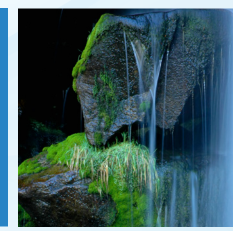
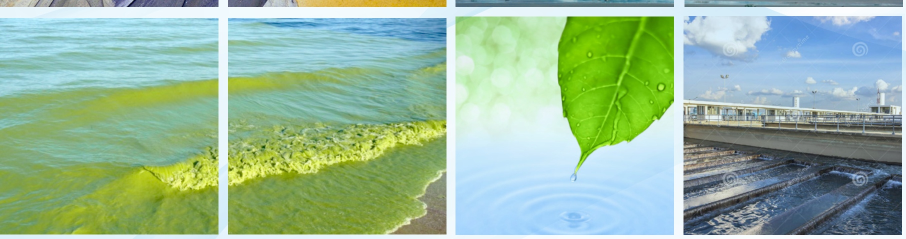
HORIBA Scientific

Aqualog® Environmental Water Research Analyzer





The Gold Standard for Water CDOM Research

www.aqualog.com

Aqualog®

For Water CDOM Research

A Faster and better spectrometer for colored dissolved organic matter (CDOM)

Not just a slow scanning PMT fluorometer for EEMs, Aqualog simultaneously acquires absorbance and fluorescence EEM's with its patented A-TEEM design and ultra-fast CCD detector, acquiring complete A-TEEM fingerprints in seconds.

Two-In-one spectrometer captures more information simultaneously

Simultaneously acquiring absorbance and fluorescence EEMs, Aqualog captures information about fluorescent molecules, such as proteins, algae and BTEX, but it also acquires information about non-fluorescing absorbing parameters, such as specific UV absorbance (SUVA).

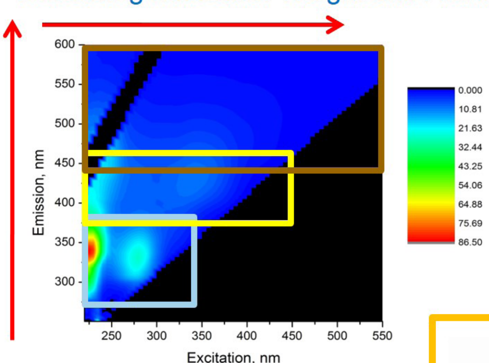
Aqualog A-TEEM fingerprints provide better chemometric analysis

With absorbance-corrected fluorescence EEM fingerprints, the Aqualog provides A-TEEM fingerprints that are independent of fluorophore concentration over a wider dynamic range, thus lending themselves to more reliable chemometric component analysis than a traditional scanning fluorescence EEM.

NIST-traceable validation

The Aqualog spectrometer is fully traceable with National Institutes of Standards and Technology (NIST) standard reference materials (SRMs) for both fluorescence and absorbance.

