

Analytical and Testing Instruments for the Environment

Guide to Environmental Testing, Regulations, and Applicable Instruments



World Map of Shimadzu Sales, Service, Manufacturing, and R&D Facilities



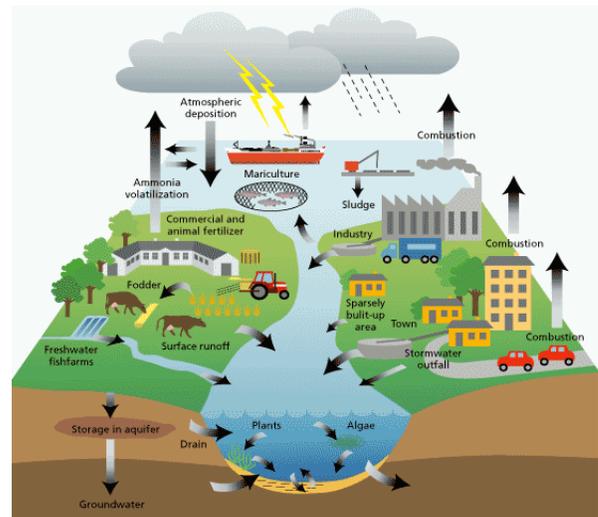
Contents

What is Environmental Testing?	4
Clean Water Act (CWA)	4
Conventional and non-conventional pollutants	4
Priority Pollutants.....	6
Safe Drinking Water Act (SDWA)	7
Lists of Chemical Contaminants, their MCL, and potential sources of contamination	8
More information about disinfection byproducts	10
Resource Conservation and Recovery Act (RCRA)	10
The SW-846	11
Analytical Instrument Selection	12
The Laboratory Balance.....	12
UV-Visible Spectrophotometry	13
Total Organic Carbon Analyzers.....	14
Total Nitrogen Analysis.....	15
Ion Chromatography	15
Metals Analysis.....	17
Atomic Absorption Spectrophotometry.....	17
Inductively Coupled Plasma – Atomic Emission Spectroscopy	18
Organic Analysis	19
Gas Chromatography	20
Gas Chromatography – Mass Spectrometry	21
Liquid Chromatography	22
Emerging Technology	23
Liquid Chromatography Tandem Mass Spectrometry	23
Gas Chromatography Tandem Mass Spectrometry.....	24
Matrix Assisted Laser Desorption Ionization (MALDI) – iD ^{Plus}	25
Unified Chromatography	26
On-line Analyzers	26
Guide to purchasing laboratory equipment for environmental testing	27

■ What is Environmental Testing?

Environmental testing is the practice of “applied analytical chemistry”. Environmental laboratories analyze samples using a list of potential contaminants to determine how much, if any, of the contaminant is present. These contaminants, the methods used to analyze for them, and the maximum amount of contaminant allowed in the sample is defined by regulation.

The discovery of pollutants in the environment led Congress to establish the Environmental Protection Agency (EPA). After the creation of the EPA Congress began to pass legislation to regulate and limit pollution. First was the Clean Air Act, followed by the Clean Water Act, Safe Drinking Water Act, and the Resource Conservation and Recovery Act. These four major pieces of legislation and their enforcement by the EPA are responsible for the birth and continued existence of the environmental laboratory testing industry.



The Federal Regulations that require water testing are:

1. Clean Water Act (CWA) – regulates pollutants from industrial discharge. Requires anyone discharging significant amounts of wastewater into US waterways to obtain a NPDES permit. Approved methods are in 40 CFR Part 136.
2. Safe Drinking Water Act (SDWA) – regulates public drinking water supplies. Approved Methods are in 40 CFR Part 141.
3. Resource Conservation and Recovery Act (RCRA) – regulates the generation and disposal of solid waste. Approved methods are consolidated in the EPA SW 846.

Each regulatory act requires that methods used for compliance with the act be approved for that purpose. For example, to analyze a wastewater for a pollutant the laboratory must use a 40 CFR Part 136 approved method. The laboratory cannot use another method, even if it is an official method, if it is not listed as approved for wastewater testing.

■ Clean Water Act (CWA)

The Clean Water Act (CWA) regulates discharge of pollutants into the waters of the United States and regulates water quality standards for surface water. Under the CWA, it is unlawful to discharge any pollutant from a point source into navigable waters without a permit. The National Pollutant Discharge Elimination System (NPDES) issues permits to industrial, municipal, and other facilities that discharge directly to surface waters. The pretreatment program regulates facilities discharging into a Publically Owned Treatment Works (POTW).

The EPA publishes laboratory analytical methods. These test procedures must be used by industries and municipalities to analyze regulated pollutants in wastewater and other environmental samples. Most of these methods are published as regulations in the Code of Federal Regulations (CFR) at Title 40 Part 136.



Conventional and Non-conventional Pollutants

Pollutants regulated under the CWA include conventional and non-conventional pollutants. Conventional pollutants are “group” parameters, often referred to as method-defined that are amenable to treatment at a POTW. The EPA has defined Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Fecal Coliform, Oil & Grease, pH, and Total Suspended Solids as conventional pollutants. Smaller wastewater treatment facilities and dischargers may only be required to monitor for one or more conventional pollutants.

Non-conventional pollutants are monitored in wastewater treatment plants or NPDES permits if they are believed to be present. Larger facilities and dischargers are required to monitor nutrients, in particular ammonia nitrogen, nitrate nitrogen, organic nitrogen, and total phosphorus. With the exception of radioactivity, non-conventional pollutants can be analyzed by UV-Visible spectrophotometry, atomic absorption spectrophotometry, inductively coupled plasma – atomic emission spectroscopy, or ion chromatography. See Table 1 for a listing of conventional and unconventional pollutants.

Table 1: Conventional and non-conventional pollutants

Conventional Pollutants
BOD
COD
TSS
Fecal Coliform
Oil & Grease
pH
Non – Conventional Pollutants
Bromide
Chlorine – Total Residual
Color
Nitrate Nitrogen
Nitrite Nitrogen
Organic Nitrogen
Phosphorus - Total
Sulfate
Sulfide
Sulfite
Surfactants
Aluminum - Total
Barium - Total
Boron - Total
Cobalt - Total
Iron - Total
Magnesium - Total
Manganese - Total
Molybdenum - Total
Titanium - Total
Tin - Total
Radioactivity

Priority Pollutants

The CWA lists pollutants that were an important starting point in developing national discharge standards. The list contains 65 pollutants that are known as “toxic pollutants”. The toxic pollutant list contains classes of chemicals that could represent tens or hundreds of chemicals in each class. For instance, a “toxic” chemical may be “lead and its compounds”. Since it is not possible to economically determine all chemical compounds containing lead, the EPA regulates “total lead” as one of the priority pollutants. The priority pollutants are a list of specific chemicals that EPA regulates for which EPA has regulatory methods of defined accuracy and precision. See Table 2 for a list of the specific priority pollutants.

Table 2: Priority Pollutants

Base-Neutral Extractable Organics	Acid Extractable Organics	Organochlorine Pesticides
Acenaphthene	p-Chloro-m-cresol	Aldrin
Acenaphthylene	2-Chlorophenol	a,b, g, or d BHC
Anthracene	2,4-Dichlorophenol	Chlordane
Benzidine	2,4-Dimethylphenol	4,4'-DDD
Benzo(a)anthracene	4,6-Dinitro-o-cresol	4,4'-DDE
Benzo(b)fluoranthene	2,4-Dinitrophenol	4,4'-DDT
Benzo(k)fluoranthene	2-Nitrophenol	Dieldrin
Benzo(ghi)perylene	4-Nitrophenol	a Endosulfan
Benzo(a)pyrene	Pentachlorophenol	b Endosulfan
Bis(2-chloroethoxy)methane	Phenol	Endosulfan sulfate
Bis(2-chloroethyl)ether	2,4,6-Trichlorophenol	Endrin
Bis(2-chloroisopropyl)ether	Total phenols	Endrin aldehyde
Bis(2-ethylhexyl)phthalate	Volatile Organics	Heptachlor
4-Bromophenyl phenylether	Acrolein	Heptachlor epoxide
Butyl benzyl phthalate	Acrylonitrile	Inorganics
2-Chloronaphthalene	Benzene	Antimony - total
4-Chlorophenyl phenylether	Bis(chloromethyl) ether	Arsenic - total
Chrysene	Bromodichloromethane	Asbestos
Dibenzo(a,b)anthracene	Bromoform	Beryllium - total
Di-n-butyl phthalate	Bromomethane	Cadmium - total
1,2-Dichlorobenzene	Carbon tetrachloride	Chromium - total
1,3-Dichlorobenzene	Chlorobenzene	Copper - total
1,4-Dichlorobenzene	Chloroethane	Cyanide - total
3,3'-Dichlorobenzidine	2-Chloroethyl vinyl ether	Mercury - total
Diethyl phthalate	Chloroform	Nickel - total
Dimethyl phthalate	Chloromethane	Selenium - total
2,4-Dinitrotoluene	Dibromochloromethane	Silver - total
2,6-Dinitrotoluene	Dichlorodifluoromethane	Thallium - total
Di-n-octyl phthalate	1,1-Dichloroethane	Zinc - total
Fluoranthene	1,2-Dichloroethane	
Fluorene	1,1-Dichloroethylene	
Hexachlorobenzene	trans-1,2-Dichloroethylene	
Hexachlorobutadiene	1,2-Dichloropropane	
Hexachlorocyclopentadiene	cis-1,3-Dichloropropene	
Hexachloroethane	trans-1,3-Dichloropropene	
Indeno(1,2,3-c,d)pyrene	Ethylbenzene	
Isophorone	Methylene chloride	
Napthalene	1,1,2,2-Tetrachloroethane	
Nitrobenzene	1,1,2,2-Tetrachloroethene	
N-Nitrosodimethylamine	Toluene	
N-Nitrosodiphenylamine	1,1,1,-Trichloroethane	
N-Nitroso-din-propylamine	Trichloroethylene	
Phenathrene	Trichlorofluoromethane	
Pyrene	Vinyl chloride	
Polychlorinated biphenyl's		
Toxaphene		
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1,2,4-Trichlorobenzene	



Base neutral extractable organics and acid extractable organics are also known as “semi-volatiles”. Semi-volatiles are determined by liquid-liquid extraction followed by gas chromatography – mass spectrometry (GCMS) according to EPA Method 625. Volatile organics are analyzed by purge and trap followed by GCMS according to EPA Method 624. Organochlorine pesticides are determined by liquid-liquid extraction followed by gas chromatography with an electron capture detector (GC-ECD) according to EPA Method 608. There are numerous methods for the determination of metals and cyanide.

