

Spectrophotometric Determination of Chlorophyll α in waters and sediments of Fresh/Estuarine/Coastal Areas.

1. SCOPE and APPLICATION

- 1.1 This is an acetone extraction method to determine chlorophyll α in fresh and estuarine waters.
- 1.2 A Method Detection Limit (MDL) of 0.62 $\mu\text{g/L}$ active chl α and 0.74 $\mu\text{g/L}$ phaeophytin was determined using the Student's t value (3.14, $n=7$) times the standard deviation of a minimum of 7 replicates. If more than seven replicates are used to determine the MDL, refer to the Student's t test table for the appropriate $n-1$ value.
- 1.3 The quantitation limit for chl α is dependent upon the volume of sample filtered.
- 1.4 This procedure should be used by analysts experienced in the theory and application of chlorophyll analysis. A three month training period with an analyst experienced in the analysis using the spectrophotometer is required.
- 1.5 This method can be used for all programs that require spectrophotometric analysis of chlorophyll α .
- 1.6 This procedure is based Standard Methods 10200H, 19th Edition.

2. SUMMARY

- 2.1 Chlorophyll α is extracted from phytoplankton cells using a 90% solution of acetone. The samples are refrigerated in the dark from 2 to 24 hours (over night is preferable). After the appropriate time, the samples are centrifuged to separate the sample material from the extract. Because the waters of the Maryland portion of the Chesapeake Bay are relatively turbid, the sample extract is filtered through a 0.45 μm ptfе or nylon syringe filter and transferred into a clean tube, and centrifuged again for 20 minutes. The extract is analyzed on a spectrophotometer. To determine phaeophytin and active chl α , the extract is then acidified using 1N HCl, and reread. The concentrations are then calculated using the monochromatic equation. Uncorrected chlorophyll may be determined using the trichromatic equation.

3. DEFINITIONS

- 3.1 Absorbance – A measure of the amount of light at a specific wavelength absorbed by a liquid.
- 3.2 Acceptance Criteria – Specified limits placed on characteristics of an item, process, or service defined in a requirement document. (ASQC)

- 3.3 Accuracy – The degree of agreement between an observed value and an accepted reference value. Accuracy includes a combination of random error (precision) and systematic error (bias) components which are due to sampling and analytical operations; a data quality indicator. (QAMS)
- 3.4 Aliquot – A discrete, measured, representative portion of a sample taken for analysis. (EPA QAD Glossary)
- 3.5 Analytical Range – The analytical range is dependent on the volume of water filtered and the volume of acetone used in the extraction.
- 3.6 Batch – Environmental samples, which are prepared and /or analyzed together with the same process and personnel, using the same lot(s) of reagents. A **preparation batch** is composed of one to 20 environmental samples of the same matrix, meeting the above mentioned criteria and with a maximum time between the start of processing of the first and last sample in the batch to be 24 hours. An **analytical batch** is composed of prepared environmental samples (extracts, digestates, or concentrates) and/or those samples not requiring preparation, which are analyzed together as a group using the same calibration curve or factor. An analytical batch can include samples originating from various environmental matrices and can exceed 20 samples. (NELAC/EPA)
- 3.7 Blank- A sample that has not been exposed to the analyzed sample stream in order to monitor contamination during sampling, transport, storage or analysis. The blank is subjected to the usual analytical and measurement process to establish a zero baseline or background value and is sometimes used to adjust or correct routine analytical results. (ASQC)
- 3.8 Calibrate- To determine, by measurement or comparison with a standard, the correct value of each scale reading on a meter or other device, or the correct value for each setting of a control knob. The levels of the applied calibration standard should bracket the range of planned or expected sample measurements. (NELAC)
- 3.9 Calibration – The set of operations which establish, under specified conditions, the relationship between values indicated by a measuring device. The levels of the applied calibration standard should bracket the range of planned or expected sample measurements. (NELAC)
- 3.10 Calibration Curve – The graphical relationship between known values, such as concentrations, or a series of calibration standards and their analytical response. (NELAC)
- 3.11 Calibration Method – A defined technical procedure for performing a calibration. (NELAC)
- 3.12 Calibration Standard – A substance or reference material used to calibrate an instrument. (QAMS)
 - 3.12.1 Initial Calibration Standard (STD) – A series of standard solutions used to initially establish instrument calibration responses and develop calibration curves for individual target analytes.
 - 3.12.2 Initial Calibration Verification (ICV) – An individual standard, analyzed initially, prior to any sample analysis, which verifies

acceptability of the calibration curve or previously established calibration curve.