Increasing Molecular Weight and Aromaticity



Parallel Factor Analysis (PARAFAC) Components

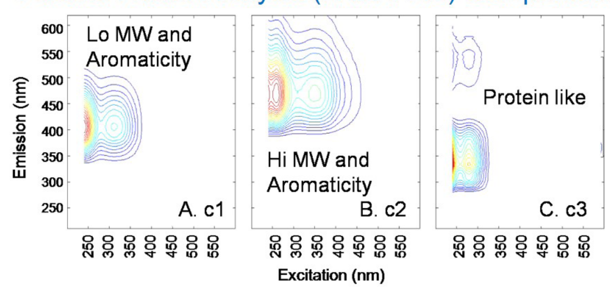
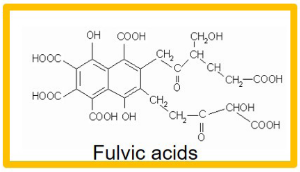
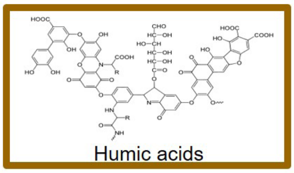
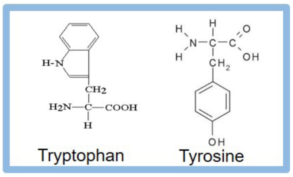
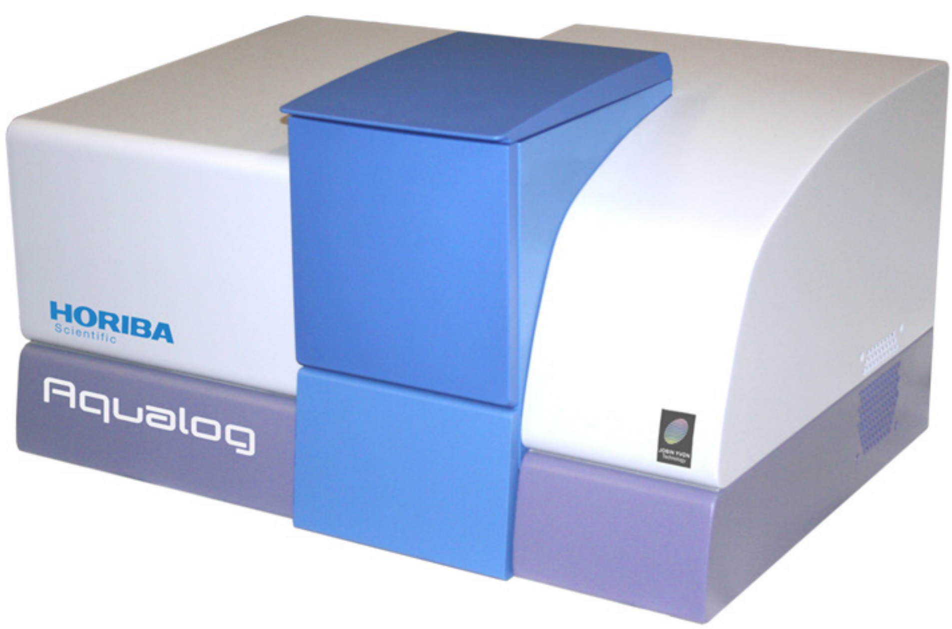


Figure 1: A Typical wastewater EEM figure and Parallel Factor Analysis (PARAFAC) extracting underlying component information.









"Our lab has used the Aqualog instrument for various research projects to characterize dissolved organic matter in water treatment processes, including biological filtration and pilot-scale treatment trains, and to identify polycyclic aromatic hydrocarbons in oil samples. The Aqualog is user-friendly and effective in measuring a variety of sample matrixes."

Melanie Vine, Ph.D. Student
Department of Civil, Construction, and Environmental Engineering,
University of Alabama

It's All About CDOM

Facing challenges like population growth and climate change, today's environmental water researchers are raising important questions on how to adapt technology and assess its effectiveness while continuing to protect public health.

Water researchers use the Aqualog A-TEEM, a novel and valuable optical tool, to investigate fluorescent dissolved organic matter (DOM) characterization, with the aid of multivariate analysis, for example, parallel factor analysis (PARAFAC) that decomposes components and assigns scores (Figure 1). This provides key information on DOM composition, allowing researchers to track the seasonal and operational trends of specific fractions of DOM in the source water and throughout the drinking water treatment plant. Raw water sampling allows utilities to understand how surface water quality is related to seasonal changes. Sampling throughout the plant allows utilities to understand how operations impact removal of specific fractions of DOM.

Of these fractions, humic and fulvic acids comprise the majority in most surface water sources. Humic and fulvic acids both contain molecules in the 200 - 600 Da range revealed by FTCIR-MS analysis. The primary differences are that humic acids have a greater C content and a higher aromatic content. Fulvic acids have a higher O content in the form of carboxyl group (COOH) and phenolic hydroxyl groups (Ar-OH). The abundance of the latter groups in fulvic acid molecules is what makes them soluble via hydrogen bonding with water molecules. Humic acids which have a lower content of COOH and Ar-OH groups are more susceptible to coagulants, in particular if Al^{+3} or Fe^{+3} are used because they become cross linked into large pseudo molecules and become very hydrophobic.