High-concentration metals are mostly determined by Inductively Coupled Plasma – Atomic Emission Spectroscopy according to EPA Method 200.7, although flame atomic absorption (AA) methods, such as Standard Methods 3111, may be used. Lower concentrations of metals may also be determined by modern ICP-AES using EPA 200.7 or by electro-thermal atomization (furnace) AA methods, such as EPA 200.9, Standard Methods 3113 B, or hydride atomization methods such as Standard Methods 3114 B. Total cyanide may be determined using UV-visible spectrophotometry after a manual distillation according to SM 4500 CN.

■ Safe Drinking Water Act (SDWA)



The Safe Drinking Water Act (SDWA) ensures the quality of Americans' drinking water. Under the SDWA, the EPA sets standards for drinking water quality and oversees the states, localities, and water suppliers who implement those standards. The United States Environmental Protection Agency (US EPA) is authorized under the SDWA to set national health-based standards for drinking water to protect against both naturally-occurring and man-made contaminants. The US EPA, states, and water systems work together to make sure that these standards are met.

Water systems must use EPA-approved analytical methods when analyzing samples to meet federal monitoring requirements or to demonstrate compliance with drinking water regulations. Approved methods are listed in the Code of Federal Regulations Title 40 Parts 141 - 143. Approved methods are developed by the EPA, other government agencies, universities, consensus methods organizations, water laboratories, and instrument manufacturers. Laboratories must be certified by the EPA or the State to analyze drinking water samples for compliance monitoring.

National Primary Drinking Water Regulations

National Primary Drinking Water Regulations (NPDWR) are legally enforceable standards that apply to all public water systems. These standards protect public health by establishing maximum concentrations of contaminants allowed in finished drinking water. These rules require that laboratories be certified and use only approved methods for analysis. Unless specifically stated in the method, laboratories are not allowed to modify sampling, preservation, or any other conditions required in the method.

Lists of Chemical Contaminants, their MCL, and Potential Sources of Contamination

Table 3: Disinfection by Products and Disinfectants

Contaminant	MCL (mg/L)	Source of contamination
Bromate	0.010	Byproduct of disinfection
Chlorite	1.0	Byproduct of disinfection
Haloacetic Acids (HAA5)	0.080	Byproduct of disinfection
Trihalomethanes	0.080	Byproduct of disinfection
Chloramines (as Cl ₂)	4	Disinfectant
Chlorine (as Cl ₂)	4	Disinfectant
Chlorine Dioxide (as ClO ₂)	0.8	Disinfectant

Table 4: Inorganic Chemicals

Contaminant	MCL (mg/L)	Source of Contamination
Antimony	0.006	Petroleum refining, fire retardants, ceramics, electronics
Arsenic	0.010	Naturally occurring, herbicide, glass and electronics production
Barium	2	Drilling mud, metal refineries, naturally occurring
Beryllium	0.004	Metal refineries. Coal burning power plants and factories, electrical, aerospace, and defense industries
Cadmium	0.005	Corrosion of galvanized pipes, naturally occurring, metal refineries, battery waste
Chromium (total)	0.1	Steel mills, paper and pulp mills
Copper	1.3	Corrosion of household plumbing, naturally occurring
Cyanide (free)	0.2	Steel and metal factories, plastic and fertilizer factories, gold and silver processing
Fluoride	4.0	Additive, naturally occurring, fertilizer and aluminum factories
Lead	0.015	Corrosion of lead solder in household plumbing, naturally occurring
Mercury (inorganic)	0.002	Naturally occurring, refineries and factories, leaking landfills
Nitrate Nitrogen	10	Fertilizer runoff, leaking septic tanks, sewage, naturally occurring
Nitrite Nitrogen	1	Fertilizer runoff, leaking septic tanks, sewage, naturally occurring
Selenium	0.05	Petroleum refineries, mine runoff, naturally occurring
Thallium	0.002	Leaching from ore-processing, electronics, glass and drug factories

Table 5: Organic Chemicals

Contaminant	MCL (mg/L)	Source of Contamination
Acrylamide	0	Added during wastewater treatment
Alachlor	0.002	Herbicide runoff
Atrazine	0.003	Herbicide runoff
Benzene	0.005	Leaking underground storage tanks, industrial discharge
Benzo(a)pyrene	0.0002	Leaking storage tanks
Carbofuran	0.04	Agricultural runoff
Carbon Tetrachloride	0.005	Chemical and industrial plants
Chlordane	0.002	Leaching of contaminated sites
Chlorobenzene	0.1	Chemical or agricultural discharge
2,4-D	0.07	Herbicide runoff
Dalapon	0.2	Herbicide runoff
1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Agricultural runoff



o-Dichlorobenzene	0.6	Industrial discharge
p-Dichlorobenzene	0.075	Industrial discharge
1,2-Dichloroethane	0.005	Industrial discharge
1,1-Dichloroethylene	0.007	Industrial discharge
Cis-1,2-Dichloroethylene	0.07	Industrial discharge
Trans-1,2-Dichloroethylene	0.1	Industrial discharge
Dichloromethane	0.005	Discharge from drug and chemical factories
1,2-Dichloropropane	0.005	Industrial discharge
Di(2-ethylhexyl)adipate	0.4	Discharge from chemical factories
Di(2-ethylhexyl)phthalate	0.006	Discharge from rubber and chemical factories
Dinoseb	0.007	Herbicide runoff
Dioxin (2,3,7,8-TCDD)	0.00000003	Emissions from waste incineration
Diquat	0.02	Herbicide runoff
Endothall	0.1	Herbicide runoff
Endrin	0.002	Leaching of contaminated sites
Epichlorohydrin	0	Impurity of water treatment chemicals
Ethyl benzene	0.7	Leaking underground storage tanks
Ethylene Dibromide	0.00005	Discharge from petroleum refineries
Glyphosate	0.7	Herbicide runoff
Heptachlor	0.0004	Leaching of contaminated sites
Heptachlor epoxide	0.0002	Breakdown of heptachlor
Hexachlorobenzene	0.001	Discharge from metal refineries or agricultural chemical factories
Hexachlorocyclopentadiene	0.05	Discharge from chemical factories
Lindane	0.0002	Agricultural runoff
Methoxychlor	0.04	Agricultural runoff
Oxamyl	0.2	Agricultural runoff
Polychlorinated Biphenyls (PCBs)	0.0005	Leaking landfills and leaching of contaminated sites
Pentachlorophenol	0.001	Discharge from wood preservation processes
Pichloram	0.5	Herbicide runoff
Simazine	0.004	Herbicide runoff
Styrene	0.1	Discharge from rubber and plastic factories, leaching of landfills
Tetrachloroethylene	0.005	Discharge from dry cleaning and factories
Toluene	1	Leaking underground storage tanks, discharge from petroleum refineries
Toxaphene	0.003	Agricultural runoff
2,4,5-TP (Silvex)	0.05	Leaching of contaminated sites
1,2,4-Trichlorobenzene	0.07	Discharge from textile factories
1,1,1-Trichloroethane	0.2	Discharge from degreasing processes
1,1,2-Trichloroethane	0.005	Discharge from chemical factories
Trichloroethylene	0.005	Discharge from metal degreasing processes
Vinyl Chloride	0.002	Leaching of PVC
Xylenes (total)	10	Leaking underground storage tanks

National Secondary Drinking Water Contaminants

National Secondary Drinking Water Contaminants (NSDWRs) are non-enforceable guidelines. NSDWRs regulate contaminants that may cause cosmetic effects or aesthetic effects in drinking water. The EPA recommends these MCLs be met, but systems are not required to comply. Many states choose to enforce these limits.

Table 6: Secondary Drinking Water contaminants and noticeable effects

Contaminant	MCL (mg/L unless otherwise noted)	Noticeable effects above the MCL
Aluminum	0.05 – 0.2	Colored water
Chloride	250	Salty taste
Color	15 (C.U.)	Visible color
Copper	1.0	Metallic taste
Corrosivity	Not corrosive	Corrodes pipes
Fluoride	2.0	Discolored teeth
Foaming Agents (surfactants or MBAS)	0.5	Frothing and foaming, cloudy, bitter taste
Iron	0.3	Yellow or orange stain
Manganese	0.05	Brown or black stain, metallic taste
Odor	3 (TON)	Rotten egg smell, musty smell
pH	6.5 – 8.5 (S.U.)	Corrosion, metallic taste or deposits
Silver	0.10	Skin and eye discoloration
Sulfate	250	Salty taste
Total Dissolved Solids	500	Salty taste, deposits
Zinc	5	Metallic taste

More Information about Disinfection Byproducts

Water suppliers often add a disinfectant to protect drinking water from water borne pathogens. Disinfectants may be chlorine, chlorine dioxide, chloramine, ozone, or treatment with ultraviolet light. Disinfection procedures can be complicated because the disinfectant can react with constituents in the sample, such as organic matter or bromide, and form byproducts that may pose health risks.

