Clarification of Free and Total Cyanide Analysis for Safe Drinking Water Act (SDWA) Compliance

Revision 1.0

Office of Water (MS-140) EPA 815-B-20-004 June 2020

Questions concerning this document should be addressed to:

Judith A. Brisbin, Ph.D.
U.S. EPA, Office of Ground Water and Drinking Water,
Technical Support Center
26 W. Martin Luther King Dr. (MS-140)
Cincinnati, OH 45268
(513) 569-7883
brisbin.judy@epa.gov

Disclaimer

The information in this document has been reviewed and approved for public dissemination in accordance with U.S. Environmental Protection Agency (EPA). References to Federal Register Notices (FRNs) and the Code of Federal Regulations (CFR) are included within this document. This document, in and of itself, does not establish any requirements beyond those specified in the federal regulatory citations or the approved analytical methods, which are incorporated by reference within those regulations. Certified laboratories that conduct sample analysis for drinking water compliance should verify whether their state drinking water laboratory certification program has requirements that extend beyond the federal regulations.

Table of Contents

Background

In 1974, Congress passed the Safe Drinking Water Act (SDWA). This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called Maximum Contaminant Level Goals (MCLG). The MCLG for cyanide is 0.2 mg/L or 200 ppb. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA set an enforceable standard for cyanide, called a Maximum Contaminant Level (MCL), at 0.2 mg/L or 200 ppb under the Chemical Phase Rule V (57 FR 31776-31849, Vol. 57, No. 138, July 17, 1992). MCLs are set as close to the health goals as feasible considering cost, benefits, and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. For cyanide, the MCL equals the MCLG, because neither analytical methods nor treatment technology pose any limitation.

EPA originally prepared this document (U.S. Environmental Protection Agency, 2016) to address frequently asked questions about drinking water analytical method measurement and monitoring requirements for cyanide, including:

- Requirements in the Chemical Phase Rule V;
- Laboratory certification requirements;
- Preservation techniques;
- Effects of water treatment on cyanide;
- Performance Evaluation (PE) sample requirements for laboratories;
- Regulated MCL for cyanide; and
- Approved analytical methods for total and free cyanide.

This update includes background on how SDWA relates to the determination of MCLGs and MCLs. Additional text has been added to the description of the Chemical Phase Rule V, which now includes the discussion on water treatment and some minor grammatical corrections. The Certification section now includes rationale for obtaining certification for both free and total cyanide. A section on the necessity to pretreat samples for interferences was added, a discussion on the use of commercial Proficiency Testing (PT) providers was added to the PE section, and a section on MCLGs was added. Finally, some of the tables in the Methodology section were removed as they proved to be redundant.

Note: All references to the Code of Federal Regulations (CFR) in this document are specific to the Revised as of July 1, 2019 CFR.

Chemical Phase Rule V

The MCLG and MCL promulgated for cyanide in the Chemical Phase Rule V (57 FR 31786, Vol. 57, No. 138, July 17, 1992) apply only to free cyanide, the species of cyanide that are of health concern due to their bioavailability and toxicity. The Table in 40 CFR 141.51 (b) defines the MCLG for cyanide (as free cyanide) as 0.2 mg/L and a Table in 40 CFR 141.62 (b) defines the MCL for cyanide (as free cyanide) as 0.2 mg/L.

Approved methods for cyanide determination under SDWA are shown in the Table in 40 CFR 141.23 (k)(1) and the associated Table in Appendix A to Subpart C of Part 141. Excerpts from both of these tables are shown on pages 7 and 8, respectively. Methods are included that determine free cyanide,

total cyanide, and other categories of cyanide compounds such as Cyanide Amenable to Chlorination (CATC). Free cyanide is a chemical definition that refers to the sum of molecular hydrogen cyanide (HCN) and cyanide ion (CN^-). Methods that determine operationally defined categories of cyanide species, such as CATC and Total Cyanide, have also been included. CATC provides a conservative estimate of toxicity because, in addition to free cyanide, it recovers some weak acid dissociable metal cyanide complexes that may or may not actually release free cyanide in the environment. Total cyanide methods are allowed for screening. These methods determine free cyanide, weak acid dissociable metal cyanide complexes and strong metal cyanide complexes. Many laboratories find the total cyanide screening methods easier, faster and cheaper than some of the other operationally defined cyanide methods (e.g., Manual Spectrometry, Cyanides Amenable to Chlorination).