The effectiveness of all water and wastewater treatment processes is impacted by organic matter, so no single treatment method can remove all the types of organic carbon present in these waters, and methods of improved characterization of organic matter are therefore needed at various stages of water and wastewater treatment. While surrogate measures of UVA254, total and dissolved organic carbon (TOC/DOC), and chemical oxygen demand (COD) indicate trends, they inadequately portray the character and composition of the organic matter removed and/or transformed at each treatment stage or reuse process.

Protein-like compounds are another significant component of natural organic matter present in most surface water sources. They are also known to be associated with the presence of municipal wastewater and microbially available substrates. Compared to humic and fulvic acids, the protein-like compounds have a lower affinity to coagulants. Since many DOM components are disinfection byproducts (DBP) precursors, Halogenated disinfectants, such as chlorine, can react with the DBP precursors to form unwanted DBPs, which include toxic substances, such as trihalomethanes (THMs) and haloacetic acids (HAAs). Because these substances are potentially carcinogenic and are regulated by the US EPA, their formation should be controlled by properly managing and optimizing the water treatment process.

The Gold Standard for Water Research

A sampling of Aqualog customers around the world

Environmental Researchers

- US Environmental Protection Agency (US EPA)
- US Geological Survey (USGS) Water Science Center
- US Naval Research Laboratory
- National Institute of Standards and Technology (NIST)
- National Aeronautics and Space Administration (NASA)
- National Oceanic and Atmospheric Administration (NOAA)
- Woods Hole Oceanographic Institution
- Stroud Water Research Center
- Trussell Technologies
- Vietnam Environment Administration
- National Laboratory for Civil Engineering (Portugal)
- Korea Institute of Civil Engineering and Building Technology (South Korea)
- Arizona State University
- Chinese Academy of Sciences (China)
- Colorado School of Mines
- Columbia University
- Florida International University
- Florida State University
- Georgia Institute of Technology
- Harbin Institute of Technology (China)
- Indiana University
- Kangwon National University (South Korea)
- King Abdullah University of Science and Technology (Saudi Arabia)
- Kobe University (Japan)
- Louisiana State University
- Michigan Technological University
- New Mexico State University
- Northeastern University
- Oregon State University
- Rutgers University
- San Diego State University
- Seattle University
- Sejong University (South Korea)
- Sichuan University (China)
- Southwest University (China)
- Swedish University of Agricultural Sciences (Sweden)
- The Ohio State University
- The University of Vermont
- Tongji University (China)
- Umeå University (Sweden)
- University of Alaska
- University of Alberta (Canada)
- University of East Anglia (UK)
- University of Extremadura (Spain)
- University of Maryland, Center for Environmental Science
- University of Massachusetts at Amherst
- University of Michigan
- University of Minnesota
- University of Montana
- University of New Orleans
- University of Science of Technology of China (China)
- University of South Africa (South Africa)
- University of Western Ontario (Canada)

Water Companies

- American Water
- Chelsea Technologies Group
- Doosan Heavy Industries and Construction
- Eskom (South Africa)
- Hazen and Sawyer
- Kurita Water (Japan)
- Public Utilities Board (PUB) of Singapore
- Sabesp (Brazil)
- Suez (Worldwide)
- WET Labs

Municipal Water Facilities

- City of Akron
- City of Philadelphia Water Department
- City of Sandusky
- City of Wheeling Water Department
- Denver Water
- Hampton Roads Sanitation District
- Las Vegas Valley Water District
- Louisville Water Company
- Metropolitan Water District of Southern California
- Middlesex Water Company
- Orange County Water District
- Umgeni Water - Amanzi (South Africa)
- West Basin Municipal Water District Water Recycling Facility

Aqualog Applications

Drinking Water for EPA Compliance

Environmental water researchers use the HORIBA Aqualog to track fluorescence fingerprints of NOM in water, also known as the precursors of the DBPs, to quickly predict, identify and optimize the organics removal, in order to mitigate the occurrence of the DBPs formation and to ensure compliance with increasingly stringent drinking water quality regulations.