A major challenge in water disinfection is adding enough disinfection chemical to kill all pathogens and still maintain the byproduct concentration below the MCL. Table 1 listed the disinfectants and disinfection byproducts that are regulated by the USEPA.

Control of disinfection byproduct formation (DBP) is accomplished by minimizing DBP precursors. Chlorine reacts with naturally occurring organic matter to form Trihalomethanes and Haloacetic acids. Organic matter in drinking water sources and finished drinking water is measured as Total Organic Carbon (TOC). Water systems that use traditional filtration methods for removal of organic matter are required to remove certain percentages of TOC depending upon the concentration of TOC and alkalinity in the source water. This rule only applies to systems treating surface water. In essence, a system measures the source water and finished water once monthly for TOC and calculates the % TOC removal. Table 7 shows the percent TOC removal requirements as a function of TOC and alkalinity concentration.

Table 7: TOC removal requirements

Source Water TOC (mg/L)	Source Water Alkalinity (mg/L as CaCO ₃)		
	0 – 60	– 120	Greater than 120
2.0 – 4.0	35.0 %	25.0 %	15.0 %
4.0 – 8.0	45.0 %	35.0 %	25.0 %
Greater than 8.0	50.0 %	40.0 %	30.0 %



■ Resource Conservation and Recovery Act (RCRA)

Under the Resource Conservation and Recovery Act (RCRA), the EPA has the authority to control hazardous waste. This includes the generation, transportation, treatment, storage, and disposal. RCRA also enables the EPA to address environmental problems that could result from underground tanks storing petroleum and other hazardous substances. The solid waste program encourages states to develop comprehensive plans to manage nonhazardous industrial solid waste and municipal solid waste. The solid waste program sets criteria for municipal solid waste landfills and other solid waste disposal facilities, and prohibits the open dumping of solid waste. The hazardous waste program establishes a system for controlling hazardous waste. The underground storage tank (UST) program regulates underground storage tanks containing hazardous substances and petroleum products.



The SW-846

The EPA publication SW-846, entitled *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, is a compendium of analytical and sampling methods that have been approved for use in complying with the RCRA regulations. SW-846 functions primarily as a **guidance document** setting forth acceptable, although not required, methods.

The Toxicity Characteristic Leaching Procedure (TCLP) determines whether a waste is hazardous. The TCLP leaching procedure is found in the SW-846 and maximum contaminant limits (MCL) are described at 40 CFR Part 261. The leaching part of the test is very specific and requires analysis for volatile and semi-volatile organics, pesticides and herbicides, and trace metals. If any of the targeted analytes exceed the MCL, the waste is considered hazardous. A waste may also be considered hazardous if it is ignitable, corrosive, or reactive. Additional tests are described in the SW 846. See Table 8 for a list of the TCLP analytes and their MCL.

Table 8: TCLP analytes and their MCL

Contaminant	MCL (mg/l)
Arsenic (As)	5.0
Barium (Ba)	100.0
Benzene	0.5
Cadmium (Cd)	1.0
Carbon Tetrachloride	0.5
Chlordane	0.03
Chlorobenzene	100.0
Chloroform	6.0
Chromium (Cr)	5.0
o-Cresol	200.0
m-Cresol	200.0
p-Cresol	200.0
Cresol	200.0
2,4-D	10.0
1,4-Dichlorobenzene	7.5
1,2-Dichloroethane	0.5
1,1-Dichloroethylene	0.7
2,4-Dinitrotoluene	0.13
Endrin	0.02
Heptachlor	0.008
Hexachlorobenzene	0.13
Hexachlorobutadiene	0.5
Hexachloroethane	3.0

Lead (Pb)	5.0
Lindane	0.4
Mercury (Hg)	0.2
Methoxychlor	10.0
Methyl ethyl ketone	200.0
Nitrobenzene	2.0
Pentachlorophenol	100.0
Pyridine	5.0
Selenium (Se)	1.0
Silver (Ag)	5.0
Tetrachloroethylene	0.7
Toxaphene	0.5
Trichloroethylene	0.5
2,4, 5-Trichlorophenol	400.0
2,4,6-Trichlorophenol	2.0
2,4,5-TP (Silvex)	1.0
Vinyl Chloride	0.2

■ Analytical Instrument Selection

Shimadzu's laboratory instruments can be used to analyze nearly all of the pollutants listed for drinking water, wastewater, groundwater, and solid waste. Designed to meet or exceed EPA method criteria, Shimadzu laboratory and on-line instruments typically achieve lower detection limits and have less interference than comparable instruments that were used to generate the original EPA-approved methods.

This guide contains a partial list of methods and corresponding instruments used for the environmental analysis. Should you require analysis by a method not listed in this guide, please contact Shimadzu.

■ The Laboratory Balance

The laboratory balance is a central and indispensable piece of laboratory equipment. A balance is necessary for almost all work in the modern environmental laboratory. The balance's use ranges from the weighing of neat materials to the actual measurement of the mass of analyte itself. The analytical balance may be used in "gravimetric analysis", a branch of chemistry that determines the concentration of an analyte by direct measurement of its mass. In the gravimetric analysis of environmental parameters, such as Total Suspended Solids, it is not uncommon to routinely measure concentrations as low as 1 ppm.

Gravimetric analysis may be simply evaporation of an aqueous sample to measure the residue, filtration and measurement of the mass collected on the filter, or it may involve the addition of chemicals to form a precipitate that can be weighed. Environmental tests, such as suspended solids Standard Methods¹ 2540 B, Total Solids Dried at 103 – 105°C (TS), 2540C Total Dissolved Solids Dried at 180°C (TDS), and 2540D Total Suspended Solids Dried at 103 – 105°C (TSS), are gravimetric techniques. Gravimetric analyses are dependent upon the accuracy of an analytical balance.

A top loading balance accurate to at least 0.1 gram, such as the [Shimadzu UX620H](#) (Figure 1), is used for preparing reagents, etc., and an accurate analytical balance, such as the [Shimadzu AUW220](#) (Figure 2), is used for preparing standard solutions and reagents requiring small mass measurements (< 1 gram), and for the accurate final measurements of solids by the Standard Methods listed above.



Figure 1: UX620H
Top-loading Balance



Figure 2: AUW220
Analytical Balance



■ UV-Visible Spectrophotometry

A good, scanning, UV-Visible spectrophotometer is an essential tool in almost every environmental laboratory. The spectrophotometer can be used to estimate organic contamination of a water sample by direct absorbance at 254 nm. In addition, it can be used to analyze metals or conventional pollutants after reaction with reagents prescribed in the methods. A wavelength range of 190 – 1100 nm makes every environmental test requiring UV-Visible spectrophotometry possible on just one instrument. See Table 9 for a listing of common environmental tests.

Table 9: Environmental Methods requiring UV-Visible Spectrophotometry

Component	Method	Technique
Aluminum	SM 3500-Al B-2011	Eriochrome cyanide R
Ammonia Nitrogen	ASTM D1426-08	Nessler
	SM 4500-NH ₃ F-2011	Manual phenate
Arsenic	SM 3500-As B-2011	SDDC
	ASTM D2972-08(A)	
Cadmium	SM 3500-Cd B-2011	Dithizone
Chloride	USGS I-1187-85	Thiocyanate
Chlorine – free and total	SM 4500-CL G-2011	DPD
Chromium VI	SM 3500-Cr B-2011	Diphenylcarbazide
Chromium - total		
Color	SM 2120 B-2011	Pt-Co
Copper	SM 3500-Cu B-2011	Neocuprione
	SM 3500-Cu C-2011	Bathocuprione
Cyanide - Total	SM 4500-CN E-2011	Pyridine barbituric acid
	ASTM D2046-09	
Cyanide - Free	ASTM D4282-02	
Fluoride	SM 4500-F D-2011	SPADNS
Iron	SM 3500-Fe-2011	phenanthroline
Total Kjeldahl Nitrogen (TKN)	ASTM D1426-08 (A)	Nessler
Lead	SM 3500-Pb B-2011	Dithizone
Manganese	SM 3500-Mn B-2011	Persulfate
Nitrate - Nitrogen	N07-0003	Reductase
Nitrate/Nitrite Nitrogen	SM 4500-NO ₃ F-2011	Cadmium Reduction
	N07-0003	Reductase
	HACH 10206	2,6-Dimethylphenol
Nitrite - Nitrogen	SM 4500-NO ₂ E-2011	diazotization
Phosphate	SM 4500-P E-2011	Molybdenum blue
	EPA 365.3	
Phenolics	EPA 420.1	4AAP
Phosphorus - Total	EPA 365.3	Persulfate/molybdenum blue
	SM 4500-P E-2011	
Silica	SM 4500-SiO ₂ C-2011	molybdate
Sulfate	SM 4500-SO ₄ E-2011	turbidimetric
Sulfide	SM 4500-S D-2011	Methylene Blue
Surfactants	SM 5540-C-2011	Methylene Blue
Zinc	SM 3500-Zn B-2011	Zincon



The [Shimadzu UV-1280 UV-Visible spectrophotometer](#) allows users to select the optimum wavelength for the analysis. Wavelengths listed in the methods, such as those listed in Table 1, are often not at the absorbance maximum, resulting in decreased sensitivity and poor linearity. The UV-1280 enables users to scan the full wavelength range on a color-developed standard, find the correct maximum, and modify the method. This 40 CFR Part 136.6 allowed method modification can result in better linearity and lower detection limits.