Note: A good resource for understanding cyanide species, in terms of chemistry related terms and definitions and operationally defined definitions, can be found in the current revision of ASTM D 6696.

The footnotes to the Table in 40 CFR 141.23 (a)(4)(i), excerpt shown on page 6, indicate that the Agency has categorized cyanide methods as either "free" or "total" cyanide. With the exception of CATC, free cyanide methods omit the distillation, digestion or ligand exchange. Recognize that CATC requires two portions of the sample be distilled and analyzed for total cyanide, one of which has chlorine added prior to distillation to destroy all amenable cyanide present; the observed difference refers to cyanides amendable to chlorination, which can be reported as free cyanide. When free cyanide is determined, report the value as free cyanide for compliance.

Screening for free cyanide using a total cyanide method is not a requirement. Laboratories or Public Water Systems (PWSs) may choose to determine free cyanide without prior determination of total cyanide. Total cyanide methods generally include a distillation, digestion or ligand exchange. If the total cyanide is $\leq$0.2 mg CN^-/L, compliance with the free cyanide MCL is documented and the value obtained may be reported as free cyanide in SDWIS. If the total cyanide is >0.2 mg CN^-/L, a measurement of free cyanide must be made using an approved free cyanide method to determine compliance.

Note: The Safe Drinking Water Information System (SDWIS) analyte codes for reporting free cyanide and total cyanide are the same (1024), principally because total cyanide can be monitored to screen for compliance with the free cyanide MCL.

Disinfection is an integral component of treatment primarily to control microbial contaminants, but regulated contaminants may also be removed as a secondary benefit. The oxidative effects of disinfection (chlorination and/or most of the alternatives like ozone, chlorine dioxide, etc.) can chemically alter the sample matrix and these oxidants may react with regulated contaminants. PWSs must still monitor for those contaminants to comply with drinking water regulations. Statements in some methods regarding disinfectant reactivity with cyanide are typically included to assist laboratories and PWSs with interpreting data, not to grant any allowance to the PWS to forgo monitoring because of the expectation that cyanide will no longer be measured in the treated water.

Certification/Accreditation

The methods for free and total cyanide are listed in Table 40 CFR 141.23 (k)(1), which includes the following introductory text emphasizing that only the approved methods may be used:

> *Analysis for the following contaminants shall be conducted in accordance with the methods in the following table, or the alternative methods listed in appendix A to subpart C of this part, or their equivalent as determined by EPA…*

Free and total cyanide are part of the National Primary Drinking Water Regulations (NPDWRs) and 40 CFR 141.23 is referenced in 40 CFR 141.28(a) stating that laboratories analyzing compliance samples must be certified or accredited as follows:

> *For the purpose of determining compliance with §141.21 through 141.27, 141.30, 141.40, 141.74, 141.89 and 141.402, samples may be considered only if they have been analyzed by a laboratory certified by the State…*

To analyze compliance drinking water samples, laboratories need to be certified or accredited for an approved analyte and method combination. Laboratories screening for free cyanide using an approved total cyanide method should also consider obtaining certification or accreditation for an approved free cyanide method. Otherwise, samples with total cyanide results >0.2 mg CN^-/L would have to be sent to another lab that is certified or accredited to perform drinking water analysis by an approved free cyanide method prior to the expiration of sample holding time.

Preservation

The preservation specified in 40 CFR 141.23 (k)(2) includes the addition of NaOH to a pH of 12 (or greater) to avoid HCN volatilization losses during sample handling and storage. This also prevents metal-cyanide complexes from precipitating out of solution. In addition, samples are cooled to 4 °C to limit the biodegradation of free cyanide. Containers and holding time are also listed.

Excerpt from Table in 40 CFR 141.23 (k)(2)

(Note: footnotes are respective of table, as published in the CFR)

Contaminant	**Preservative[1]**	**Container[2]**	**Time[3]**
Cyanide	4 °C, NaOH	P or G	14 days

[1] For cyanide determinations samples must be adjusted with sodium hydroxide to pH 12 at the time of collection. When chilling is indicated the sample must be shipped and stored at 4 °C or less.

[2] P = plastic, hard or soft; G = glass, hard or soft.