Photo credit:Tom Archer

Harmful Algal Blooms (HABs)

These blooms are a particular issue in the Great Lakes region of the United States in the late summer months. Several species of cyanobacteria can produce a variety of toxins including hepatotoxins and neurotoxins. Environmental water researchers use the HORIBA Aqualog to monitor fluorescence signatures of organic matter derived from HABs which can be an indicator of upcoming blooms.

Membrane Fouling in Advanced Water Treatment

Potable reuse, wastewater recycling has the positive impact on both water availability and water contamination. Researchers have been conducting laboratory research on potable water reuse for decades. The technologies often involved are membrane treatments, however, membrane fouling occurs when contaminants deposit on the surface of a membrane, which leads to deterioration of membrane performance and decrease in treatment efficiency. In these studies, researchers use the Aqualog to investigate specifically how the performance and fouling of membrane treatments, is affected by the design and operation of the upstream wastewater effluent, the removal of organic micropollutants by ozone, biofiltration, and most recently, how functional chemistry affects the ability of membranes to remove low-molecular weight organics.

Climate Change and NOM in Aquatic Environments

The Aqualog is being used in a wide range of different aquatic environments, from cold arctic regions to boreal lakes and streams, from ice glaciers to coastal water, to help environmental researchers understand the biogeochemical origin of climate change. By tracking the emerging patterns of global CDOM distribution, researchers can then determine the contribution of carbon from different origins into the CDOM pool.

Petroleum and Oil Products Spills

Global drinking water sources remain prone to carcinogenic petroleum product contaminations due to lack of detection capacity at, or before treatment plant intake. The Aqualog A-TEEM method provides a reliable optical detection of these compounds at low quantities discriminating from the highly absorbing and fluorescent backgrounds of natural Dissolved Organic Matter (DOM) components. Environmental water researchers use the HORIBA Aqualog to monitor fluorescence signatures of Benzene, Toluene, Ethylbenzene and Xylene (BTEX), as well as polycyclic aromatic hydrocarbons (PAHs), which represent typical water soluble fractions of petroleum products, as an early warning detection of petroleum and oil product spills.

Unique Aqualog A-TEEM Benefits

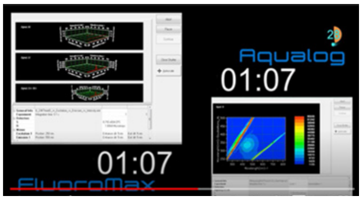
Not just a scanning fluorometer for EEMs, but a much faster and better A-TEEM™ spectrometer for colored dissolved organic matter (CDOM)

Aqualog A-TEEM versus Traditional Scanning EEM Fluorometer

Aqualog represents the future of analytical bench-top fluorescence spectroscopy by providing faster, better and more accurate information than traditional scanning fluorometers.

Traditional scanning spectrofluorometers have been used to collect a molecular fingerprint, in the form of a fluorescence excitation emission matrix, or EEM. Sometimes also referred to as 3D Fluorescence, an EEM is a three-dimensional data set of fluorescence excitation wavelength versus fluorescence emission wavelength, versus fluorescence intensity. With a scanning spectrofluorometer, this data set is acquired by sequentially scanning a series of emission spectra, at varying excitation wavelengths, and then reconstructing the resultant data set three dimensionally. This three-dimensional data set can be used with third party multivariate analysis software for component analysis, as is done with other analytical techniques such as FTIR, HPLC and MS. There are, in fact, many scientific papers published citing the use of scanning spectrofluorometers for fluorescence EEM component analysis in the water research field. But if an EEM provides more information for a scientist, why aren't EEM publications growing faster? Because a PMT scanning fluorometer is very slow to acquire an EEM.