- 3.12.3 Continuing Calibration Verification (CCV) – An individual standard which is analyzed after every 10-15 field sample analysis.
- 3.13 Certified Reference Material – A reference material one or more of whose property values are certified by a technically valid procedure, accompanied by or traceable to a certificate or other documentation which is issued by a certifying body. (ISO 17025)
- 3.14 Corrective Action – Action taken to eliminate the causes of an existing nonconformity, defect or other undesirable situation in order to prevent recurrence. (ISO 8402)
- 3.15 Deficiency – An unauthorized deviation from acceptable procedures or practices. (ASQC)
- 3.16 Demonstration of Capability – A procedure to establish the ability of the analyst to generate acceptable accuracy. (NELAC)
- 3.17 Detection Limit – The lowest concentration or amount of the target analyte that can be determined to be different from zero by a single measurement at a stated degree of confidence.
- 3.18 Duplicate Analysis – The analyses of measurements of the variable of interest performed identically on two sub samples (aliquots) of the same sample. The results from duplicate analyses are used to evaluate analytical or measurement precision but not the precision of sampling, preservation or storage internal to the laboratory. (EPA-QAD)
- 3.19 External Standard (ES) – A pure analyte (anacystis nidulans algae, or equivalent) that is measured in an experiment separate from the experiment used to measure the analyte(s) in the sample. The signal observed for a known quantity of the pure external standard is used to calibrate the instrument response for the corresponding analyte(s). The instrument response is used to calculate the concentrations of the analyte(s) in the unknown sample.
- 3.20 Field Duplicates (FD1 and FD2) – Two separate samples collected at the same time and place under identical circumstances and treated exactly the same throughout field and laboratory procedures. Analyses of FD1 and FD2 provide a measure of the precision associated with sample collection, preservation and storage, as well as with laboratory procedures.
- 3.21 Field Reagent Blank (FRB) – An aliquot of reagent water or other blank matrix that is placed in a sample container in the laboratory and treated as a sample in all respects, including shipment to the sampling site, exposure to the sampling site conditions, storage, preservation, and all analytical procedures. The purpose of the FRB is to determine if method analytes or other interferences are present in the field environment.
- 3.22 Holding time – The maximum time that samples may be held prior to analysis and still be considered valid. (40 CFR Part 136) The time elapsed from the time of sampling to the time of extraction or analysis, as appropriate.

- 3.23 Instrument Detection Limit (IDL) – The minimum quantity of analyte of the concentration equivalent which gives an analyte signal equal to three times the standard deviation of the background signal at the selected wavelength, mass, retention time absorbance line, etc.
- 3.24 Laboratory Duplicates (LD1 and LD2) – Two aliquots of the same sample taken in the laboratory and analyzed separately with identical procedures. Analyses of LD1 and LD2 indicate precision associated with laboratory procedures, but not with sample collection, preservation, or storage procedures.
- 3.25 Laboratory Reagent Blank (LRB) – A matrix blank (i.e., 90% acetone) that is treated exactly as a sample including exposure to all glassware, equipment, solvents, and reagents that are used with other samples. The LRB is used to determine if method analytes or other interferences are present in the laboratory environment, the reagents, or the instrument.
- 3.26 Laboratory Control Sample (LCS) – A sample matrix, free from the analytes of interest, spiked with verified known amounts of analytes from a source independent of the calibration standard or a material containing known and verified amounts of analytes. The LCS is generally used to establish intra-laboratory or analyst-specific precision and bias or to assess the performance of all or a portion of the measurement system. (NELAC)
- 3.27 Limit of Detection (LOD) – The lowest concentration level that can be determined by a single analysis and with a defined level of confidence to be statistically different from a blank. (ACS)
- 3.28 Limit of Quantitation (LOQ) – The minimum levels, concentrations, or quantities of a target variable (target analyte) that can be reported with a specified degree of confidence. The LOQ is set at 3 to 10 times the LOD, depending on the degree of confidence desired.
- 3.29 Linear Dynamic Range (LDR) – The absolute quantity over which the instrument response to an analyte is linear. This specification is also referred to as the Linear Calibration Range (LCR).
- 3.30 Material Safety Data Sheets (MSDS) – Written information provided by vendors concerning a chemical's toxicity, health hazards, physical properties, fire, and reactivity data including storage, spill, and handling precautions.
- 3.31 May – Denotes permitted action, but not required action. (NELAC)
- 3.32 Method Detection Limit (MDL) – The minimum concentration of an analyte that can be identified, measured, and reported with 98% confidence that the analyte concentration is greater than zero.
- 3.33 Monochromatic equation – Also known as Lorenzen's modified monochromatic equation, it requires the absorbance values of 664 and 665 nm before and after an acidification step of 90 seconds to calculate the amount of chlorophyll α and phaeophytin in the sample. The chlorophyll a is reported as corrected for phaeophytin. Chlorophyll b and c cannot be calculated using this equation.
- 3.34 Must – Denotes a requirement that must be met. (Random House College Dictionary)