[3] In all cases samples should be analyzed as soon after collection as possible. Follow additional (if any) information on preservation, containers or holding times that is specified in method.

Sample Pretreatment and Interferences

Pretreatment methods for interferences are found in most cyanide test methods. Some interferences in total cyanide methods are eliminated or reduced by distillation while others need to be removed from the sample prior to analysis. Interferences such as oxidizing agents and sulfides are almost universally tested for and removed by special procedures as a part of pretreatment, before the addition of sodium hydroxide preservation. A positive potassium iodide-starch paper result for oxidizing agents (e.g., chlorine, ozone) is normally addressed by adding small amounts of ascorbic acid, sodium arsenite, or sodium thiosulfate. A positive sulfide result using lead acetate test paper may be addressed by small additions of powdered cadmium carbonate, powdered lead carbonate, or lead acetate, followed by filtration. Additional interferences may include: aldehydes, carbonates, nitrates, nitrites, fatty acids, and glucose and other sugars. Test and/or pretreat for these if you suspect that they are present in your samples at levels that could affect the test results. Most other interfering substances are removed in total cyanide methods by the distillation. Be aware when pretreating for multiple interferences that the analysis of a series of Laboratory Fortified Matrices (LFMs) may be required to verify the suitability of

the chosen treatment. In addition, minimize prolonged exposure of the sample to sunlight (i.e., ultraviolet radiation). Prior to pH adjustment, hydrogen cyanide can be volatilized (photo-liberated), which reduces the concentration of total cyanide and metal-cyanide complexes; after pH adjustment, photodecomposition of some metal cyanide complexes may occur and increase the concentration of free cyanide (Ghosh, Dzombak, Drop, & Zheng, 2006).

Pretreatment methods should be chosen carefully, keeping the matrix in mind. For example, it has been noted that dechlorinating chloramine-disinfected drinking water samples using ascorbic acid (at a high pH) may produce false positive cyanide test results (Delaney & Blodget, 2017). It has been suggested that using sodium borohydride in place of ascorbic acid would avoid this situation. Some test methods, such as EPA Method 335.4 (Rev. 1.0), would allow for this substitution because they allow for using other compatible procedures (not specifically listed in the method) for the removal or suppression of interferences provided they do not adversely affect the overall performance of the method. A series of LFMs with acceptable recoveries may be suitable to verify the revised pretreatment.

Performance Evaluation (PE) Acceptance Limits

The Table in 40 CFR 141.23 (k)(3)(ii) (excerpt shown below) lists the PE Acceptance Limit for cyanide as ± 25% at ≥0.1 mg/L. Commercial vendors accredited by a recognized Proficiency Testing Provider Accreditor use these codified acceptance limits when conducting PE, or Proficiency Testing (PT), studies. Laboratories may use any commercial PT provider acceptable to their Certifying Authority.

Excerpt from Table in 40 CFR 141.23 (k)(3)(ii)

Contaminant	**Acceptance Limit**
Cyanide	± 25% at ≥0.1 mg/L

Maximum Contaminant Level Goal (MCLG)

The Table in 40 CFR 141.51 (b) (excerpt shown below) lists an MCLG of 0.2 mg/L for "cyanide (as free cyanide)." EPA determined that this level of contamination in drinking water is not likely to cause adverse health effects. This is a non-enforceable health goal.

Excerpt from Table in 40 CFR 141.51 (b)

Contaminant	**MCLG (mg/L)**
Cyanide (as free Cyanide)	0.2

Maximum Contaminant Level (MCL)

The Table in 40 CFR 141.62 (b) (excerpt shown below) lists an MCL of 0.2 mg/L for "cyanide (as free cyanide)." Cyanide is therefore regulated as free cyanide. Regulators use this value to determine if a PWS is in compliance with the regulations. For cyanide, this value is the same as its MCLG.

Excerpt from Table in 40 CFR 141.62 (b)

Contaminant	**MCL (mg/L)**
(13) Cyanide (as free Cyanide)	0.2

Methodology

Methodologies for cyanide are shown in Tables in 40 CFR 141.23 (a)(4)(i), 40 CFR 141.23 (k)(1) and Appendix A to Subpart C of Part 141. Excerpts from these tables are shown below.