	Aqualog A-TEEM	Scanning EEM
Acquisition Speed	Fast, 1 minute	Slow, 45 minutes
Spectroscopic Method	Fluorescence & Absorbance	Fluorescence only
Emission Detector	CCD camera	Photon multiplier tube (PMT)
Inner Filter Effects Correction	Automatic, real-time	Need a second instrument
CIE Chromaticity and Lab	Yes	No
Multi-block for Enhanced Multivariate Analysis	Yes	No



Check out our 60 second video demonstrating the awesome speed of Aqualog, compared to a scanning PMT fluorometer at Aqualog.com.

With an ultrafast CCD detection technology, HORIBA Aqualog solves the serious speed limitations of scanning spectrofluorometers so that an entire fluorescence EEM can be acquired in mere seconds to minutes depending on the sample [high specificity and ultrahigh-sensitivity at a 6 million nm/min emission scan rate, that's up to **4,000 times faster** than traditional PMT-based fluorometers]. HORIBA has also solved the problems associated with the fluorescence inner filter effect by taking advantage of the fact that the A-TEEM technique also collects absorbance of the same sample at the same time as the fluorescence, and uses the absorbance to correct EEMs for the inner filter effect (IFE).

Below is a good example to show how even a small concentration difference in a single molecule, gallic acid, can have a significant effect on the shape of an EEM fingerprint, but with proper IFE correction an A-TEEM fingerprint remains the same. With our new A-TEEM technology you can easily and effectively identify, quantify and understand individual organic compounds in complex mixtures in minutes.

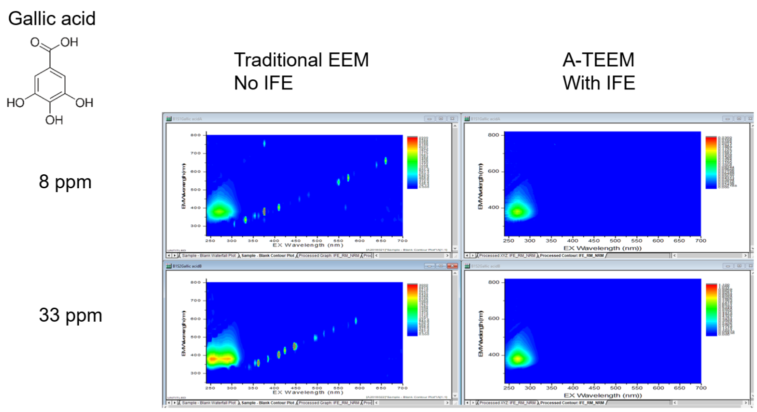


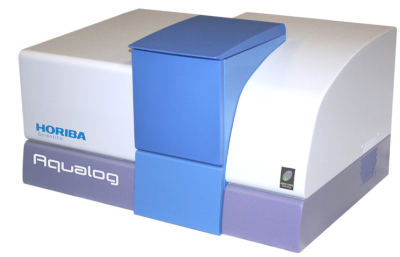
Figure 2: EEM measurements for gallic acid at concentrations of 8 ppm and 33 ppm, respectively. The left panel shows raw EEM without IFE correction which leads to different fingerprints for the same compound. The right panel shows processed EEM with IFE correction yielding the true A-TEEM fingerprint.