- 3.35 Path Length – The path length is the width of the cuvette cell (length between optical non-frosted sides). For this method, 5 and 1 cm path length cuvettes are used.
- 3.36 Precision – The degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves; a data quality indicator. Precision is usually expressed as standard deviation, variance or range, in either absolute or relative terms. (NELAC)
- 3.37 Preservation – Refrigeration, freezing, and/or reagents added at the time of sample collection (or later) to maintain the chemical and or biological integrity of the sample.
- 3.38 Quality Control Sample (QCS) – A sample of analytes of known and certified concentrations. The QCS is obtained from a source external to the laboratory and different from the source of calibration standards. It is used to check laboratory performance with externally prepared test materials.
- 3.39 Run – One sample analysis from start to finish, including printout.
- 3.40 Run Cycle – Typically a day of operation – the entire analytical sequence of runs from the first run to the last run and including the transfer of run cycle data to the disc.
- 3.41 Sample Volume – Volume of water filtered.
- 3.42 Sensitivity – The capability of a test method or instrument to discriminate between measurement responses representing different levels (concentrations) of a variable of interest.
- 3.43 Shall – Denotes a requirement that is mandatory whenever the criterion for conformance with the specification requires that there be no deviation. (ANSI)
- 3.44 Should – Denotes a guideline or recommendation whenever noncompliance with the specification is permissible. (ANSI)
- 3.45 Standard Reference Material (SRM) – Material which has been certified for specific analytes by a variety of analytical techniques and/or by numerous laboratories using similar analytical techniques. These may consist of pure chemicals, buffers, or compositional standards. The materials are used as an indication of the accuracy of a specific analytical technique.
- 3.46 Trichromatic equation – Also known as Jeffrey and Humphrey’s Trichromatic Equations, they require absorbance values at 664, 647, and 630 nm to calculate the amount of uncorrected chlorophyll *a* in a sample. Chlorophyll *b* and *c* pigments can also be determined. No acidification is required and phaeophytin cannot be calculated from this equation.

4. INTERFERENCES

- 4.1 Light and heat cause the chlorophyll molecule to break down. Therefore, the samples should be kept cold in the dark and care should be taken when grinding the samples so as not to overheat the sample.
- 4.2 Any compound that absorbs light between 630 and 665 nm may interfere with chlorophyll measurement. The absorbance measurement at 750 nm is

subtracted from the sample's other measured absorbances (665, 664, 647, and 630 nm) to account for the turbidity of the clarified sample. If the absorbance at 750 nm is above 0.007 absorbance units (AU), the sample may be filtered one more time.

- 4.3 The spectral overlap of chlorophyll *a*, *b*, and *c* and phaeophytin can cause over or under-estimation of chlorophyll and/or phaeophytin. The amount of chlorophyll *b* and *c* in a sample is dependent on the taxonomic composition of the phytoplankton it contains. In the trichromatic equation, chlorophyll *a* may be overestimated in the presence of phaeophytin. In the monochromatic equation, chlorophyll *a* may be slightly overestimated in the presence of chlorophyll *b* and phaeophytin may be overestimated in the presence of carotenoids.