Excerpt from Table in 40 CFR 141.23 (a)(4)(i)

(Note: footnotes are respective of table, as published in the CFR)

Contaminant	MCL (mg/L)	Methodology	Detection limit (mg/L)
Cyanide	0.2	Distillation, Spectrophotometric[3]	0.02
		Distillation, Automated, Spectrophotometric[3]	0.005
		Distillation, Amenable, Spectrophotometric[4]	0.02
		Distillation, Selective Electrode[3 4]	0.05
		UV, Distillation, Spectrophotometric[9]	0.0005
		Micro Distillation, Flow Injection, Spectrophotometric[3]	0.0006
		Ligand Exchange with Amperometry[4]	0.0005

[3] Screening method by [*sic*] total cyanides.
[4] Measures "free" cyanides when distillation, digestion, or ligand exchange is omitted.
[9] Measures total cyanides when UV-digestor [*sic*] is used, and "free" cyanides when UV-digestor [*sic*] is bypassed.

[Note: The detection limits (DLs) listed in this table are intended for comparing relative method sensitivities to aid in selecting a method suitable to analyze composited samples (40 CFR 141.23 (a)(4)). This table is also used in conjunction with Consumer Confidence Reports (40 CFR 141.151 (d)). Laboratory certification is not directly contingent upon achieving these DLs, however, state laboratory certification programs can be more restrictive within their primacy programs as the laboratory certification authority.]

The Table in 40 CFR 141.23 (a)(4)(i) has several footnotes that indicate:

- Screening methods by total cyanides are designated with footnote 3.
- Free cyanide methods, i.e., when omitting distillation, digestion or ligand exchange, are designated with footnote 4.
- Selective Electrode methods are designated with both footnotes 3 and 4, indicating methods are approved to measure free (without distillation) and total cyanides (after distillation).
- UV, Distillation, Spectrophotometric methods include footnote 9, indicating methods are approved to measure free (when UV-digestor is bypassed) and total cyanides (with UV-digestor).

Excerpt from Table in 40 CFR 141.23 (k)(1)

(Note: footnotes are respective of table, as published in the CFR)

Contaminant	Methodology[13]	EPA	ASTM[3]	SM[4] (18th, 19th ed.)	SM[4] (20th ed.)	SM Online[22]	Other
12. Cyanide	Manual Distillation followed by		D2036-98 A	4500-CN^- C	4500-CN^- C		
	Spectrophotometric, Amenable		D2036-98 B	4500-CN^- G	4500-CN^- G	4500-CN^- G-99	
	Spectrophotometric [*sic*] Manual		D2036-98 A	4500-CN^- E	4500-CN^- E	4500-CN^- E-99	I-3300-85[5]
	Spectrophotometric [*sic*] Semi-automated	335.4[6]					
	Selective Electrode			4500-CN^- F	4500-CN^- F	4500-CN^- F-99	
	UV, Distillation, Spectrophotometric						Kelada-01[17]
	Micro Distillation, Flow Injection, Spectrophotometric						QuikChem 10-204-00-1-X[18]
	Ligand Exchange and Amperometry[21]		D6888-04				OIA-1677, DW[20]

[3] Annual Book of ASTM Standards, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428, http://www.astm.org.; Annual Book of ASTM Standards 1994, Vols. 11.01 and 11.02; Annual Book of ASTM Standards 1996, Vols. 11.01 and 11.02; Annual Book of ASTM Standards 1999, Vols. 11.01 and 11.02; Annual Book of ASTM Standards 2003, Vols. 11.01 and 11.02.

[4] Standard Methods for the Examination of Water and Wastewater, American Public Health Association, 800 I Street NW., Washington, DC 20001-3710; Standard Methods for the Examination of Water and Wastewater, 18th edition (1992); Standard Methods for the Examination of Water and Wastewater, 19th edition (1995); Standard Methods for the Examination of Water and Wastewater, 20th edition (1998). The following methods from this edition cannot be used: 3111 B, 3111 D, 3113 B, and 3114 B.

[5] U.S. Geological Survey, Federal Center, Box 25286, Denver, CO 80225-0425; Methods for Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Inorganic and Organic Constituents in Water and Fluvial Sediment, Open File Report 93-125, 1993; Techniques of Water Resources Investigation of the U.S. Geological Survey, Book 5, Chapter A-1, 3rd edition, 1989.