A UV-Visible spectrophotometer should not be thought of as monochromatic (single wavelength), but rather a narrow band of light on both sides of the wavelength selected. Too narrow a band decreases sensitivity and too wide a band decreases linearity. The 5nm band of the Shimadzu UV-1280 is narrow enough for maximum linearity and broad enough for low detection limits. For example, Figure 3 shows a calibration for Chromium 6, indicating accurate quantitation well below the USEPA MCL of 0.1 mg/L.

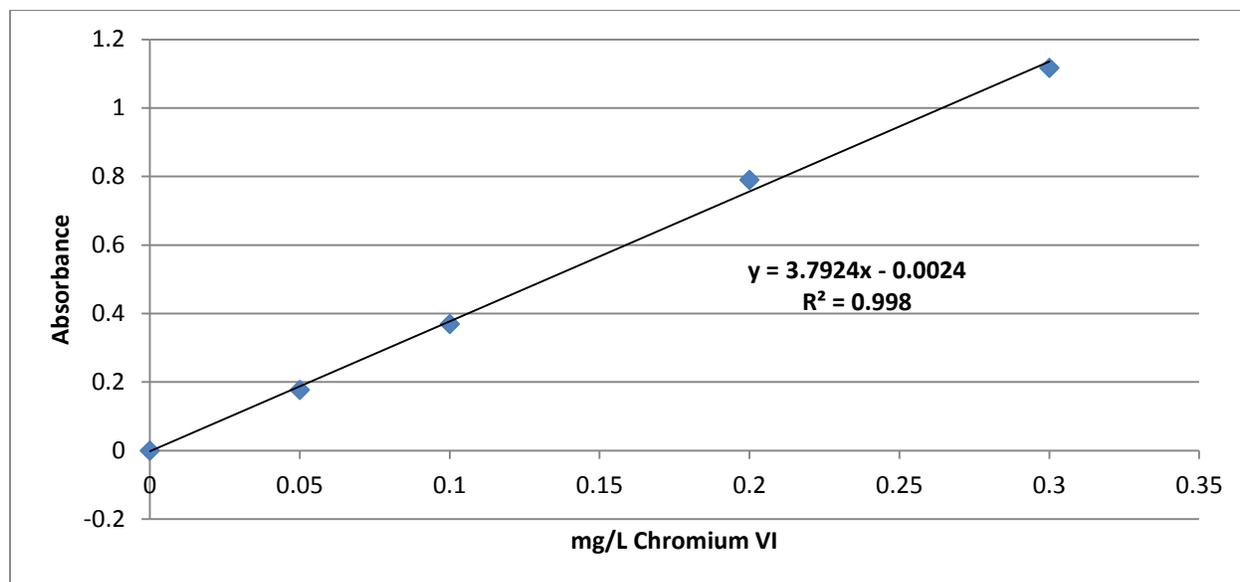


Figure 3: Calibration Curve for Chromium 6 on the Shimadzu UV-1280

■ Total Organic Carbon Analyzers

Total Organic Carbon (TOC) methods analyze for organic carbon and express the result as the amount of carbon found. TOC does not distinguish between various organic species and only indicates that organic carbon compounds are present. Organic carbon analyzers operate by the determination of the amount of total carbon present in a sample aliquot. Total carbon consists of inorganic and organic carbon. The inorganic carbon, present as carbonate or bicarbonate ions, must be removed or quantified prior to the analysis of organic carbon. Once the inorganic carbon is removed, subsequent analysis of the sample aliquot assumes that all carbon remaining is organic.



Shimadzu is known world-wide for developing the high-temperature catalytic oxidation technique (HTCO). This highly efficient oxidation technique is specified in several USEPA-approved methods, including EPA 415.3, SM 5310B, and ASTM D7573. Catalytic combustion oxidizes organic carbon containing compounds more effectively than competing wet chemical oxidation methods.

The [Shimadzu TOC-L](#) use a platinum catalyst heated at 680 – 720 °C. The temperature required for catalytic combustion is significantly lower than required for combustion without a catalyst, increasing combustion tube life and minimizing the effect of high salt content in samples.



Shimadzu is the leader in TOC analysis and has developed instruments capable of accurately and precisely determining TOC from very low parts per billion to thousands of parts per million. Applicable matrices vary from very clean ambient or finished drinking water, highly particulated wastewaters, and highly mineralized plating solutions, to soil and filter media.

Total Organic Carbon (TOC) analyzers are used to measure the organic matter disinfection byproduct precursors in source water and finished drinking water. The preferred technique for source water is HTOC because it completely oxidizes large organic molecules, such as humic acids, that are not always completely oxidized using wet chemical methods. A higher TOC value measured in the source water results in a higher calculated % TOC removal.

Total Nitrogen Analysis



There is currently no automated nationwide EPA-approved method for the determination of total nitrogen in ambient water and wastewater. There are approved methods for the determination of inorganic nitrogen ($\text{NO}_3\text{-N}$, $\text{NO}_2\text{-N}$, and $\text{NH}_3\text{-N}$), and organic nitrogen (TKN – $\text{NH}_3\text{-N}$). While there are no methods for the determination of total nitrogen, it is still a required parameter in monitoring nutrient pollution for ambient water criteria.

High-temperature catalytic oxidation with chemiluminescence detection obtains total nitrogen using a Shimadzu TOC-L fitted with a [total nitrogen \(TN\) module](#). The technique is rapid, accurate, and obtains results in five minutes or less.

■ Ion Chromatography

The purpose of ion chromatography is to separate analytes and measure them separately. [Ion chromatography](#) makes it possible to separate ions, measure them directly or react them chemically, and determine the concentration of individual reaction products from a single sample injection. Thus, with ion chromatography, multiple analytes can be determined from one injection.

One of the most common uses of ion chromatography is the determination of anions in aqueous samples. With one injection, the most common anions in water can be accurately measured in about 10 to 15 minutes. Anion chromatography is used extensively in the analysis of anions and disinfection byproducts in drinking water, and since 2012, has been approved for the analysis of anions and cations in wastewater.



The ion chromatograph described in EPA Methods 300.0 and 300.1 consists of an autosampler, a pump, an injection valve, a column and guard column, a suppressor, and a conductivity detector. Separation of analytes takes place on the column while the guard column helps to prevent contamination of the column.

The suppressor changes the eluent composition to a composition with lower electrical conductivity. Solutions such as aqueous sodium carbonate are used as the eluent. When anions are separated, the presence of sodium ions generates eluted carbonate ions. Eliminating the sodium ions just before the detector changes the eluent to a slightly acidic aqueous carbonate solution, with lower electric conductivity. Meanwhile, in the regions where the inorganic anions in the sample elute, the carbon dissociation equilibrium shifts toward creating more H^+ ions that become pair ions in order to maintain balanced charges (see the chromatogram of H^+ ions in the eluent in Figure 4). Because hydrogen ions have a higher equivalent electric conductivity than other ions, this increases the peak response (Figure 4).

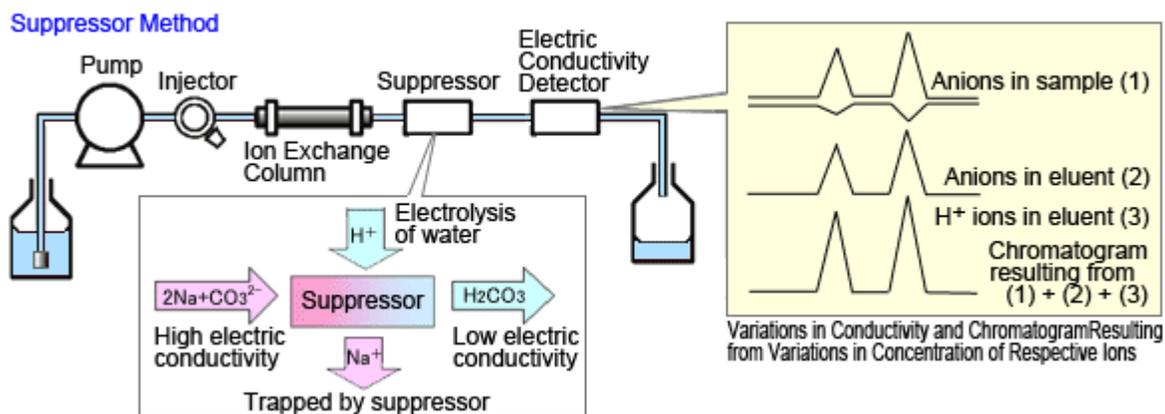


Figure 4: Schematic of the suppressor method for ion chromatography of anions

Ion Chromatography with suppressed conductivity is an excellent technique for the determination of anions in drinking water, relatively clean groundwater, and wastewater. In samples of unknown matrices, conductivity should first be determined so that dilutions can be made prior to analysis. These dilutions are necessary to avoid overlap of large peaks with smaller peaks and to bring large amounts of analyte (usually chloride or sulfate) within calibration range. Unfortunately, this necessary pre-dilution sometimes causes other analytes to be diluted below detectable levels.

The ion chromatograph may also be run without suppression, making it possible to analyze higher concentrations of anions without dilution. Standard Methods 4110C is a non-suppressed conductivity method approved for anions in wastewater.

The non-suppressor method connects the electric conductivity detector directly to the outlet of the anion separation column. Anions in the sample are retained in the separation column by anion exchange to separate them from cations in the eluent. Due to the ion exchange, the concentration of anions in the eluent in this region decreases. Electric conductivity detectors detect the total of all three types of ions – anions in the sample, anions in the eluent, and cations in the eluent (Figure 5). Therefore, a low-concentration aqueous organic acid solution with high elution strength is used as the eluent.