Hardware and Software

Hardware

The only true simultaneous absorbance-fluorescence system available

- TE-cooled CCD fluorescence emission detector for rapid data acquisition up to **100 times faster** than any other benchtop fluorometer
- Corrected UV-VIS absorbance detection path for stability and accuracy
- Double grating excitation monochromator for superior stray light rejection
- Matching bandpass for absorbance and fluorescence spectra
- Thermostated and microstirred cuvette holder
- 10mm quartz cuvette
- Sealed ultrapure water standard



Software

- Optimized experiment set-up menus minimize user configuration time
- Complete NIST-traceable corrected fluorescence spectra automatically generated
- Spectral and kinetic analysis tools for both absorbance and fluorescence data
- Methods and batch protocols for automating multiple sample measurement
- Export format for third party multivariate analysis software

Accessories

Aqualog Datastream Dashboard is powered by Solo_Predictor software from Eigenvector Research, Incorporated

Aqualog® Datastream Dashboard

Features

- Water quality report dashboard
- Seamless integration with Aqualog
- Convenient HTML-based interface
- Push-button method operation
- Simple administrator level controls for calibration and method development

Benefits

- Easy access through internet or intranet
- Dashboard shows the latest readings, time series and tables for trends and analysis
- WTP can upload their own independent data

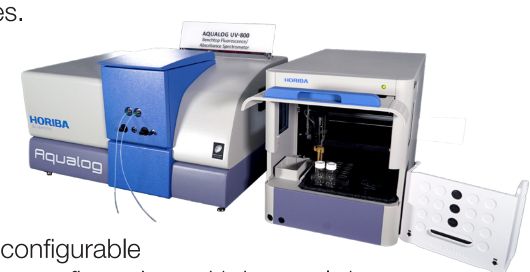
Automatic Sipper Accessory

New for our Aqualog® A-TEEM™ spectrometer, the Aqualog automatic sipper accessory handles sampling from a single source, in addition to dispensing rinsing solutions, detergents and controlling reverse-flow drainage The 4-sample changer unit connects to the main sipper unit to enable sampling of up to 4 sources.

The sipper offers convenient installation and operation, with built-in automatic cleaning, leak detection and protection. It is fully integrated into the new Aqualog 4.0 software for batch analysis and has a variety of uses in water, pharmaceutical, beverage phenolics and many other applications.

When used at a water treatment plant, the sipper and four channel accessory enable the Aqualog to automatically extract and monitor raw, settled and finished water samples. Each sample changer unit is compatible with overflow and filtration devices, serving up to 4 independent water treatment plant sources.

Fast-01 Autosampler Accessory



The Fast-01 can be configured to use a variety of sample-vials and racks to meet your application needs and enables complete temperature control. Sample vial repeats and injection volumes are easily facilitated with the Aqualog 4.2+ software, which also offers preconfigured blank files.

All data files can be exported with ISO-formatted time-date stamping and user-configurable Sample ID and repeat codes. All aspects of the Fast-01 hardware control are at your fingertips, with key real-time access features to facilitate the configuration and execution of your batch experiments, as well as priming, cleaning and maintenance.

Additional Accessories:

- Two position thermostated and microstirred cuvette holder
- Four position thermostated and microstirred cuvette holder
- External water bath for temperature control

Aqualog Specifications

Fluorescence Hardware	
Light source	Extended-UV: 150W vertically mounted xenon arc lamp
Excitation range	200 nm to upper limit of emission detector
Excitation bandpass	5 nm
Excitation monochromator	Subtractive double monochromator
Excitation gratings	1200 gr/mm, 250 nm blaze
Excitation wavelength accuracy	±1 nm
Choice of detector	Red-extended
Emission range	250-800 nm
Emission grating	285 gr/mm; 350 nm blaze
Hardware pixel binning	0.58, 1.16, 2.32, 4.64 nm/pixel
Emission bandpass	5 nm
Emission spectrograph	Fixed, aberration-corrected 140 mm focal length
Emission detector	TE-cooled back-illuminated CCD
Emission integration time	5 ms minimum
CCD gain options	2.25 e-/cts in high gain, 4.5 e-/cts in medium gain, 9 e-/cts in low gain
Sensitivity	Water-Raman SNR > 20,000:1 (RMS method) (350 nm excitation, 30s integration)
Weight	32.72 kg (72 lbs)
Dimensions	LWH (618 x 435 x 336 mm); (24" x 17" x 13")