[6] "Methods for the Determination of Inorganic Substances in Environmental Samples," EPA/600/R-93/100, August 1993. Available as Technical Report PB94-120821 at National Technical Information Service (NTIS), 5301 Shawnee Road, Alexandria, VA 22312. http://www.ntis.gov.

[13] ...

[17] The description for the Kelada-01 Method, "Kelada Automated Test Methods for Total Cyanide, Acid Dissociable Cyanide, And Thiocyanate," Revision 1.2, August 2001, EPA # 821-B-01-009 for cyanide is available from the National Technical Information Service (NTIS), PB 2001-108275, 5285 Port Royal Road, Springfield, VA 22161. The toll free telephone number is 800-553-6847. Note: A 450-W UV lamp may be used in this method instead of the 550-W lamp specified if it provides performance within the quality control (QC) acceptance criteria of the method in a given instrument. Similarly, modified flow cell configurations and flow conditions may be used in the method, provided that the QC acceptance criteria are met.

[18] The description for the QuikChem Method 10-204-00-1-X, "Digestion and distillation of total cyanide in drinking and wastewaters using MICRO DIST and determination of cyanide by flow injection analysis," Revision 2.1, November 30, 2000, for cyanide is available from Lachat Instruments, 6645 W. Mill Rd., Milwaukee, WI 53218. Telephone: 414-358-4200.

[20] Method OIA-1677, DW "Available Cyanide by Flow Injection, Ligand Exchange, and Amperometry." January 2004. EPA-821-R-04-001, Available from ALPKEM, A Division of OI Analytical, P.O. Box 9010, College Station, TX 77842-9010.

[21] Sulfide levels below those detected using lead acetate paper may produce positive method interferences. Test samples using a more sensitive sulfide method to determine if a sulfide interference is present, and treat samples accordingly.

[22] Standard Methods Online, American Public Health Association, 800 I Street NW., Washington, DC 20001, available at http://www.standardmethods.org. The year in which each method was approved by the Standard Methods Committee is designated by the last two digits in the method number. The methods listed are the only online versions that may be used.

Excerpt from Table in Appendix A to Subpart C of Part 141

(Note: footnotes are respective of table, as published in the CFR)

Contaminant	**Methodology**	**EPA method**	**SM 21st edition[1]**	**SM 22nd edition[28]**	**SM 23rd edition[49]**	**SM online[3]**	**ASTM[4]**	**Other**
Cyanide	Manual Distillation with $MgCl_2$ followed by:		4500-CN^- C	4500-CN^- C	4500-CN^- C	4500-CN^- C-99	D2036-06 A	
	Spectrophotometric, Amenable		4500-CN^- G	4500-CN^- G	4500-CN^- G		D2036-06 B	
	Spectrophotometric Manual		4500-CN^- E	4500-CN^- E	4500-CN^- E		D2036-06 A	
	Selective Electrode		4500-CN^- F	4500-CN^- F	4500-CN^- F			
	Gas Chromatography/ Mass Spectrometry Headspace							ME355.01[7]

[1] Standard Methods for the Examination of Water and Wastewater, 21st edition (2005). Available from American Public Health Association, 800 I Street, NW., Washington, DC 20001-3710.

[3] Standard Methods Online are available at http://www.standardmethods.org. The year in which each method was approved by the Standard Methods Committee is designated by the last two digits in the method number. The methods listed are the only online versions that may be used.

[4] Available from ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 or http://astm.org. The methods listed are the only alternative versions that may be used.

[7] Method ME355.01, Revision 1.0. "Determination of Cyanide in Drinking Water by GC/MS Headspace," May 26, 2009. Available at http://www.nemi.gov or from James Eaton, H & E Testing Laboratory, 221 State Street, Augusta, ME 04333. (207) 287-2727.

[28] Standard Methods for the Examination of Water and Wastewater, 22nd edition (2012). Available from American Public Health Association, 800 I Street NW., Washington, DC 20001-3710.

[49] Standard Methods for the Examination of Water and Wastewater, 23rd edition (2017). Available from American Public Health Association, 800 I Street NW, Washington, DC 20001-3710.

Matching up the "Methodology" in the cyanide entry in the Table at 40 CFR 141.23(a)(4)(i) with the methods in the cyanide entries in the Tables at 40 CFR 141.23 (k)(1) & Appendix A to Subpart C of Part 141, the methods approved for free cyanides, total cyanides, and/or both can be determined.