5. SAFETY

- 5.1 Safety precautions must be taken when handling reagents, samples and equipment in the laboratory. Protective clothing including lab coats, safety glasses and enclosed shoes should be worn. In certain situations, it will be necessary to also use gloves and/or a face shield. If solutions come in contact with eyes, flush with water continuously for 15 minutes. If solutions come in contact with skin, wash thoroughly with soap and water. Contact Solomons Rescue Squad (911) if emergency treatment is needed and also inform the CBL Business Manager of the incident. Contact the CBL Business Manager if additional treatment is required.
- 5.2 The toxicity or carcinogenicity of each reagent used in this procedure may not have been fully established. Each chemical should be regarded as a potential health hazard and exposure should be as low as reasonably achievable. Cautions are included for known hazardous materials and procedures.
- 5.3 Do not wear jewelry when troubleshooting electrical components. Even low voltage points are dangerous and can injure if allowed to short circuit.
- 5.4 The following hazard classifications are listed for the chemicals used in this procedure. Detailed information is provided on Material Safety Data Sheets (MSDS).

Chemical	Health	Flammability	Reactivity	Contact	Storage
Hydrochloric Acid	3	0	2	4	White
Acetone	2	3	0	3	Red

On a scale of 0 to 4 the substance is rated on four hazard categories: health, flammability, reactivity, and contact. (0 is non-hazardous and 4 is extremely hazardous)

STORAGE

Red – Flammability Hazard: Store in a flammable liquid storage area.
 Blue – Health Hazard: Store in a secure poison area.
 Yellow – Reactivity Hazard: Keep separate from flammable and combustible materials.
 White – Contact Hazard: Store in a corrosion-proof area.
 Green – Use general chemical storage (On older labels, this category was orange).
 Striped – Incompatible materials of the same color class have striped labels. These products should not be stored adjacent to substances with the same color label. Proper storage must be individually determined.

6 EQUIPMENT AND SUPPLIES

- 6.1 A scanning spectrophotometer capable of measuring wavelengths within the visible range. This laboratory uses Shimadzu UV2401PC and UV2450PC spectrophotometers.
- 6.2 Freezer, capable of maintaining $-20^{\circ} \pm 5^{\circ}$ C.
- 6.3 Lab ware – All reusable lab ware (glass, Teflon, plastic, etc) should be sufficiently clean for the task objectives.
- 6.4 A centrifuge.
- 6.5 A Teflon pestle for grinding, either by hand or power, and/or a sonicator.
- 6.6 5-cm path length and 1-cm path length cuvettes of either special optical glass or quartz.

7 REAGENTS AND STANDARDS

- 7.1 Purity of Water – Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to ASTM Specification D 1193, Type I. Freshly prepared water should be used for making the standards intended for calibration. The detection limits of this method will be limited by the purity of the water and reagents used to make the standards.
- 7.2 Purity of Reagents – Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without compromising the accuracy of the determination.
- 7.3 Acetone ($\text{H}_2\text{C}=\text{O}=\text{CH}_2$), 90% v/v

Acetone, reagent grade	900 ml
De-ionized water	100 ml

Using a graduated cylinder, add 100 ml de-ionized water to 900 ml acetone.
- 7.4 Hydrochloric Acid, 1N –

Hydrochloric acid (HCl), concentrated,	8.6 ml
De-ionized water, q.s.	100 ml

In a 100 ml volumetric flask, add 8.6 ml of concentrated hydrochloric acid to ~60 ml of de-ionized water. Dilute to 100 ml with de-ionized water.

7.5 Blanks – A reagent blank of 90% acetone is used.

7.6 Standards – Standards used are one of the following:

7.6.1 Chlorophyll α from *Anacystis nidulans* algae, PN C6144-1MG, ordered from Sigma/Aldrich. If chlorophyll from algae is not available, chlorophyll α from spinach may be substituted.

7.7 Quality Control Sample (QCS) – For this procedure, the QCS can be any certified sample which is obtained from an external source. If a certified sample is not available, then use the standard material.

8 SAMPLE COLLECTION, PRESERVATION, AND STORAGE

8.1 Water collected for chl α should be filtered through a Whatman GF/F glass fiber filter (nominal pore size 0.7 μ m), or equivalent.

8.2 Water collected for chl α should be filtered as soon as possible. If immediate filtration is not possible, the water samples should be kept on ice in the dark and filtered within 24 hours.

8.3 The sample is kept frozen at -20° C or lower. Filter pads should be folded in half and may be stored in folded aluminum foil pouches.