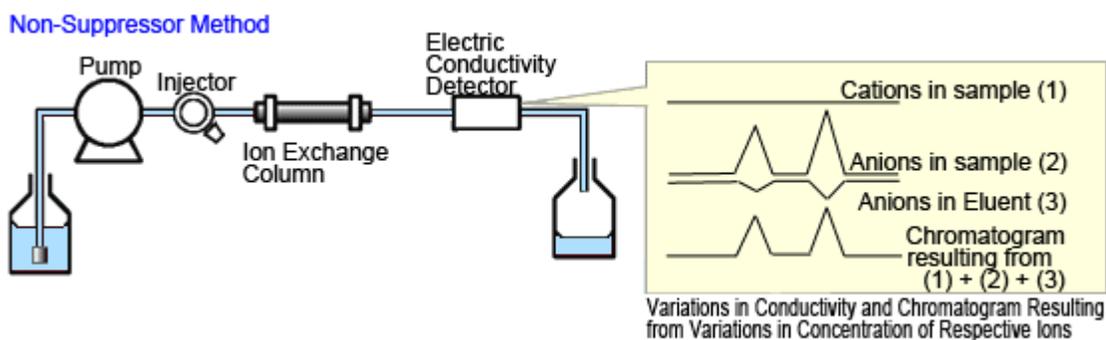


Figure 5: Schematic of the non-suppressor method for cations and anions



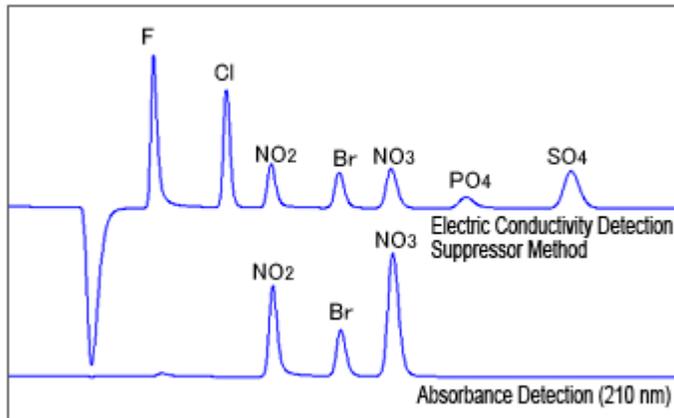


Figure 6: Example of Electric Conductivity Detection and Direct Absorbance Detection

Some inorganic anions have absorption peaks in the UV wavelength range. Nitrite, bromide, nitrate, and other ions can be detected at wavelengths near 210 nm. This technique, though not yet EPA approved, is useful for determining trace concentrations of nitrite, bromide, and nitrate in samples such as production water, that are very high in chloride and/or sulfate.

■ Metals Analysis

Metals analysis is loosely defined and encompasses the metals listed in SDWA, CWA, and RCRA regulations, along with major cations. Precious metals, such as platinum, and rare earth elements (REE) are not typically found in environmental samples. Most metals regulations require analysis of total metals. Total metals are defined as a preliminary acid digestion of unfiltered sample followed by determination of the metal by an approved method. Some regulations specify dissolved metals. Dissolved metals are filtered through a 0.45 μm filter prior to the acid digestion. If the filtered sample has a turbidity of less than 1 NTU and no color, then the preliminary acid digestion for dissolved metals may be omitted.

Multiple analysis techniques and methods are necessary to meet the detection limit for the analysis of all metals in the respective EPA target lists. Different techniques may include UV-Visible spectrophotometry, AA, or ICP-AES. The methods used depend on the regulation, the MCL, the required method detection limits (MDL), and the complexity of the matrix. Unless only analyzing drinking water, it is likely the analysis will involve a variety of matrices, including total dissolved solids (TDS), trace metal concentration, and organic concentration. These could be water, acid digestions, leachate solutions or soil extracts and digests. The greater the variability of the matrix, the more important it is to choose instruments capable of overcoming matrix interferences.

■ Atomic Absorption Spectrophotometry



[Atomic Absorption Spectrophotometry \(AAS\)](#) is a single-element technique used to measure metals in aqueous samples. AA is the instrument of choice for laboratories running fewer than six elements per sample in only a few samples per day because of its great flexibility and lower operating costs.

AA can be operated in three atomization modes; flame, furnace, or hydride. Flame AA is used to measure elements in the ppm (mg/L) range while furnace and hydride measure elements in the ppb ($\mu\text{g/L}$) or low ppb range. Hydride atomization is especially useful for the determination of arsenic and selenium. See Table 10 for examples of metals determined by AA and their detection limits (MDL).

Table 10: Atomic Absorption Detection Limits

Element	Flame MDL (µg/L)	Furnace MDL (µg/L)
Ag	5	
Al		0.1
As (hydride)		0.1
Ba		0.02
Be		0.1
Cd	3	0.004
Cr	10	0.02
Cu	10	
Fe	30	
Mn	10	
Pb		0.05
Sb (hydride)		0.2
Se (hydride)		0.2
Sr*	20	
Zn	2	

*Strontium is not regulated, but has been proposed for future drinking water regulation

■ Inductively Coupled Plasma – Atomic Emission Spectroscopy

[Inductively Coupled Plasma Atomic Emission Spectroscopy \(ICP-AES\)](#) is a multiple-element technique used to measure metals and semi-metals in aqueous samples. ICP-AES is capable of analyzing up to 71 elements in 1-2 minutes; however, realistically, most laboratories limit the number of metals to 20 or fewer. ICP-AES detection limits are mostly between Flame AA and Furnace AA. Attachments, such as ultrasonic nebulization, can lower ICP detection limits significantly. ICP-AES is the instrument of choice for high-throughput laboratories routinely analyzing multiple elements on a large number of samples. See Table 11 for examples of metals determined by ICP-AES and their MDLs.

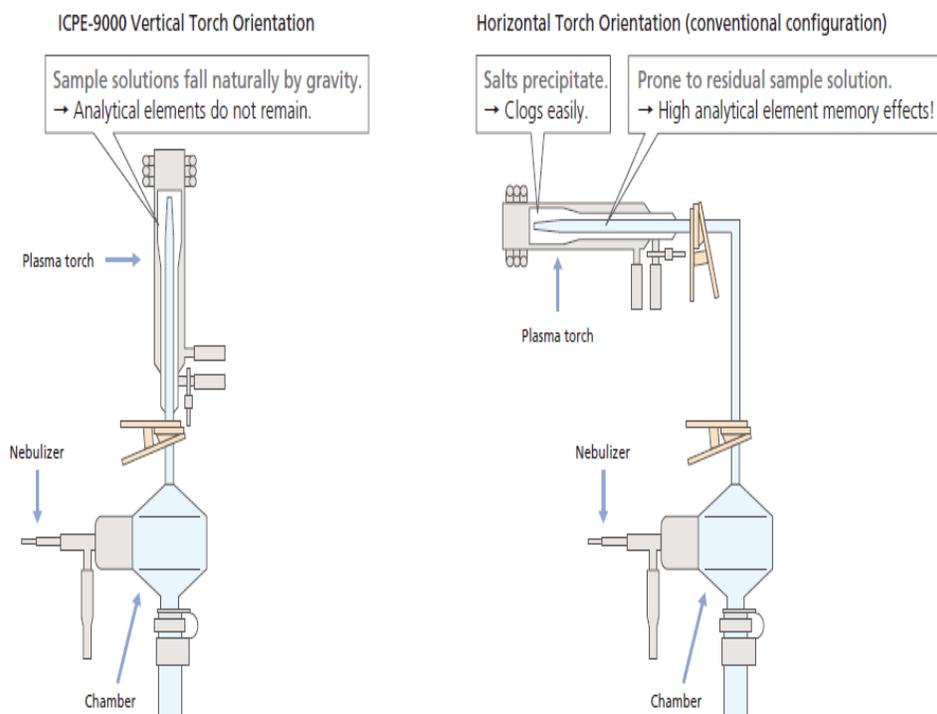
**Table 11:** ICP-AES MDLs

Element	Standard Nebulizer MDL (µg/L)	Ultrasonic Nebulizer MDL (µg/L)
Ag	0.3	0.04
Al	0.5	0.2
As	4	3
Ba	0.01	0.01
Be	0.02	0.002
Cd	0.1	0.02
Cr	0.3	0.06
Cu	0.4	0.03
Fe	0.1	0.05
Mn	0.03	0.01
Pb	2	0.3
Sb	3	5
Se	4	0.8
Sr*	0.007	0.001
Zn	0.2	0.02

*Strontium is not regulated, but has been proposed for future drinking water regulation



The [Shimadzu 9800 series ICP-AES](#) measures up to 110,000 emission lines and is capable of both axial and radial view in a single sample aspiration without loss in sensitivity or linear range. High-resolution optics and a vertical-oriented torch minimize both physical and spectral interferences. The specially designed mini-torch and vacuum purged optical box result in lower argon consumption compared to any other ICP-AES on the market.



The ICPE-9000 torch is oriented vertically to minimize analytical element memory effects.

■ Organic Analysis

In environmental testing, organic analysis includes compounds containing carbon and one or more other elements such as hydrogen, chlorine, nitrogen, and sulfur. Trace organic analysis is the determination of organic compounds at concentrations below 1000 parts per million. The analysis provides the identity (qualitative identification) and the amount (quantitation). Trace organic analysis “looks” for very small concentrations of target analytes in the presence of much higher concentrations of non-target compounds contained in the sample. Generally, environmental organic analysis includes a separation of a mixture of analytes and a determination of their identity and concentration as an integrated measurement step.