Absorbance Hardware	
Scanning range	200-800 nm (UV lamp)
Bandpass	5 nm
Slew speed	Maximum 500 nm/s
Optical system	Corrected single-beam
Detector	Si photodiode
Wavelength accuracy	±1 nm
Wavelength repeatability	+/- 0.5
Photometric accuracy	+/- 0.01 AU from 0 to 2 AU
Photometric stability	<0.002 AU per hour
Photometric repeatability	+/- 0.002 AU (0 to 1 AU)l
Stray Light	<1% measure with KI standard
Performance Validation Tests	NIST Fluorescence Standard Reference Materials for spectral calibration and correction (SRMs: 2940, 2941, 2942, 2943) Starna® Standard Reference Material for Quinine Sulfate Fluorescence Emission Spectral Correction (RM-QS00) Spectrophotometry (RM-06HLKI) Water Raman Signal-to-Noise evaluation (RM-H2O) US Pharmocopia (USP) 857 compliant absorbance photometric accuracy/linearity tests with (Starna) NIST SRM 935a potassium dichromate; stray light tests with potassium iodide (KI), sodium nitrite (NaNO2), acetone

> *"The University of South Africa's Nanotechnology and Water Sustainability (NanoWS) research unit has been at the forefront of water research in South Africa, developing and optimizing various materials for removal of various pollutants from our different water sources. We continue to use the Aqualog and Eigenvector for the complete quantitative spectral profile of all colored and fluorescent dissolved organic carbon (DOC) components.The service team at Horiba also provides professional and comprehensive after sales care of their customers, availing their expertise and support throughout or research thus impacting the quality of life our people positively"*

Dr. Thabo TI Nkambule
Nanotechnology & Water Sustainability
(NanoWS) Research Unit
College of Science
University of South Africa

> *"In my research, I use EEM/PARAFAC data generated by the HORIBA Aqualog® instrumentation/software to understand better water quality and organic carbon distribution throughout the drinking water and wastewater treatment industries. My background is in government, academia, and industrial labs. I encourage academic environmental science and engineering programs to obtain this instrumentation to prepare students for jobs in the water industry. In addition, the Aqualog instrument (dual UV-Vis and fluorescence) obtains data much more rapidly using a single instrument than traditional spectrofluorometric instrumentation, such that experiments are achieved within limited academic student-lab timeframes."*

Martha J.M. Wells, Ph.D.
Owner/Consulting Chemist, EnviroChem Services,
Emeritus Professor of Chemistry
Tennessee Technological University