8.4 Frozen chl α filters should be extracted within 4 weeks. Once the sample is extracted, the clarified extract may be stored at -20° C for up to another 30 days.

9 QUALITY CONTROL

9.1 The laboratory is required to operate a formal quality control (QC) program. The minimum requirements of this program consist of an initial demonstration of laboratory capability and the continued analysis of laboratory instrument blanks and calibration standard material, analyzed as samples, as a continuing check on performance. The laboratory is required to maintain performance records that define the quality of data generated.

9.2 Initial Demonstration of Capability

9.2.1 The initial demonstration of capability (DOC) – is used to characterize instrument performance (MDLs) and laboratory performance (analysis of QC samples) prior to the analyses conducted by this procedure.

9.2.2 Method Detection Limits (MDLs) – MDLs should be established for chl α using a low level ambient water sample. To determine the MDL values, analyze a minimum of seven replicate filtered aliquots of water. Perform all calculations defined in the procedure (Section 11) and report the concentration values in the appropriate units. Calculate the MDL as follows:

$$\text{MDL} = St_{(n-1, 1-\alpha=0.99)}$$

Where, $t(n-1, 1-\alpha=0.99)$ = Student's t value for the 99% confidence level with $n-1$ degrees of freedom ($t = 3.14$ for 7 replicates)

n = number of replicates

S = Standard Deviation of the replicate

analyses.

- 9.2.3 MDLs should be determined yearly. If more than 7 replicates are analyzed, use the appropriate $n-1$ value obtained from the table for the Student's t test.

9.3 Assessing Laboratory Performance

- 9.3.1 Laboratory Reagent Blank (LRB) – The laboratory reagent blank is analyzed at the beginning of each sample run, after every tenth sample, and at the end of the run. The LRB consists of 90% acetone treated the same as the samples. LRB data are used to assess contamination from the laboratory environment.

9.4 Data Assessment and Acceptance Criteria for Quality Control Measures

- 9.4.1 The Acceptance Criteria for chl a is 0.9990. If the r^2 is less than acceptable, the standards must be made again.

9.5 Corrective Actions for Out of Control Data

- 9.5.1 The sample is first analyzed using the 5 cm path length cuvette. If the 665 nm reading is above 1.000 absorbance units, the sample should be reread using the 1 cm cuvette.
- 9.5.2 If the absorbance of the LRB shows an upward trend, AUTOZERO and re-BASELINE, then reread that LRB.

10 CALIBRATION AND STANDARDIZATION

- 10.1 Calibration – Quarterly calibrations with standards of known concentration are performed.
- 10.2 In using *Anacystis nidulans* algae, the concentration must be determined by spectrophotometer.

11 PROCEDURE

- 11.1 Sample Preparation – water column
 - 11.1.1 Filter a known volume of water through a Whatman GF/F filter pad (nominal pore size 0.7 μm). Good color is needed on the pad. Do not rinse the pad.
 - 11.1.2 Fold pad in half, sample inside, wrap in aluminum foil, label and freeze for analysis within 4 weeks.
 - 11.1.3 Before analysis, briefly thaw pads, and then place in a 15 ml centrifuge tube. Add 10 ml of 90% acetone. Work under subdued lighting.
 - 11.1.4 Write all information in the lab bench sheet.
 - 11.1.5 Using a Teflon pestle, grind the filter against the side of the tube until the filter is well ground. If hand grinding, 10-15 seconds is all that is necessary. Power grinding requires vigilance, because excess heat will degrade the chlorophyll. Allow the sample to extract for 2 - 24 hours in the dark under refrigeration. Overnight is recommended.
 - 11.1.6 Remove tubes from refrigerator.
 - 11.1.7 Shake tubes, and then centrifuge at ~2400 rpm for 30 minutes. Using a syringe, pull the extract from the first tube and filter while transferring to a second numbered centrifuge tube. The extract is filtered through 0.45 μm ptfе or nylon syringe filters. The transferred samples may be stored in the freezer for up to 30 days after extraction. When ready to analyze the samples, centrifuge again for 20 minutes at ~ 2400 rpm.
- 11.2 Pollution Prevention and Waste Management
 - 11.2.1 This method generates hazardous waste.
 - 11.2.2 Acetone waste is stored in 4 liter jugs in the cabinet under the hood and transferred to the hazardous waste area of the Storage Facility on campus.
 - 11.2.3 Do not pour acetone down the sink.
 - 11.2.4 Decant the waste acetone into the waste jugs, and then allow the remaining ground filter pad or sediment to dry in the hood.
 - 11.2.5 The dried waste may then be put in the trash.
- 11.3 Using the Shimadzu UVProbe software:
 - 11.3.1 Turn on the spectrophotometer (either the UV2401 or the UV2450) and the computer. Open the UVProbe software. Select photometric mode and connect to the instrument to turn on the lamps. Allow the instrument to run the lamp check and click OK. Allow the lamps to warm up for a minimum of 45 minutes before beginning sample analysis.
 - 11.3.2 Using the 5 cm path length cuvettes, fill both the reference and sample cuvettes with 90% acetone. Wipe the windows of the cuvettes carefully with lens paper to dry. Click on AUTOZERO,