Separation techniques usually involve transport of the sample mixture through a column containing a material that selectively retains components as they travel through the column either as a liquid or a gas. Ideally, the separation is fast, efficient, and complete. In reality, complete separation is rare and the method consists of a series of compromises. Compounds that elute from the column are detected based on a physical or chemical property, producing a signal that is proportional to concentration.

■ Gas Chromatography



Gas chromatography is a relatively inexpensive laboratory instrument used to separate components in a mixture. These mixtures, usually a sample extracted with organic solvent, are injected into a gas stream and propelled through a very long open tubular column lined with a high boiling point liquid phase. The column is in an oven, and ramping the oven temperature causes the individual components to separate as a function of temperature and degree of reaction with the liquid phase lining the column walls.

Once the separated components emerge from the column, they pass through a detector that registers a signal proportional to concentration.

Flame ionization detectors (FID) are useful for detecting hydrocarbons and used in methods such as SW846 Method 8015. Other common detectors are the electron capture detector (ECD), flame photometric detector (FPD), and the thermionic detector (also known as a nitrogen phosphorus detector or NPD). See Table 12 for examples of EPA chromatography methods and the required detectors.

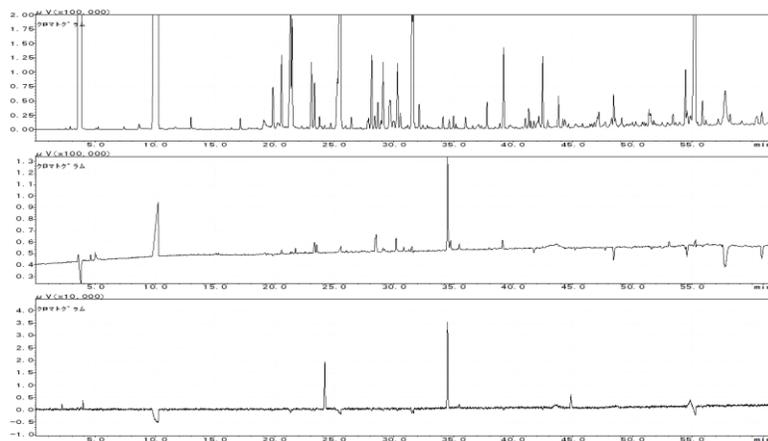
Table 12: Examples of EPA Chromatography Methods and the Required Detectors

Contaminant Group		Method	Detector
Organochlorine pesticides and PCB's		508 (dw) 608 (ww) 8081 (sw)	ECD
Organophosphorus pesticides		614 (ww) 8140 (sw)	FPD
Organophosphorus and organonitrogen pesticides	507 (dw)	NPD	
Chlorinated Acid Herbicides	515 (dw) 615 (ww) 8150 (sw)	ECD	

dw = drinking water

ww = wastewater

sw = solid waste



Three detectors can be simultaneously mounted in the [GC-2010 Plus](#): ECD, effective for chlorinated and pyrethroid-based pesticides; FPD, effective for sulfur- and phosphorous-based pesticides; and FTD, effective for nitrogen- and phosphorous-based pesticides.



Since 1956, Shimadzu has been developing innovative gas chromatography solutions, combining engineering expertise with customer needs. The GC-2010 Plus enables reliable, high-precision, trace analysis. Rapid oven cooling, high-performance flow control, backflush technology, and industry-leading detector sensitivity combine to provide you with shortened analysis times and low detection limits.

■ Gas Chromatography – Mass Spectrometry

Gas Chromatography Mass Spectrometry (GCMS) combines the separation of GC with a mass selective detector that produces a fragmentation pattern specific to each analyte. This provides GC analysis with a means to obtain both qualitative and quantitative information, eliminating the need for a second column confirmation. GCMS is used for the analysis of volatiles, semi-volatiles, pesticides, herbicides, and other organic contaminants in drinking water, wastewater, and solid waste.



Laboratories needing to run volatile or semi-volatile organics in environmental samples should seriously consider GCMS. Modern GCMS instruments are not expensive (relatively speaking) and, whether you are a commercial laboratory or a non-profit, your return on investment is quicker than you may think. Modern GCMS systems are much simpler than they were when the methods were originally written and are usually capable of detection limits much lower than in the published methods.

Methods are defined by the EPA program to which the methods are applied: 500 series for drinking water, 600 series for wastewater, and 8000 series for everything else. These EPA methods define a list of target compounds, required detection limits, calibration ranges, the analytical technique that must be used, and minimum quality control requirements. The Shimadzu GCMS-QP-2010 SE coupled with the EST Purge and Trap (or any purge and trap) is the instrument of choice for volatiles, and the Shimadzu GCMS-QP2010 Ultra is the instrument of choice for semi-volatile analysis.

GCMS-QP2010 SE



The [Shimadzu GCMS-QP2010 SE](#) is “designed” for volatiles analysis so that it can pass the required BFB tune check compound criteria easily. The GCMS-QP2010 SE keeps cost low enough so you can easily afford a volatiles GCMS and a purge and trap.

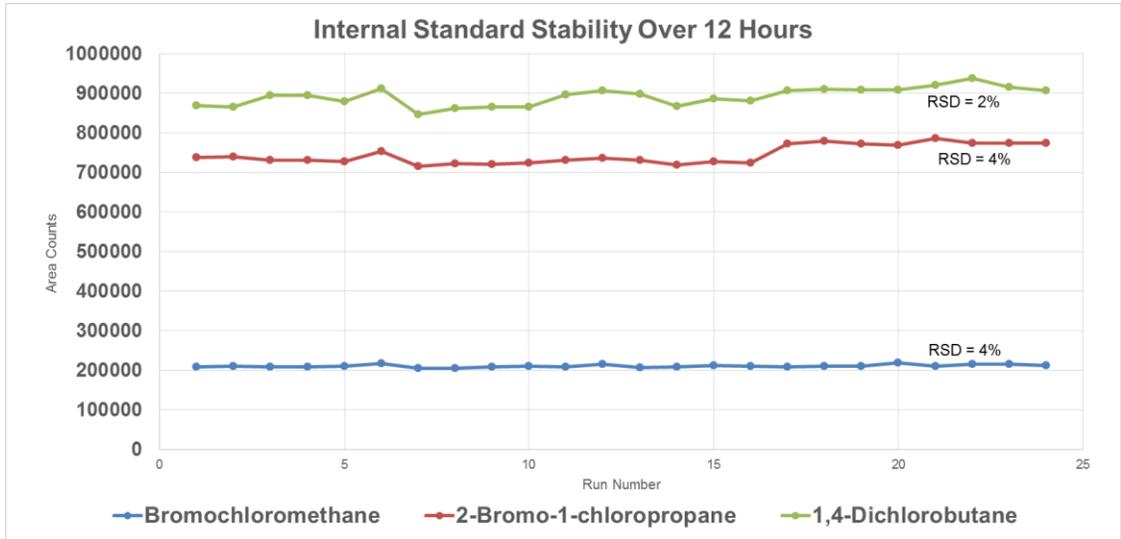


Figure 7: Long-term Stability of the GCMS-QP2010 SE

Of course, a GCMS-QP2010 SE can be used for semi-volatile analysis and is capable of reaching the required detection limits of EPA semi-volatile methods, but it is not as sensitive, nor as fast, as the GCMS-QP2010 Ultra (see below). A GCMS-QP2010 SE with Shimadzu “twin-line capability” enables smaller labs that feel they are unjustified at purchasing two instruments to run volatiles and semi-volatiles on one instrument without changing columns.

GCMS-QP2010 Ultra

The [Shimadzu GCMS-QP2010 Ultra](#) is the best GCMS on the market in regards to vacuum pump down, speed, and sensitivity. The high scan speed enables shortening of chromatographic runs, doubling throughput. The high scan speed enables multiple spectra across a peak with no loss of sensitivity at the higher masses. The GCMS-QP2010 Ultra is designed for high sensitivity at the higher masses, and capable of passing a DFTPP tune check without difficulty. The higher sensitivity of the GCMS-QP2010 Ultra enables analysts to extract less sample volume (for example 100 milliliters instead of 1000 milliliters) and still obtain the required detection limits. Extracting less sample volume saves the lab shipping costs and reduces instrument maintenance because less contamination is injected into the GC.

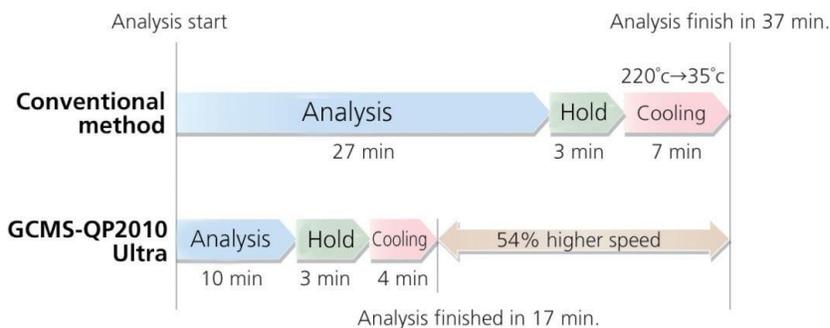


Figure 8: Increase in Productivity using Fast Analysis on the GCMS-QP2010 Ultra



■ Liquid Chromatography



[High Performance Liquid Chromatography \(HPLC\)](#), formerly known as high pressure liquid chromatography, is used to separate then detect components in a mixture. The HPLC pumps pressurized liquid containing sample through a column where separation takes place. As individual components emerge from the column, they pass through a detector that generates a signal proportional to concentration. Qualitative identification is made by retention time and quantitation is made by comparing sample intensity to a calibration curve generated by analysis of standard solutions.