The Future of Fluorescence

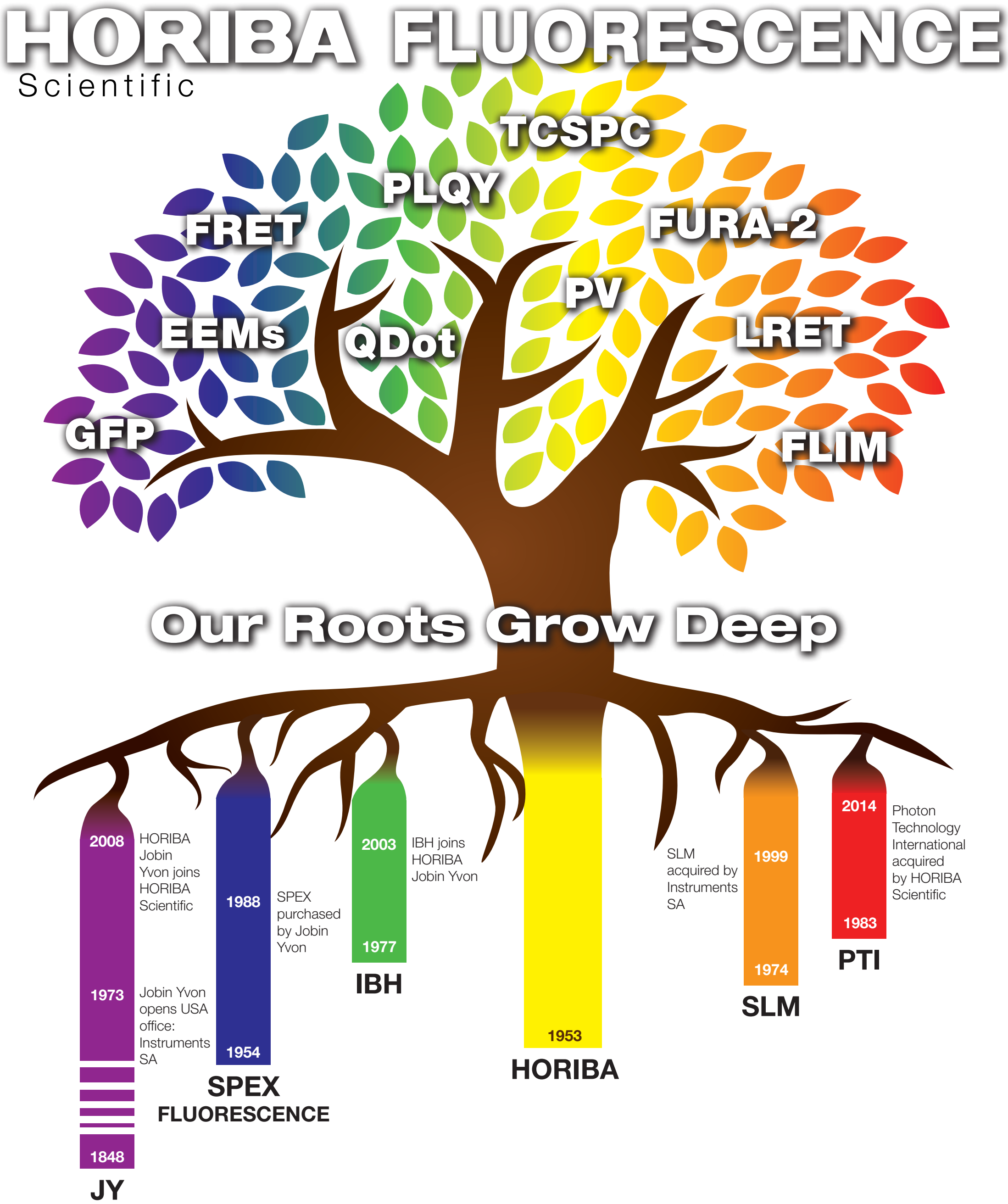
A-TEEM™ MOLECULAR FINGERPRINTING

Beyond Water Research

Aqualog was designed for quantitative and predictive water analysis, and it is ideal for the task. However, Aqualog, with its unique A-TEEM molecular fingerprinting benefits, has proven itself to be an invaluable tool in a wide variety of industrial applications such as at water treatment plants, and for industrial QC/QA in Pharma, wine and spirits, olive oils and much more. For more information about industrial applications of Aqualog visit www.a-teem.com.

EIGENVECTOR RESEARCH

Aqualog A-TEEM chemometrics analysis presented here are derived from Eigenvector Research Incorporated, Solo software.



Acronyms

A-TEEM	Absorbance -Transmission and Fluorescence Excitation and Emission Matrix	HABs	Harmful Algal Blooms MCL Maximum Contaminant Level
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes	MW	Molecular Weight
DBPs	Disinfection By-product(s)	NOM	Natural Organic Matter
DOC	Dissolved Organic Carbon	PAHs	Polycyclic Aromatic Hydrocarbon
EEM	Excitation and Emission Matrix	PARAFAC	Parallel Factor Analysis
EPA	Environmental Protection Agency	SUVA	Specific Ultraviolet Absorbance
HAA	Haloacetic Acids	THM	Trihalomethanes
		TOC	Total Organic Carbon

HORIBA
Scientific

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HORIBA Scientific has a policy of continuous product development, and reserves the right to amend part numbers, descriptions and specifications without prior notice.

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