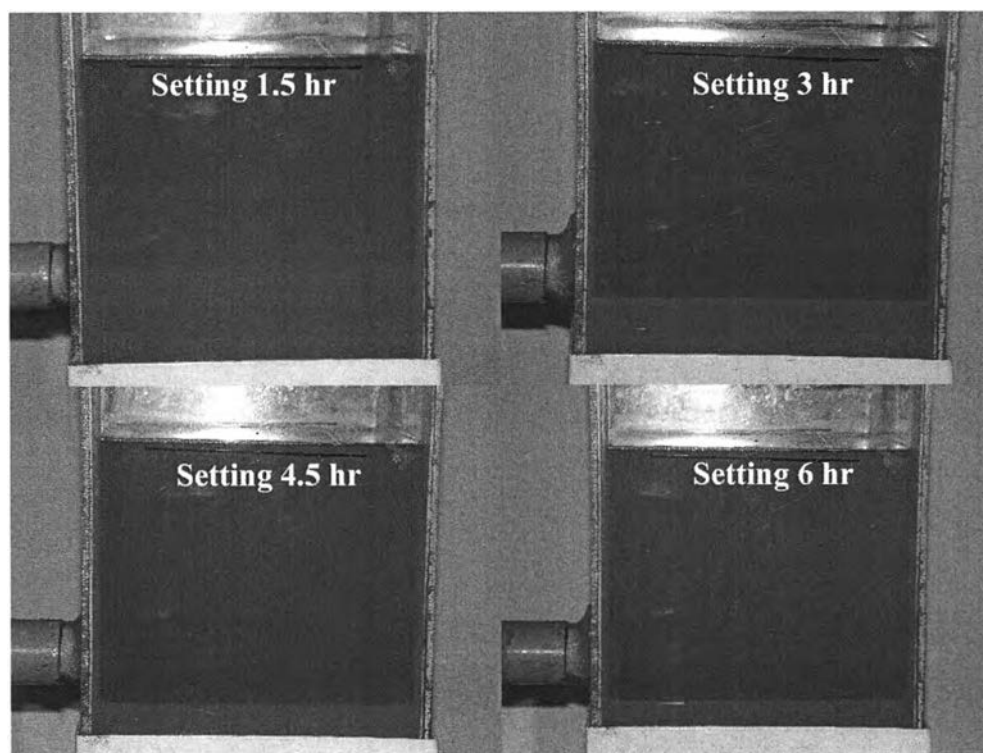


Figure B.12 Model scale reactor after adding white slurry.

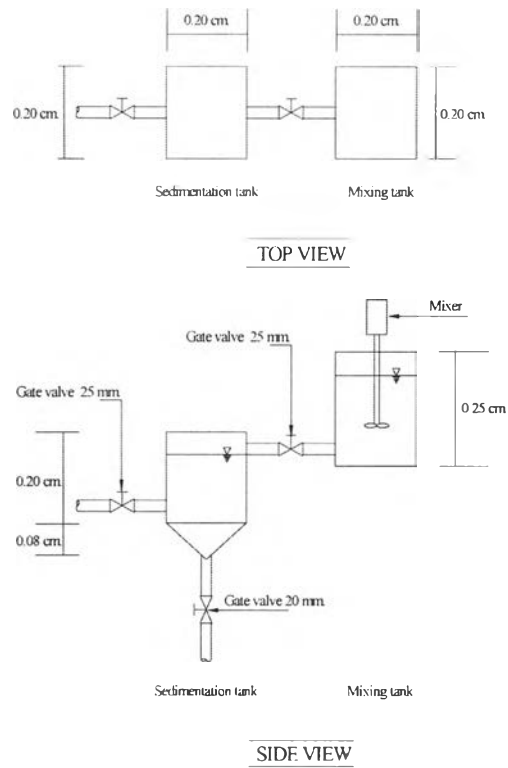


Figure B.12 Detail of model scale reactor.

BIOGRAPHY

Mr. Panomchai Weerayuttasil was born in Nakhonphanom, Thailand, on May 25, 1964. He received a Bachelor Degree in Environmental Engineering from Khon Kaen University in 1986. He started as a graduate student in International Program in Environmental Management, Chulalongkorn University in May 2000 and completed the program in October 2003.