Detectors may include UV or visible spectrophotometry, fluorescence spectrometry, or mass spectrometry. Some components, such as polynuclear aromatic hydrocarbons (PAH), may be measured directly by UV absorbance. Other compounds, such as carbamate pesticides, require a post-column derivatization reaction to convert the analytes to a measurable form prior to detection.

Table 13: EPA-approved HPLC Methods

Contaminant Group	Method	Detection Technique
Carbamate Pesticides	EPA 531.1 (dw)	Post column derivatization
	EPA 531.2 (dw)	
	EPA 632 (ww)	
	SW 846 8315 (sw)	
PAH	EPA 610 (ww)	UV absorbance
	EPA 550.1 (dw)	UV absorbance and Fluorescence
Glyphosate	EPA 547	Post column derivatization
Phenyl urea compounds	EPA 532 (dw)	UV absorbance
Diquat/Paraquat	EPA 549 (dw)	UV absorbance
Chlorinated Acids	EPA 555 (dw)	UV (210-310nm)
Carbonyl compounds	SW 846 8315a (sw)	UV-Vis
Non-volatiles (Dyes)	SW846 8321 (sw)	UV (may also use MS)

■ Emerging Technology

Emerging technology is defined here as techniques that are not yet written into methods required for compliance monitoring. Liquid Chromatography Tandem Mass Spectrometry (LC-MS/MS) has seen the greatest interest in new methods, particularly for the Unregulated Contaminants Monitoring Rule (UCMR) of the Safe Drinking Water Act. LC-MS/MS methods are superior to existing GC-ECD methods for acid herbicides and carbamates because the LC-MS/MS does not require derivatization.

■ Liquid Chromatography Tandem Mass Spectrometry



[Liquid Chromatography Tandem Mass Spectrometry \(LC-MS/MS\)](#) is a powerful technique capable of analyzing polar and large molecule organic compounds in ambient water, drinking water, and wastewater effluents. New methods for emerging contaminants, such as pharmaceutical and personal care products (PPCP), and new methods for polar pesticides and herbicides, such as atrazine and 2,4-D, that are difficult to analyze by GC or GCMS are being developed.

LC-MS/MS has an advantage of very rapid analysis times (2-10 minutes) for large numbers of components with very minimal sample preparation. Figure 9 shows the analysis of a water sample for 29 polar pesticides and herbicides after very minimal sample preparation. Notice the number of peaks that seem to overlap. Unlike conventional chromatography, the tandem mass spectrometers are so selective that even when peaks overlap they can be qualitatively and quantitatively analyzed.

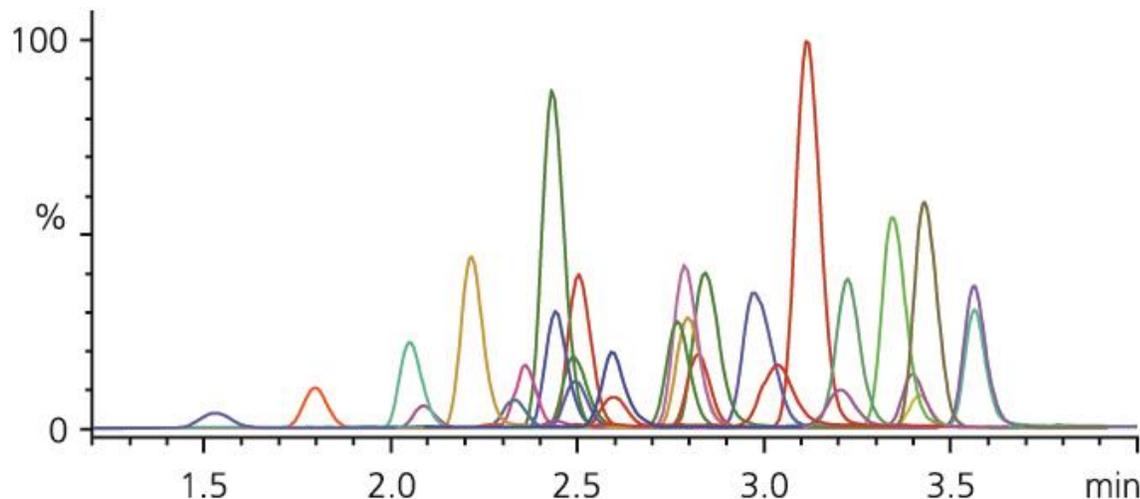


Figure 9: Analysis of 29 polar pesticides and herbicides in 4 minutes

■ Gas Chromatography Tandem Mass Spectrometry

Tandem mass spectrometry is the linking together of two quadrupoles. Ions are separated in the first quadrupole, fragmented further in a collision cell, and the product ions are separated and analyzed by a second quadrupole. (These analyzers are often called “triple quadrupole” analyzers; technically, there are only two quadrupoles with a collision cell between them). This technique eliminates matrix interferences, making it highly selective and extremely sensitive. Data can be collected in at least four modes, as shown in Table 14. The faster scanning analyzers are also capable of Scan/MRM and Scan/SIM all in a single method.

Table 14: Analysis Modes for Tandem GCMS Analyzers

Analysis Mode	First Quadrupole	Second Quadrupole
Product Ion Scan	SIM	Scan
Multiple Reaction Monitoring	SIM	SIM
Precursor Scan	Scan	SIM
Neutral Loss Scan	Scan	Scan

Multiple Reaction Monitoring (MRM) is used for maximum selectivity and the lowest detection limits. The technique eliminates matrix noise and allows only the selected product ion through the second quadrupole. Although the sensitivity is actually less, the noise is reduced so much that MRM detection limits are typically 5–10 times lower than SIM detection limits.

Figure 10 is an example of a chromatogram of Method 624 Semi-Volatile compounds in full scan mode, Method 608 pesticides, and xx PCB congeners in MRM mode. Fast scanning [GC-MS/MS](#) makes it possible to acquire full scan data, keeping in compliance with existing USEPA methods. The MRM mode, with sensitivity greater than SIM, makes it possible to determine pesticides and PCBs at concentrations equivalent to GC-ECD Method 608.



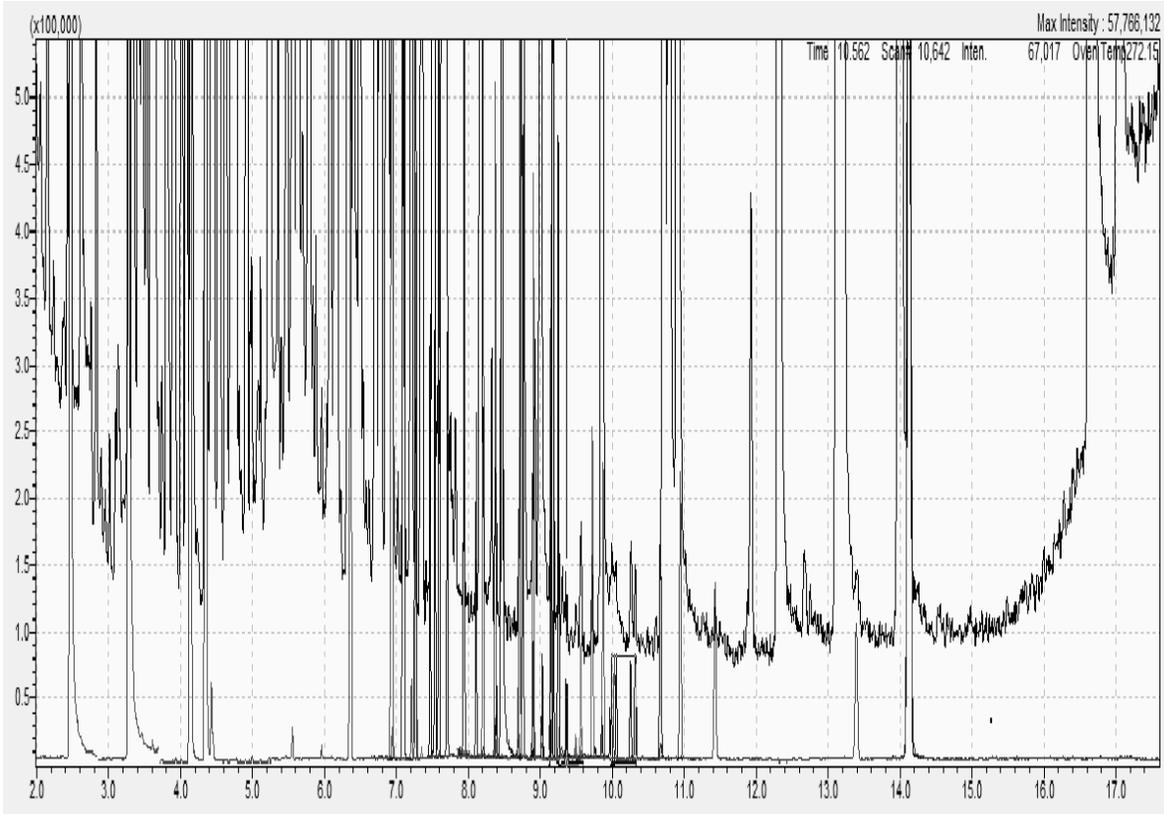
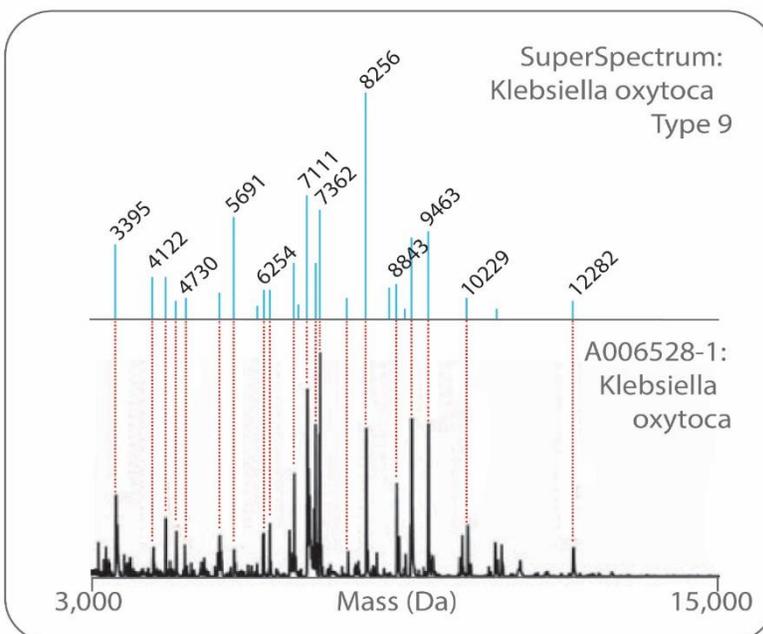