then run a BASELINE. When the baseline is complete, label the first line of the sample table as blk1. Click on READ UNK (unknown) or press F9 to begin scanning. All wavelengths should be very close to zero. If not, AUTOZERO again, and rerun the BASELINE. Run blk2 if needed.

- 11.3.3 The reference cuvette is filled with 90% acetone and is left in place. Periodically check the liquid level, adding more 90% acetone as needed.
- 11.3.4 Begin analyzing samples. Enter the sample name in the sample table twice, once with a “b” designation for before acid, and again with an “a” designation for after acid.
- 11.3.5 Dispense sample into the sample cuvette. Wipe the windows of the cuvette carefully with lens paper and place in the cell holder.
- 11.3.6 Check the absorbance at 750 nm. If it is at 0.007 or below, press F9 to start the scan. If it is above 0.007, the sample may be filtered one more time through a 0.45 um ptfе syringe filter. If the 750 nm absorbance is still not below 0.007, proceed with the scan. It may be necessary to recheck the zero if several samples in a row start above 0.007 at the 750 nm reading.
- 11.3.7 After the first scan is read, add enough 1N HCl to the sample to achieve a concentration of 0.003 N HCl within the sample. One drop of acid is used in the 1-cm path length cuvettes and 3 drops in the 5-cm cuvettes. Gently stir the sample for 30 seconds and wait another 30 seconds before starting the scan. A total of 90 seconds is needed to complete the reaction before reading. A 30 second wait is built into the method.
- 11.3.8 Rinse the sample cuvette with acetone after each sample. Then rinse with a small amount of sample before filling.
- 11.3.9 Repeat steps 11.3.4 through 11.3.6 for all samples, adding a blank after every 10 samples.
- 11.3.10 Run a blank at the end
- 11.3.11 Save the file. Right click on Properties.
- 11.3.12 Hide columns TYPE, EX, and CONC. Print file.
- 11.3.13 Save the file again as a text file to be imported into a spreadsheet for calculation.

12. Calculations:

Chlorophyll corrected for phaeophytin (ug/L or mg/m³):

$$\text{Chlorophyll } \alpha \text{ corrected (ug/L)} = \frac{26.7(664_B - 665_A) \times V_1}{V_2 \times L}$$

Phaeophytin (ug/L or mg/m³):

$$\text{Phaeophytin } \alpha \text{ (ug/L)} = \frac{26.7 [1.7(665_A) - 664_B] \times V_1}{V_2 \times L}$$

Uncorrected chlorophyll (ug/L or mg/m3):

$$\text{Chlorophyll } \alpha \text{ uncorrected (ug/L)} = \frac{[11.85(664_B) - 1.54(647_B) - 0.8(630_B)] \times V_1}{V_2 \times L}$$

Chlorophyll/Phaeophytin ratio:

Absorption peak ratio: $664_B/665_A$

Where: 664_B = Subtract 750 nm value (turbidity correction) from absorbance at 664 nm before acidification.

665_A = turbidity corrected absorbance at 665 nm after acidification.

647_B = turbidity corrected absorbance at 647 nm before acidification.

630_B = turbidity corrected absorbance at 630 nm before acidification.

V_1 = volume of extract (mL)

V_2 = volume of sample filtered (L)

L = path length (cm)

13 References:

- 13.1 APHA, Standard Methods for the Examination of Water and Wastewater, Method #10200H, 19th Edition.
- 13.2 EPA Method 446.0.