See below for free and total cyanide method summary tables. Please note the following for both tables:

1. For the cyanide methods referenced from Standard Methods, 4500-CN- Sections A. Introduction and B. Preliminary Treatment of Samples are included by reference (i.e., they are part of the method requirements).
2. SM 4500-CN- C from the 21st, 22nd and 23rd Editions of Standard Methods were written with the option of omitting $MgCl_2$ as a distillation reagent. EPA's approval of these methods (83 FR 51636-51652, Vol. 83, No. 198, October 12, 2018) is conditioned on the use of $MgCl_2$. The use of $MgCl_2$ not optional for compliance monitoring.

Summary Table for Total Cyanide

Methodology	**EPA**	**ASTM**	**SM (ed.)**	**Other**
Manual Distillation with $MgCl_2$ followed by Manual Spectrophotometry		D2036-98 A, -06 A	4500-CN^- C (18th thru 23rd & -99 online) + 4500-CN^- E (18th thru 23rd & -99 online)	USGS I-3300-85
Manual Distillation followed by Semi-Automated Spectrophotometry	335.4 (Rev. 1.0)			
Manual Distillation with $MgCl_2$ followed by Cyanide-Selective Electrode			4500-CN^- C (18th thru 23rd & -99 online) + 4500-CN^- F (18th thru 23rd & -99 online)	
Automated UV Distillation followed by Automated Spectrophotometry				Kelada-01 (Rev. 1.2; EPA 821-B-01-009)
Micro Distillation, Flow Injection, followed by Automated Spectrophotometry				QuikChem 10-204-00-1-X (Rev. 2.1)

Summary Table for Free Cyanide

Methodology	EPA	ASTM	SM (ed.)	Other
Manual Spectrometry, Cyanides Amenable to Chlorination[1, 2]		D2036-98 A, -06 A + D2036-98 B, -06 B	4500-CN^- G (18^{th} thru 23^{rd} & -99 online) + 4500-CN^- C (with $MgCl_2$) (18^{th} thru 23^{rd} & -99 online) + 4500-CN^- E (18^{th} thru 23^{rd} & -99 online)	
Cyanide-Selective Electrode[2]			4500-CN^- F (18^{th} thru 23^{rd} & -99 online)	
Automated Spectrophotometry[3]				Kelada-01 (Rev. 1.2; EPA 821-B-01-009)
Amperometry[2]		D6888-04		OIA-1677, DW (EPA 821-R-04-001)
Headspace Gas Chromatography/ Mass Spectrometry				ME355.01 (Rev. 1.0)

[1] To determine cyanides amenable to chlorination distillation as described in Part C of the Standard Method is still required. This requires analysis of two sample aliquots. The first aliquot is subjected to a chlorine treatment to decompose the cyanides. The second aliquot has no chlorine treatment. Both aliquots are distilled followed by manual spectrometry. The difference between the cyanide concentrations found in the two samples is expressed as cyanides amenable to chlorination.

[2] Free cyanide omits the distillation, digestion or ligand exchange.

[3] Measures "free" cyanides when UV-digestor is bypassed.

References

Delaney, M. F., & Blodget, C. (2017). Free Cyanide Forms During Drinking Water Free Cyanide Determination. *Journal of the American Water Works Association, 109*(12), 27. Retrieved October 3, 2019, from https://doi.org/10.5942/jawwa.2017.109.0120

Ghosh, R. S., Dzombak, D. A., Drop, S. M., & Zheng, A. (2006). Analysis of Cyanide in Water. In D. A. Dzombak, R. S. Ghosh, & G. M. Wong-Chong, *Cyanide in Water and Soil: Chemistry, Risk, and Management* (pp. 123-153). Boca Raton: CRC Press Taylor & Francis Group.

U.S. Environmental Protection Agency. (2016, August). Cyanide Clarification of Free and Total Cyanide Analysis for Safe Drinking Water Act (SDWA) Compliance (EPA 815-B-16-012). Cincinnati, OH: Office of Water. Retrieved January 2, 2020, from (https://www.epa.gov/sites/production/files/2016-08/documents/cyanide-clarification-free-and-total-cyanide-analysis-safe-drinking-water.pdf