Figure 10

■ Matrix Assisted Laser Desorption Ionization (MALDI) – iD^{Plus}

MALDI uses mass spectrometry to analyze large biomolecules, such as proteins, peptides, and sugars. The [MALDI iD^{Plus}](#) can be used to reliably identify micro-organisms. Samples are cultured in a suitable medium, a colony is scraped off the plate, and a suitable “matrix” is added. The sample plus matrix is transferred to the MALDI plate and irradiated with a laser. Positively charged ions are swept into the MS detector, generating mass spectra that are unique to that organism. The MALDI irradiation and identification takes less than two minutes. ID plus is superior to qPCR because only live, growing organisms are detected.



■ Unified Chromatography

[Unified Chromatography](#) combines Supercritical Fluid Extraction (SFE), Supercritical Fluid Chromatography (SFC), and HPLC with UV-Vis or mass spectrometry detectors. SFE extracts a sample, usually a solid, with a supercritical fluid. In this case the fluid is carbon dioxide (CO₂). SFC is a form of liquid chromatography using CO₂ as the mobile phase. Eluent from the SFC passes through a UV-Vis or mass spectrometry detector producing a signal.

The Unified Chromatography system completely automates sample preparation and analysis. Analysts simply weigh sample into a vessel, place in the autosampler, enter the sample ID's, and run the method.

■ On-line Analyzers

The USEPA issues NPDES permits to regulate point sources that discharge pollutants into "waters of the United States". Point sources are pipes or man-made ditches that convey industrial or municipal wastewater directly into "navigable" surface waters. Unlike pollution from industry or municipalities, non-point source pollution is caused by rainfall or snowmelt moving across or through the ground. As the water moves, it carries with it man-made or natural pollutants and deposits them into "navigable waters of the United States".

In a recent EPA unpublished report, the EPA connects the influence of intermittent and/or perennial tributaries on the physical, chemical, and biological properties of "navigable" waters. The report also notes the role wetlands play in the removal of excess nutrients, as a breeding ground for aquatic life, and as a sink for the accumulation of sediment, nutrients, and environmental pollutants. These smaller tributaries function as nutrient sources. While nutrients are essential to support life, excess nutrients lead to eutrophication and dead zones. Thus, the role of the tributary nutrient loading has a significant impact downstream.

Regulation of Point Sources Did Not Lower Nutrients or Prevent Dead Zones

The EPA has determined that revised water quality standards are necessary to help control the nutrient load of US waters. These new standards will establish maximum allowed nutrient concentrations for various water bodies based on type and designated use. After 40 years of regulation at the end of a pipe, the nutrient concentrations in streams, rivers, and lakes are still high and the size of dead zones in the Chesapeake Bay and Gulf of Mexico is increasing. The EPA will eventually require States to establish and meet numeric ambient water quality criteria regulating the concentration of nutrients and other contaminants.



On-line Analysis Is Needed to Reduce Nutrients in Ambient Streams

Current EPA Clean Water Act (CWA) regulations require that chemical analysis for compliance monitoring be done using methods published at Code of Federal Regulations (CFR) Title 40 Part 136. These laboratory methods define sample collection, preservation, storage, extraction/digestion, analysis, and quality control measures that must be taken. Laboratory methods require that samples be collected and transported to laboratories for analysis and are biased low because sample collection occurs during good weather and nutrient loading onto streams mostly occurs during storm events. To accurately quantify and properly model nutrient loading, on-line (or in situ) analyzers are needed.

- The [Shimadzu TOC-4200](#) for on-line Total Organic Carbon and Total Nitrogen and the Shimadzu TOC-4110 and TOC-4110C on-line Total Nitrogen, Total Phosphorus, and Total Organic Carbon analyzers are perfectly suited to fulfill the EPA's need to collect real-time ambient water nutrient concentrations.
- The Shimadzu analyzer is capable of automatic multiple point calibrations and automatic analysis of quality control samples, making fully compliant with EPA methods, and meets CWA requirements for quality control.
- The TOC-4200 and TOC-4110 are complete systems capable of pretreating, digesting, and analyzing the sample automatically; as a result, they save time and labor, and eliminate errors associated with sample preparation.
- While the Shimadzu high-temperature oxidation with chemiluminescence detection method for total nitrogen is not yet EPA approved, approval is expected within the next five years.
- The [TNPC-4110](#) measures total phosphorous by heated or UV persulfate oxidation followed by molybdenum blue absorptiometry. This technique is consistent with Standard Methods 4500-P E, an EPA-approved method.
- The TNPC-4110 measures total organic carbon by the EPA-approved high-temperature oxidation method SM 5310B.



■ Guide to Purchasing Laboratory Equipment for Environmental Testing

Any purchases of laboratory equipment or instruments must fit the laboratory's needs. Choosing the right instrument for your laboratory is an expensive process for laboratory management. Choosing the wrong instruments will:

1. Affect results
2. Affect analysis reports
3. Affect analyst training
4. Affect profit
5. Affect the purchaser's (or final decision maker) standing in the company

Instruments must be purchased at the right price, but also must do the job that it was purchased for, now and in the future. Future use requires that the instrument be purchased from a reputable company, such as Shimadzu, that will be able to provide you with service and support for the lifetime of your instrument.

You are buying instruments that you need to analyze samples by approved methods. The method defines the matrix, extraction, detection limits, calibration range, and determination technique, as well as the instrumentation necessary to do the test. You can be assured that if you purchase an instrument from Shimadzu that your new instrument is suitable for the test. Therefore, when comparing with competitors, base your decision on reliability, throughput, sensitivity, and dependability of service and support.

As a purchaser of laboratory instruments, you should be less interested in “specifications” and more interested in verifying that the instruments can actually run the environmental methods for which they are intended. Prior to calling your salesperson or writing a bid proposal, seek information through web searches, literature, brochures, tradeshow, and word of mouth. Compile a list of specifications and reduce the list to the needs necessary to run the method. Once you have a list of needs, present these needs to vendors and let them come up with an instrument that best fits your needs.

Not all instruments are the same. It is Shimadzu’s goal that once an instrument is installed in your laboratory that it is the beginning of a long-term relationship. Shimadzu wants to ensure you that we have provided you with the “best fit” for the least cost to you. This cannot be done if you only list out and require certain bid specifications. Your Shimadzu sales professional is a consultant with your best interests in mind. The sales consultants will:

1. Help you to prepare bid specifications that meet your needs
2. Help you to select the best instrument to fit your needs
3. Be involved with the installation
4. Help you solve your problems
5. Assist you with vendor support

The end result is that your product is a piece of paper with words and numbers on it. Those words represent samples and the numbers represent analytical results acquired by an instrument. The numbers need to be reasonably accurate, and they need to be collected when you need them. You do not have time to “fiddle” with an instrument to get it working or to get your quality control to pass. You need your results, and you need them now. To get those results you need reliable instruments made for the task that you are trying to do.

[Shimadzu laboratory and on-line instruments](#) are accurate and precise, and designed to meet or exceed EPA method criteria. They can be used to analyze nearly all of the pollutants listed for drinking water, wastewater, groundwater, and solid waste. You can rely on Shimadzu to provide you with the instruments you need to make your environmental laboratory successful.

This guide contains information on environmental analysis. If you require information not provided in this guide, please contact Shimadzu.

■ Reference

¹ Standard Methods for the Examination of Water and Wastewater 22nd edition





Shimadzu Corporation

www.shimadzu.com/an/

Shimadzu Scientific Instruments

7102 Riverwood Drive, Columbia, Maryland 21046, U.S.A.
Phone: 800-477-1227/410-381-1227, Fax: 410-381-1222

www.ssi.shimadzu.com

Company names, product/service names and logos used in this publication are trademarks and trade names of Shimadzu Corporation or its affiliates, whether or not they are used with trademark symbol "TM" or "®".
Third-party trademarks and trade names may be used in this publication to refer to either the entities or their products/services. Shimadzu disclaims any proprietary interest in trademarks and trade names other than its own.

For Research Use Only. Not for use in diagnostic procedures.

The contents of this publication are provided to you "as is" without warranty of any kind, and are subject to change without notice. Shimadzu does not assume any responsibility or liability for any damage, whether direct or indirect, relating to the use of this publication.